I. Call to Order and Opening Remarks
   The Vice Chair called role. 15 of 20 active voting members or proxies of the technical section were present. 11 current friends of the technical section were also present. There were 117 attendees: 58 were from member DOTs, 6 from AASHTO, 3 from FHWA, 1 from TRB, 3 from Academia and 46 from Industry. See Attachment 1 – TS 4b attendance for the meeting attendance.

II. Roll Call

<table>
<thead>
<tr>
<th>Name</th>
<th>State</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey, William R.</td>
<td>Virginia</td>
<td>X</td>
</tr>
<tr>
<td>Peoples, Christopher A.</td>
<td>North Carolina</td>
<td>X</td>
</tr>
<tr>
<td>San Angelo, Michael</td>
<td>Alaska</td>
<td></td>
</tr>
<tr>
<td>Stolarski, Phil</td>
<td>California</td>
<td></td>
</tr>
<tr>
<td>Zipf, Karl (proxy)</td>
<td>Delaware</td>
<td>X</td>
</tr>
<tr>
<td>Knight, Chase</td>
<td>Florida</td>
<td>X</td>
</tr>
<tr>
<td>Douds, Richard</td>
<td>Georgia</td>
<td>X</td>
</tr>
<tr>
<td>Pfeifer, Brian (proxy)</td>
<td>Illinois</td>
<td>X</td>
</tr>
<tr>
<td>Davis, Jason</td>
<td>Louisiana</td>
<td>X</td>
</tr>
<tr>
<td>Bradbury, Richard L</td>
<td>Maine</td>
<td>X</td>
</tr>
<tr>
<td>Staton, John (proxy)</td>
<td>Michigan</td>
<td>X</td>
</tr>
<tr>
<td>Trautman, Brett</td>
<td>Missouri</td>
<td>X</td>
</tr>
<tr>
<td>Streeter, Donald A.</td>
<td>New York</td>
<td>X</td>
</tr>
<tr>
<td><strong>Horner, Ron-Retired</strong></td>
<td>North Dakota</td>
<td></td>
</tr>
<tr>
<td>Lane, Becca</td>
<td>Ontario</td>
<td></td>
</tr>
<tr>
<td>Ramirez, Timothy</td>
<td>Pennsylvania</td>
<td>X</td>
</tr>
<tr>
<td>Short, Temple</td>
<td>South Carolina</td>
<td>X</td>
</tr>
<tr>
<td>Egan, Brian</td>
<td>Tennessee</td>
<td>X</td>
</tr>
<tr>
<td>Williams, Kurt</td>
<td>Washington</td>
<td></td>
</tr>
<tr>
<td>Payne, Barry (proxy)</td>
<td>Wisconsin</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rothblatt, Evan</td>
<td>AASHTO - Liaison</td>
<td>X</td>
</tr>
<tr>
<td>Malusky, Katheryn</td>
<td>AASHTO - Liaison</td>
<td>X</td>
</tr>
<tr>
<td>Fragapane, Ryan</td>
<td>AASHTO</td>
<td>X</td>
</tr>
</tbody>
</table>
III. Approval of Technical Section Minutes

Approval of January 18, 2017 Mid-Year Webinar minutes

A motion was made by NY to accept the minutes, seconded by ME. All were in favor.

IV. Old Business

A. SOM Ballot Items – Items were addressed at Mid-Year Webinar.

B. TS Ballots

SOM TS4B 17-01 Summer Ballot results are due July 25, 2017

Item 1 Revise M 252-09 (2017) Standard Specification for Corrugated Polyethylene Drainage Pipe. These proposed revisions were based on last year’s reconfirmation ballot comments.

Task Force 2017-2 reviewed M252 and revised the definitions in Section 3 for crease, buckling and delamination to correlate with visual evaluations associated with performing the pipe flattening test in Section 9.2. These are the same changes incorporated into M294 last year.

The standard specification passed technical section ballot with 16 affirmative votes, 0 negatives and 2 no votes.

Pennsylvania Comments:

1. In Section 7.1.1, add to the end of the existing sentence the following "in the pipe or fittings as furnished. There shall be no evidence of cracking or delamination when tested in accordance with Section 9.2".

2. In Section 7.6, suggest revising this section completely (to move existing text around differently) since the definition of buckling was added in Section 3.2 and the definition of buckling is a decrease or downward deflection in the load-deflection curve. Suggest revising this Section completely as follows: "There shall be no evidence of buckling (a decrease or downward deviation in the load-deflection curve), cracking, splitting, or delamination when the pipe is tested in accordance with Section 9.2."

3. In Section 7.8, revise from "pipe wall when" to "pipe wall or liner when".
4. In Section 9.2, with addition of Section 3.2 (buckling definition), suggest revising the 3rd sentence completely to read "The specimen shall fail if buckling (a decrease or downward deviation in the load-deflection curve), cracking, splitting, or delamination is observed with the unaided eye at 20 percent or less deflection."

5. In Section 9.2, end of 3rd sentence which indicates "at 20 percent or less deflection", does the language "or less" require visual observation for cracking, splitting, or delamination during loading? The 4th sentence was revised to visually check for evidence of cracking, splitting or delamination immediately after the specimen has started to unload. Can the "or less" part be visually evaluated during the specimen unloading?

Chair - not exactly sure what is being asked in No.5? PA explained what they meant: The proposed revision was to look visually for the cracking, not during the loading, but immediately after you unload. Does the "or less" part mean that you are going to have to look at lower loads than 20%? Clarification wording is needed. Chair stated the idea was to run the test to 20% and then look for the cracking and splitting. PA thinks this is editorial in nature.

M 252 Section 9.2 will now read: “Pipe Flattening—Flatten the pipe specimen from Section 9.1 until the vertical inside diameter is reduced by 20 percent. The rate of loading shall be the same as in Section 9.1. The specimen shall fail if buckling (a decrease or downward deviation in load-deflection curve), cracking, splitting, or delamination is observed with the unaided eye at 20 percent deflection. Immediately after the specimen has started to unload, check for visible evidence of cracking, splitting or delamination."

6. In Section 13.1, should the keywords "corrugated; drainage; polyethylene; pipe" be added?

Section 7.6 is missing the associated verbiage from M294. "Pipe specimens shall show no visual evidence of cracking, splitting or delamination when tested in accordance with section 9.2. (Dave Kuniega)

Chair’s recommendation: Make editorial changes suggested in 1, 2, 3, 4, 6 and technical change in 5. Reconvene the task force and finalize for SOM and TS concurrent ballot by September 22, 2017.

Illinois Comments:

1. Section 1.1.2: Workmanship and brittleness should be included in the list. In addition, to be consistent with M294 and other specifications, revise "forms of marking" to "form of markings."

Chair: Good comment. I agree with this suggestions and it will be referred to Task force. The task force added these two words to Section 1.1.2.

2. Section 2.2: ASTM D4218 does not appear to be referenced in AASHTO M 252-09 (2017).

Chair: Task Force should check. If ASTM is not called out in Specification it should be removed from references. The task force elected to add the words in accordance with D4218 in Section 6.1.1, 6.1.2 and 6.1.3 to indicate what test is being performed to determine the carbon black content.

3. Section 7.4.2: Should the section also state perforations shall be uniformly spaced along the length and the circumference of the pipe?

Chair: This seems reasonable. The task force added this word to Section 7.4.2.

Missouri Comments:

1. On Page 4, it appears the section number ‘7.2.4’ was deleted inadvertently

Chair: Will check/discuss with publication staff.
Resolution:
Chair asked Task force 2017-02 to reconvene and consider each of the suggested comments and arrive at consensus. A motion was made by ME and seconded by NC to approve M 252 for concurrent TS and SOM ballot once the task force has made editorial changes. All were in favor. These changes will be moved to the full SOM concurrent ballot. Task Force 2017-02 agreed with comments suggested by PA, IL and MO. The task force addressed the comments as indicated on the preceding pages. See Attachment 2 for all the updates to M252.

Item 2 Revise M330 Standard Specification for Polypropylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter. These proposed revisions were based on last year’s reconfirmation ballot comments. Task Force 2017-2 reviewed M330 and revised the definitions in Section 3 for crease and delamination. The Task force eliminated the definition for buckling because the pipe flattening test is run to a 40 percent deflection. The Task Force also attempted to clarify the terms; pipe liner and pipe wall in several places in the specification.

The specification passed technical section ballot with 15 affirmative votes, 1 negative and 2 no votes.

Florida Negative:
No objection to the principle of the changes, however there are some instances where the language needs further clarification and requires terminology in agreement with diagram labels.
1. Page 5: The definition of delamination for Type D pipe should include terminology consistent with Figure 1 labels.
2. Page 6: Diagram labels should be updated and the same terminology used throughout the Specification. Suggestions: Corrugated Wall, Inner Wall (Liner), Outer Wall
3. Page 17: Measurement of thickness should include outer wall thickness for Type D pipe.
4. Page 18: Terminology used for delamination should be consistent with Figure 1 labels.
5. Page 19: Labels on Figure 4 should be consistent with Figure 1.
Chair: Will ask Task Force and publication staff to review these five suggestions and correct for concurrent ballot. This may require redrawing Figure 1 or obtaining CADD image from PP manufacturer. FL believes these are editorial suggestions.

Pennsylvania comments:
1. In Section 3.1.1, add "or liner" to the end of existing language".
2. In Section 4.1.3, 1st sentence, revise from "smooth waterway braced" to "smooth waterway liner braced" or "smooth liner waterway braced".
3. In Section 4.1.3, 2nd sentence, revise from "Both walls shall" to "Both liner and outer wall shall".
4. In Figure 1, for Type C, revise label from "Corrugations or Ribs" to "Wall" or "Wall (Corrugations and Ribs)". For Type S, revise label from "Corrugations or Ribs" to "Outer Wall" or "Outer Wall (Corrugations or Ribs)" and revise label from "Inner Wall (Liner)" to "Inner Liner". For Type D, revise label from "Exterior Wall" to "Outer Wall" and revise label from "Inner Wall (Liner)" to "Inner Liner".
5. In Section 6.3, at end, revise from "Section 3.5" to "Section 3.1.5".
6. In Section 7.1.1, add new sentence to end as follows "There shall be no evidence of cracks, splits or delaminations when tested in accordance with Section 9.2."
   Perhaps this is already adequately covered in Section 7.5?
7. In Section 7.1.2, 1st sentence, revise from "corrugated shell" to "corrugated wall".
8. In Section 7.1.2, 2nd sentence, revise from "both walls shall" to "both liner and outer wall shall".
9. In Section 7.2.2, revise from "outer walls" to "outer wall".
10. In Section 7.5, revise from "of wall cracking, splitting, or delamination" to "of liner or outer wall cracks, splits, or delaminations" to match up with Section 3.1.1 and definition of "crack" not "cracking".
11. In Section 9.2, Note 2, end of 1st sentence, revise from "pipe wall" to "pipe wall profile" or "pipe wall and liner profile".
12. In Section 9.7, 1st paragraph, end of 1st sentence, revise from "Section 3.4" to "Section 3.1.3".
13. In Section 9.7, 2nd paragraph, 1st line, revise from "Section 3.4" to "Section 3.1.3".
14. In Section 9.7, 2nd paragraph, last 2 lines, revise from "the inner or outer wall" to "the inner liner or outer wall".
15. In Section 13.1, should the keyword "pipe" be added?
16. Minor edits to align this spec with associated properties in M294. Note that buckling was never in M330. Question why it is stricken from this version? (David Kuniega)
   Chair: Will ask Task force 2017-02 to reconvene and consider each of the suggested comments and arrive at consensus. These are editorial in nature.

Michigan Comment:
1. Page M-330-9 is blank: please mark as purposefully blank or remove.
   Chair: This page was not purposefully left blank. Editing by the Task Force to a protected document is probably the cause for this page being left blank.

Illinois Comments:
1. Section 1.1.2: Perforations should be included in the list.
3. Section 3.1.1: Should "or liner" be added at the end of the sentence?
4. Figure 1: For the Type D pipe, should "Exterior Wall" be revised to "Outer Wall" to be consistent with 3.1.3 and 4.1.3?
5. Section 7.2.2: Revise "outer walls" to "outer wall."
6. Section 9.6.4: Should outer wall also be referenced?
7. Section 9.7: In the first and second paragraph, revise "Section 3.4" to "Section 3.1.3."
8. Section 11.1: U.S. Customary Units should be provided.
   Chair: Will ask Task force 2017-02 to reconvene and consider each of the suggested comments and arrive at consensus.

Louisiana Comment:
1. I understand taking the pipe to 40% deflection is harsh and evidence of "buckling" would be pronounced in the latter stage of the test. However, is it possible to have buckling at less than 20% deflection and still pass the test for cracking, splitting, or delamination? If the pipe lost strength at 15% but did not split or crack, are we opening ourselves to a possible weak pipe technically meeting the specification?
   Chair: Will look into an answer to these two questions. If an explanation is found out before the meeting, the explanation will be shared with TS.
PPI: The buckling test is not a test for M 330 polypropylene. This comment refers to the calculated deflection limit for flattening. The Chair will relay this information to LA.

Chair explanation: This is an excellent question and it is difficult to answer. As I understand it, the original intent of this specification M 330 for Polypropylene pipe in a storm water application is that the 40% deflection test is all that would be required because it is very harsh test. The buckling definition came from research on M 294 HDPE pipe and a deflection limit is calculated in the section of M 294 for performing the pipe flattening test. When NCHRP Report 631 came out the deflection limits for HDPE pipe were placed in the specification for the flattening test. Afterwards there was concern that the test for M 294 was not being run to 20% deflection. HDPE pipe was only being run to the deflection limit which was close to 20% but could be on smaller diameters as low as 14 or 15%. When this would happen then the HDPE pipe was not being evaluated for cracking, splitting or delamination. The technical section rectified this by requiring M294 pipe to be run to 20% deflection to evaluation for cracking, splitting or delamination. This appears to be a similar case. Currently M 330 has a buckling definition but no specified method for determining the minimum buckling criteria. ASTM specifications for sanitary sewers have a criterion for buckling but other ASTM polypropylene pipe specifications have only the deflection for evaluating cracking, splitting and delamination. Criteria could be placed in M 330 if it is determined to be necessary.

Comments from Friends of the Committee:

American Concrete Pipe Association (Josiah W Beakley)

1. It appears the definition for buckling was removed without adding a replacement. Should it not have the same definition as the one used in M252? The buckling definition was removed because there is not a criterion in the pipe flattening test section for PP pipe in a storm water application to meet. See above explanation.

2. In the definition for delamination, I believe the second sentence should say, “For Type D pipe, delamination is a separation of the inner and/or outer wall and the corrugation as evidenced by a visible gap extending completely between the wall and corrugation at any point around the circumference of the pipe.” I believe this wording matches better with Figure 1. The Chair forwarded this suggestion to the task force for consideration along with Florida’s suggestions.

3. Section 7.2.2. I am not sure how anything is termed a “wall” in this standard. If the liner is only there for water flow, and is not a major part of the structure, as continuously stated by the manufacturers of this product, then how does putting that same thickness on the outside of the pipe suddenly make it a “wall”. The Chair forwarded this suggestion to the task force for consideration.

4. Section 9.2. Why do you wait until you unload the specimen to look for cracking, splitting, and delamination? Can you hold the specimen at 20% deflection for 5 minutes and examine it for damage? The chair understands that it is unsafe to attempt to look for cracks while the pipe is still under a test load to produce a 40% deflection.

5. Section 9.7. I don’t believe you are trying to insert a feeler gauge between the “inner supports and the liner” and the “outer wall”. You are not inserting it between the outer wall, but rather the outer wall and the corrugation. Thus, it might read better as, “between the bottom of the corrugation (‘supports’ if you
would prefer to call it that) and the inner liner, and the top of the corrugation
('supports' if you would prefer to call it that) and outer liner”.

Chair: The TS would like to thank you for reviewing and commenting on this
specification. The TS will ask Task force 2017-02 to consider each of the suggested
comments. ACPA believes these items were previously mentioned by DOTs. These
changes are going to be sent through tech section ballot.

Resolution:

Chair: Asked Task force 2017-02 to reconvene and consider each of the suggested
comments and arrive at consensus. The chair also asked the Technical Section to approve
M 330 for concurrent TS and SOM ballot once the task force has made the editorial and
technical changes. A motion was made by NC to move M 330 to concurrent ballot once
these changes were made by the task force. The motion was seconded by NY. All were in
favor.

Task Force 2017-02 agreed with editorial changes suggested by PA and IL. Once these
changes were agreed upon the Task Force reviewed the suggestions made by Florida and
ACPA to ensure terminology was in agreement with diagrams and figure labels in the
standard. Florida provided new figures for the standard. This was accomplished in
September 2017. See Attachment 3 for all the updates to M 330.

Item 3 Revise M 326-08 (2017) Standard Specification for Polyethylene (PE) Liner Pipe, 300-
to 1600-mm Diameter Based on Controlled Outside Diameter. These proposed revisions
were based on last year’s reconfirmation ballot comments, Task Force 2017-3 reviewed
M326 and revised the definitions in Section 3 for crease and buckling to correlate with visual
evaluations in section 7.5 associated with performing the pipe flattening test in Section 9.2.
These are the same changes incorporated into M294 last year.

The standard specification passed technical section ballot with 16 affirmative votes, 0
negatives and 2 no votes.

Michigan Comment:
1. Page spacing M 326-10 and M 326-11 between X 1.2.3 and X 1.3
   Chair: This page was not purposefully left blank. Task Force editing to a protected
document is probably the cause. Chair will resolve with publication staff help.

Pennsylvania comments:
1. In Section 3.3, suggest deleting the text","generally associated with wall buckling" to
   be consistent with similar language in M 294, Section 3.4.
2. In Section 7.2, add new sentence to end as follows "There shall be no evidence of
   cracks, splits or delaminations when tested in accordance with Section 9.2."
   Perhaps this is already adequately covered in Section 7.5?
3. In Section 7.5, since definition of buckling in Section 3.4 was revised, suggest moving
   text around to read "There shall be no evidence of buckling (a decrease or
   downward deviation in the load-deflection curve), cracking, splitting, or
   delamination when the pipe is tested in accordance with Section 9.2."
4. In Section 9.2, 3rd sentence, since definition of buckling in Section 3.4 was revised,
suggest moving text around in 3rd sentence to read "The specimen shall fail if
   buckling (a decrease or downward deviation in the load-deflection curve), cracking,
   splitting, or delamination is observed with the unaided eye at 20 percent or less
   deflection." **Or less was removed.**
5. In Section 9.2, end of 3rd sentence, it indicates "at 20 percent or less deflection", does the language "or less" require visual observation for cracking, splitting, or delamination during loading? The 4th sentence was revised to visually check for evidence of cracking, splitting or delamination immediately after the specimen has started to unload. Can the "or less" part be visually evaluated during the specimen unloading?

6. In Section 13.1, should the keywords "liner pipe" be added? Yes, this was added.

Chair’s recommendation: These are editorial comments in 1, 2, 3, 4, 5 and 6. The task force should reconvene and finalize for SOM and TS concurrent ballot by September 8, 2017.

Illinois Comment:
1. Section 7.5: Should "delamination" be deleted from Section 7.5? If not, a definition of delamination should be included in Section 3. Terminology.  
   Chair: Good comment. Inquire into whether or not a solid wall pipe will have delamination when performing pipe flattening test. Delamination definition added.
2. Section 7.6.4: In the second sentence revise "small" to "smaller."
   Chair: Editorial change. Check with Publication staff.

Missouri Comment:
1. On Page 5, it appears the section number '7.4' was deleted inadvertently  
   Chair: Will check.

Comments from Friends of the Committee:

American Concrete Pipe Association (Josiah W Beakley)
1. Section 9.2. Why do you wait until you unload the specimen to look for cracking, splitting, and delamination? Can you hold the specimen at 20% deflection for 5 minutes and examine it for damage?  
   The Chair understands that it is unsafe to attempt to look for cracks while the pipe is still under a test load.

Resolution:
Chair: Asked Task force 2017-03 to reconvene and consider each of the suggested comments and arrive at consensus. A motion was made by PA, seconded by ME to approve for concurrent TS and SOM ballot once task force has made editorial changes. All were in favor to move this to a concurrent ballot after the task force reviewed these changes.

Task Force 2017-03 agreed with editorial changes suggested by PA, IL and MO. The Task Force also found a typographic error in Table 2 specifically the Minimum Wall Thickness is listed as 0.314” for 14” diameter SDR 41 pipe. The correct wall thickness should be 0.341” or 8.6 mm. The chair will update this table for TS and SOM concurrent ballot. See Attachment 4 for the updates to M 326.

Item 4 Revise M294 Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter. “NCHRP 4-39 Study on the Field Performance of Corrugated HDPE Pipe Manufactured with Recycled Content” is complete. The Author, Michael Pluimer drafted a recommended practice for incorporation into M294 for HDPE pipe manufactured with recycled materials. The practice requires the manufacturer to perform an un-notched constant ligament strength test. This test has been developed to insure HDPE manufactured pipe with recycled HDPE will have an estimated performance life of 100 years. These
proposed changes were presented during last year’s Technical section Meeting and an additional presentation will be given during this year’s TS meeting.

The standard specification passed technical section ballot with 13 affirmative votes, 3 negatives and 2 no votes.

California Negative:
While Caltrans supports use of recycled material wherever possible, we do not support at this time the proposed modifications to the Standard Specification for Corrugated Polyethylene Pipe, 200 to 1500 mm (12-60 in) Diameter, AASHTO Designation M294, for the following reasons:

1. The proposed modifications do not provide for a distinction of pipe made with recycled materials. It’s desirable to differentiate recycled verses non-recycle pipe so that Departments can appropriately account for the very different Environmental Product Declarations (EPDs) associated with pipe made from recycled materials. Beyond accurate EPDs, an ability to differentiate recycled verses non-recycle will also provide a means by which limitations of use can be established and thus aid with recycled material implementation within a large DOT.

Chair: Need the committee to consider if this negative is persuasive or decide on a path forward. If a specification rewrite differentiated between recycled M294 pipe and non-recycled M294 would this change to M 294 specification be an acceptable path forward? Industry is in support of doing this. Caltrans (in the chair’s opinion) would be in favor of accepting this solution to address their negative. Industry suggested this language could be added to the Markings section.

2. These modifications are largely based upon NCHRP Study 4-39, Field Performance of Corrugated HDPE Pipes Manufactured with Recycled Content. This report is an unedited final report yet to be published. As such, the Subcommittee is encouraged to pursue recycled material changes after publication of this report and when the transportation engineering community has a reasonable time to consider its findings.

Chair: Need the committee to consider if this negative is persuasive or decide on a path forward. How much time is a reasonable amount of time to consider findings?
Committee seemed to think a month or six weeks was appropriate. Chair will ask NCHRP to allow this report to be submitted to whole SOM not just TS members. The report was sent to full SOM on August 30, 2017.

Florida Negative:
The subject research seems to have good value; however more time is needed to thoroughly review the data, details of the report, and adequacy of the proposed test method in identifying the presence of contaminants. Since the UCLS method is a recently implemented ASTM Standard, there is still no sufficient data on precision. I would like to read the report before proceeding, please. (Please note Florida did not make this comment).

Meeting discussion - Mike Pluimer mentioned a precision and bias statement isn’t needed to have an ASTM standard published. A precision and bias statement does need to be published within the next couple years. Mike believes this information will be available within a year.

A member of the SOM asked, “Can the owner request virgin resin?” The chair says yes, based on the discussion of Caltrans negative.
Michigan Negative:
I would like to read the report before proceeding, please.

Report sent out to full SOM on August 30th.

New York Comments:
Comments: concerned with long term creep with use of recycled materials. Would prefer more testing of this durability aspect before accepting use with 100 year assumptions. Chair: Unsure how to satisfy the more testing to insure durability. NY is not sure how much more testing would be needed to be satisfactory.

Pennsylvania Comments:
1. In Section 2.2, for ASTM D4883, revise from "Techniques" to "Technique".
2. In Section 3.5, revise from "micro-cracks and around" to "micro-cracks around".
3. In Section 6.1.1.1, consider revising from "specimens taken" to "specimens die cut".
4. In Section 6.1.1.1, consider revising from "ground-up pieces of pipe that have" to "ground-up pieces of pipe (from liner and/or outer wall) that have" to provide clarification that this material can come from anywhere and not just the liner as is required for the specimens die cut directly from the pipe liner.
5. In Section 6.1.1.1, next to last line, revise from "in accordance to ASTM F2136" to "in accordance with ASTM F2136".
6. In Section 6.1.1.1.1, revise from "finished pipe inner liner" to "finished pipe liner".
7. In Section 6.1.1.2, 1st & 2nd lines, revise from "in accordance to ASTM F3181" to "in accordance with ASTM F3181".
8. In Section 6.1.1.2, 2nd line, revise from "ASTM F3181 and Section 9.4" to "ASTM F3181 and the procedures described in Section 9.4" for consistency with similar language at end of Section 6.1.1.1.
9. In Section 6.1.1.2, 6th line, consider revising from "conservatively assumed" to "conservatively specified" or "conservatively required".
10. In Section 6.1.1.3, 2nd line, revise from "in accordance to ASTM D3895" to "in accordance with ASTM D3895".
11. In Section 6.1.1.3, 2nd & 3rd line, revise from "in accordance to ASTM D638" to "in accordance with ASTM D638".

PA comments 1 to 11 are editorial in nature.

12. If the UCLS and OIT tests are only required for pipes manufactured from recycled materials, how will the purchasing agency know for sure the pipe contains recycled materials to ensure/verify the manufacturer is performing the required UCLS and OIT testing on some frequency? Will the use of recycled materials in the manufacture of pipe be indicated within the pipe markings and/or in the pipe certification documentation?

These questions are not editorial. NTPEP test plan could address concerns on testing frequencies in first question. The second question is similar to California’s first negative comment. The use of recycled material will be included in the markings on the HDPE pipe. The pipe will be marked each ten feet with the words manufactured with recycled content.

13. In Figure 2, revise definition from "C = Distance from Centroid to Inner Wall" to "C = Distance from Centroid to Inner Liner".

14. In Section 9.4.1.2, consider revising from "specimens are taken" to "specimens are die cut".
15. In Section 9.4.1.2, add a new sentence to the end that reads "Specimens die cut from the finished pipe liner shall be tested as noted in Section 6.1.1." to be consistent with similar/same language contained in Section 9.4.1.3 at end.
16. In Section 9.4.1.3, consider revising from "If specimens are taken" to "If specimens are die cut".
17. In Section 9.4.1.3, revise from "ground-up pieces of pipe that have" to "ground-up pieces of pipe (from liner and/or outer wall) that have".
18. In Section 9.4.2, 3rd line, consider revising from "on specimens taken" to "on specimens die cut" or "on specimens die cut or machined" as ASTM F3181, Section 5.1 indicates "Alternatively, specimens may be prepared by machining"; however, ASTM F3181, Section 6.2 indicates "The specimen is prepared by cutting out a Test Method D638 Type I specimen" which does not seem to include the alternative machining method for specimen preparation.
19. In Section 9.4.2, 4th line, revise from "in accordance to" to "in accordance with".
20. Following Section 12, consider adding new Section 13 for KEYWORDS and adding the keywords "corrugated; pipe; polyethylene; recycled material" and perhaps others consistent with the keywords added to M 252 for example.
21. Use of the NCLS and UCLS will probably NOT be done by DOT's as a routine test (for reasons including sample prep as well as the actual testing). Given the latitude of the manufacturer to provide EITHER virgin or recycled resin, the owner will have to TRUST the certification of the manufacturer OTHERWISE the recycled testing will have to be done as A DEFAULT for confirmation purposes. This will require the owner to pay for 3rd party testing of these products. (David Kuniega)

This could be included in NTPEP testing plan.
22. Have Author clarify the background and distinctions between Comment [MP5} on page M 294-5 and Section A1.2.1 as they relate to different NCLS testing times. (David Kuniega)

Chair: Comments 1 to 11 and 13 to 20 are editorial in nature. Comments 12, 21 and 22 are more than editorial. The Chair believes that the NTPEP testing plan for HDPE pipe can address these three issues.

Illinois Comments:
1. Section 1.1.2: Perforations should be included in the list.
2. Section 2.1: R 16 does not appear to be referenced in AASHTO M 294-16.
3. Section 2.2: D4218 and D5397 do not appear to be referenced in AASHTO M 294-16.
4. Section 3.5: In the second sentence it reads "â€¦ and micro-cracks and around a contaminantâ€¦" Should the second "and" be deleted?
5. Section 5.1.6: The wording for Section 5.1.6 (Certification, if desired (Section 12.1)) has been included in the heading for Section 6.
6. Section 7.8.4" In the second sentence revise "small" to "smaller."
7. Section 9.7: Should references to Figures 3 and 4 be revised to Figures 5 and 6 in both paragraphs in Section 9.7?

Chair: Editorial in nature.

Missouri Comments:
1. On Page 3, Section 3.11, recommend adding the word 'containers' at the end of the sentence for clarification. The sentence word read as follows:

Proposed: "... laundry detergent bottles, milk bottles and other consumer good containers."

2. On Page 4, it appears the section number '5.1.6' was deleted inadvertently.
3. On Page 5, Section 6.1.1.1, need to define 'NCLS' before utilizing the abbreviation in the rest of the specification.
4. On Page 5, Section 6.1.1.2, need to define 'UCLS' before utilizing the abbreviation in the rest of the specification.
5. On Page 5, Section 6.1.1.3, recommend the last part of the last sentence be placed into a note. It is providing information on why the ultrasound technique can be used to determine the density. The new note would read as follows:
   Proposed "Note # - Ultrasound density is not affected by colorant and other inorganic compounds that may be present in these materials."

   Chair: Editorial in nature.

Comments from Friends of the Committee:

Forterra Pipe and Precast (Oliver Stanislaus Delery Jr)
ASTM Committee F-17 recently balloted similar changes to their specification and due to the negative votes submitted, the ballot item was pulled as apparently a number of those negatives were found to be persuasive. While I cannot copy all of the ASTM submittals, this committee should consider the major objections including:
1. Very limited research of only 6 pipe samples;
2. Service life predictions use a very limited range of service temperatures;
3. A separate specification should be used for recycled resins as it is too confusing to not only the designer but his/her coordination with the field inspectors who will have to check each pipe to determine whether recycled content is in use.
4. Most of the research is based on "post consumer" resins but the specification allows "post industrial" also.
5. The installation used in the research paper is a very high quality and not the typical installation used in most pipe projects.

   Chair: Thank you for reviewing and providing input for technical section consideration on this specification and research report.

American Concrete Pipe Association (Josiah W Beakley) See Appendix
Chair: Thank you for reviewing and providing input for technical section consideration on this specification and research report.

Resolution: A Task Force was set up to address negatives by CALTRANS, Florida and Michigan. The task force will also look at incorporating the comments from PA, IL and MO. The Task Force 2017-05 included Mike Pluimer, NC, PA, NY, FL, MI and CALTRANS.

A motion made by ME, seconded by NY to move the recycled changes to concurrent and SOM ballot after task force review.

CALTRANS first negative that the modifications to M 294 did not provide a distinction for pipe made with recycled materials was satisfied by inserting into the Markings Section 11.1.5 the statement: "If the pipe was manufactured with recycled content, it shall be designated accordingly with the phrase “Contains Recycled Resins”; This means that M 294 pipe will have the phrase “contains recycled resins” clearly marked at intervals of 10 ft. on the pipe.

CALTRANS second negative on the fact that the report is an unedited final report yet to be published was not resolved. The chair had received word that the technical review had been completed and there were no technical changes made to the report at that time. It is understood that the final report will be published with the same technical information by the end of this year. This issue was discussed at the SOM meeting and the Executive Secretary of the Subcommittee.
on Materials recommended that CALTRANS or any other state should vote an administrative negative to cover this point. Therefore it was recommended that California repeat their vote exactly as stated on the TS ballot above on this point. The task force had a webinar on September 29, 2017 and discussed Florida’s concerns on the level of impurities in Post-Consumer Recycled Material, pipe size influence on UCLS test and a label for the durable sticker like M 294-R. The answers to these concerns are summarized as: The purpose of the UCLS test is to detect small amounts of impurities in recycled material, the size of the pipe does not influence the UCLS test and adding M 294-R to the durable sticker will not present any problem. The task force also discussed that frequencies of quality control testing for OIT and UCLS would be determined based on PPI guidance to manufacturers and quality assurance testing frequencies would be determined in the NTPEP work plan. There are also a couple ASTM Work Items on quality control testing underway at the present time. This discussion satisfied the inquiries in comment twelve submitted by PENNDOT. MI has had time to read the report and Michael Pluimer described how the long term creep modulus testing was performed using a Step Isothermal Model (SIM) Test in response to NY question. The task force considered each of the comments from PA, IL and MO in updating the specification. See Attachment 5 for these updates to M 294.

C. Task Force Reports

Task Force 2017-01 - Assignment was to review the corrugated metal pipe specification for M190 and consider adding a subsection for determining the coating thickness to Section 7. The task force was also asked to review M243 and to determine if a method should be specified to measure the coating thickness of 1.27 mm. Should the specified measurement be modified to “minimum of 1.3 mm” given this is a field applied asphalt mastic coating? Task Force Members are Mike McGough (NCSPA), Tim Ramirez (PA) and VA.

Report from Mike McGough: Mike suggested that a simple penetrometer could be used to determine if the minimum coating thickness was applied to the corrugated metal pipe invert. PA is okay with the proposed type of method being used in the specification. A motion to accept this as a method and place the details in M 190 in a concurrent and SOM ballot was made by PA, seconded by NC. All were in favor. This specification was not updated in time for a TS and SOM ballot. It will be prepared for review at the next technical section ballot in 2018.

Task Force 2017-02 - Assignment was to review the HDPE pipe specification M252 and the polypropylene pipe specification M330 and incorporate the same changes made in M294 related to definitions for crease, buckling and delamination used in the visual evaluations associated with performing the pipe flattening test in these standards. Task Force Members are: Dan Currence (PPI), Tim Ramirez (PA), Therese Kline (MI), Don Streeter (NY), Brian Chestnut (Lane), Heather Christensen (Prinsco), and Jim Goddard.

Report – Revisions were made to both M252 and M330. The revisions are Item 1 and 2 on SOM TS4B 17-01 Summer Ballot.

Task Force 2017-03 - Assignment was to review the HDPE pipe liner specification M326 and incorporate the same changes made in M294 related to definitions for crease, buckling and delamination used in the visual evaluations associated with performing the pipe flattening test in these standards.
Task Force Members are: Tim Toliver (Advanced Pipe Services), Tim Ramirez (PA), Don Streeter (NY), Dan Currence (PPI), Jim Goddard and VA.

Report – Revisions were made to M326. The revisions are Item 3 on SOM TS4B 17-01 Summer Ballot.

Task Force 2017-04 - Assignment was to review the provisional steel reinforced HDPE pipe specification MP 20 and incorporate the same changes made in M294 related to definitions for crease, buckling and delamination used in the visual evaluations associated with performing the pipe flattening test in MP 20 if they apply. If they are they should be handled by TS ballot.

Task Force Members are: Darrell Sanders (Contech) and Stewards (MI and NC) of MP 20

Report from Darrell Sanders – nothing to report
The chair noted there had not been any significant changes made since MP 20 had become a provisional standard.

The Chair asked the technical section for a decision to Adopt or Drop this standard. This is last year as provisional.
A motion to adopt this as a full standard was made by NC, seconded by FL. All were in favor. This will go to full SOM ballot. See Attachment 6 for MP 20 to be adopted as full standard on SOM ballot.

V. New Business

A. Research Proposals
1. 20-7 RPS
2. Full NCHRP RPS

No Proposals to date

B. AMRL/CCRL - Observations from Assessments

C. NCHRP Issues

Final report on “NCHRP 4-39 Update: Field Performance of Corrugated HDPE Pipe Manufactured with Recycled Content”

D. Correspondence, calls, meetings, webinar,

E. Presentation by Industry/Academia

Ryan Fragapane with AASHTO gave update on NTPEP programs

NTPEP Corrugated Metal Pipe program:

• Ready to perform CMP audits at this time.
• Working with Industry on last minute concerns of program.
• Several States requiring NTPEP for 2017/2018
NC: One of industry concerns are there are not enough states willing to adopt the program yet. We need commitment from the states to participate.

TN, NC, NY, WI, VA, FL, VT will be adopting this program within the next year. MT is planning on implementing it in 2019. KS is interested in the program and is thinking about adopting it.

General NTPEP Updates:

The Thermoplastic Pipe committee continues to look at Steel Reinforced Polyethylene Pipe (SRPE) for inclusion in the audit program. For those not familiar with this pipe design, it is comprised of a polyethylene liner (smooth) that has outer ribs into which flat steel ribbons are fabricated. The steel ribbons “stand up” from approximately 1 to 3 inches in height, depending on the diameter of the pipe, and wind helically down the outside of the pipe. The steel is completely encapsulated in the plastic. Presently there is one manufacturer of this pipe. AASHTO has a provisional standard for this pipe, MP 20 “Steel-Reinforced Polyethylene (PE) Ribbed Pipe, 300- to 1500-mm (12- to 60-in.) Diameter”.

A representative of the NYDOT expressed interest at the last NTPEP Annual Meeting in adding two additional pipe categories to the Thermal Pipe Committee: ASTM F714 and ASTM F894. The F714 standard is titled “Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter”. Section 1.3 states, “The piping is intended for new construction and insertion renewal of old piping systems used for the transport of water, municipal sewage, domestic sewage, industrial process liquids, effluents, slurries, etc, in both pressure and non-pressure systems.” The F894 standard is titled, “Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe”. Section 4.1 Uses states, “The requirements of this specification are intended to provide pipe suitable for underground or over ground gravity flow drainage of sewage, surface water, and industrial waste.”

There have been 3 plants this past year to lose their certificate of compliance from 3 different companies, all for pipe/resin comparison testing failures. In order to lose their certificate of compliance, the initial samples failed at least one test and a resample also failed at least one test. Two of the three locations have had follow-up audits and their certifications have been reinstated.

NTPEP will conduct 21 PP pipe audits, 52 HDPE Pipe audits, and 2 PVC pipe audits in 2017.

Michael Pluimer PhD. with Cross Roads Engineering presented a summary of NCHRP Project 4-39: “Field Performance of Corrugated HDPE Pipes Manufactured with Recycled Materials” and answered questions. The Presentation is Attachment 7 to minutes.

Tim Toliver P.E. with Advanced Pipe Services gave a presentation on a new type of SRHDPE that will be coming to the DOT market next year: “Steel Reinforced Corrugated Polyethylene Pipe – Materials and Design Method” Tim’s presentation was limited to approximately ten minutes due to the discussion on recycled HDPE. The Presentation is Attachment 8 to minutes.

F. Proposed New Standards
G. Proposed New Task Forces

Task Force 2017-05 was established to review the negatives, comments and suggestions made on TS4B 17-01 Summer ballot item 4 on M 294 HDPE pipe specification in order to prepare M 294 for concurrent and SOM ballot. Task Force is composed of Michael Pluimer, NC, VA, NY, CALTRANS, PENNDOT and Florida.

H. Standards Requiring Reconfirmation

There are no Standards requiring reconfirmation in this technical section this year. MP20 a provisional standard is in its last year and must be approved as a full standard or deleted.

I. SOM Ballot Items (including any ASTM changes/equivalencies)

There are 5 SOM ballot items. Standards M 252, M 330, M326 and M 294 are concurrent TS and SOM ballot items and MP 20 is an SOM ballot item only. See Attachment 9 Ballot items for details and Attachment 10 for Technical Section 4b Summary.

VI. Open Discussion

Missouri requested the technical section discuss T 249 Lock seam test Section 2.3:

In Section 2.3 of T 249 - The edges of the sheets within the cross section of the lock seam shall lap at least 4.0 mm for pipe 250 mm or less in diameter and at least 7.9 mm for pipe greater than 250 mm in diameter, with an occasional tolerance of –10 percent of lap width allowable. The lapped surfaces shall be in tight contact. There shall be no visible cracks in the metal, loss of metal-to-metal contact, or excessive angularity on the interior of the 180-degree fold of metal at the completion of forming the lock seam. Measure the seam lap and retaining offset distances (Figure 2) for conformance with specified maximum or minimum dimensions. See Figure 3 for examples of unacceptable seam cross sections.

![Excessive Interior Angularity](image1)

![Insufficient Retaining Offset](image2)

![Excessive Interior Angularity and Roller Indentation](image3)

**Figure 3**—Examples of Unacceptable Seams

Missouri question was: “Does lock seam need to pass both tensile strength and Figure 3 examples of unacceptable seam cross sections?”

The Chair stated as time was running out that after looking at the standard he believes it needs to meet both the visual examination and the tensile strength requirement.

VII. Adjourn
The meeting was adjourned at 3:05 pm.

BLUE = Information proposed before meeting or suggested by Chair in preparation for meeting
Red = Actions that took place at the meeting or as a result of meeting.
Red = Important Actions, Resolution of Task forces and Attachments

VIII. Appendix - Comments

Comments from Friends of Committee on M 294

American Concrete Pipe Association (Josiah W Beakley)

My initial comment is that HDPE pipe using recycled resin should be incorporated into a standard of its own. The differences between virgin resin and recycled resin and their requirements should not get confused within a single standard. Additionally, there is very little supporting data on the accuracy of the test methods incorporated for recycled resin. There needs to be additional research that focuses on the variables of size, manufacture, installation quality, installation depth, etc. What is presented here is something that would otherwise be in a provisional standard when it is ready. That is where this should start, in a provisional standard of its own.

Section 2.1 – Does an “AASHTO Standard Practice for Service Life Determination of Corrugated HDPE Pipes Manufactured with Recycled Materials” exist? No, it is in the NCHRP report. If so, shouldn’t it have an AASHTO number designation?

Section 2.3 – While the thesis referenced in this section provides information with regards to the use of recycled resins in HDPE pipe, it is not sufficient to validate the added test methods or justify the addition of recycled resin to this standard. The NCHRP 04-39 research report is supposed to be published in late 2017. The distribution of the draft report to the TS 4b members one week before the ballot is due is not sufficient time for review of the report. The fact that the ballot came out before the report indicates this is being rushed.

Section 6.1.1.1 – I would disagree with Dr. Pluimer’s assessment that Report 631 showed a 24 hour test to be equivalent to an 18 hour test on the liner. It showed some correlation for the limited tests that were run, and even with that there was some very large deviations. The whole point is that every profile and manufacturing process will develop its own induced stresses, and should be tested accordingly. The basis of the research for NCHRP Report 631 was to develop a desperately needed test for the finished product. This test should not be thrown away on a whim.

Section 6.1.1.2 – This section should start out, “For pipes manufactured with recycled materials, UCLS testing shall be conducted in addition to the NCLS test...”. How often is this test to be performed? How often is the NCLS test performed? Both tests should be performed at a higher rate for recycled resin since the quality is probably not as consistent. Thus, it would be appropriate to have a stand-alone standard for HDPE pipe with recycled resins to address these issues.

I am not sure that a factored tensile design stress of 500 psi is conservative. AASHTO design allows for much higher tensile stress than this. We have not seen any legitimate effort to address the tension stresses that go across the liner of the profile, and are often the critical limit state in these profiles.
If you are concerned with the effect of potential contaminants in the resin, then you should be testing more than the standard 5 samples used for virgin resins, since the contaminants are random and may be different in size, making it hard to correlate a service life with such a small sample.

Service temperature is defined as the temperature “at which the pipe will be operating for the life of the project”. This temperature is critical in determining the service life. It would seem apparent that depending upon the location of the installation, the service temperature will fluctuate greatly, possibly down to 0 deg. C in freezing environments and up to 27 deg. C in shallow installations in warmer environments. In some locations it will be subjected to both. Is the service life the average, or should it be determined in a different manner?

There is a great variance between the required average failure time and the minimum failure time. I am not aware of any other test method for pipe materials that allows such a great disparity between the average value used for determining a property of the pipe material, and the minimum value allowed within that average. This variance needs to be tightened. Additionally, if you are only testing a very small sampling of the resin, such as is done here, it may be that the test with the lowest value is representative of what occurs when you have a contaminant in the sample, versus the other test values that may have been fortunate enough to have not had a contaminant. Would you not want to use the lowest value, since that is representative of what can occur in the field? If you only take 5 samples, than in essence you have a 20% chance that the material will exhibit a problem much earlier than the prediction you made based on the much higher average value. Is that an acceptable risk?

Section 6.1.1.3 - The determination of the OIT test time is not really covered in reference 3, and very little information is given here with respect to how 20 minutes was established. There are a few ASTM Standards that use 25 minutes for gravity pipe, but even that value would be suspect when applying it to recycled resin material that will have stress risers.

Section 9.4.1 – This should remain as is. The standard needs a test for the finished product.

Section 9.4.1.3 – There is almost no occasion where a sample cannot be cut from the liner. This section should be removed in its entirety. At the very least, it should not be modified.

Section 9.4.2 – This section is not appropriate. It is not a test on the finished product, and more research needs to be presented to justify the test values.

Section A2 – Does an AASHTO procedure, as referenced in 2.1 exist for this? **Yes, it is in NCHRP report.**
Standard Specification for

Corrugated Polyethylene Drainage Pipe

AASHTO Designation: M 252-09 (2017)

Technical Section: 4b, Flexible and Metallic Pipe

Release: Group 2 (June 2017)
Standard Specification for

Corrugated Polyethylene Drainage Pipe

AASHTO Designation: M 252-09 (2017)

Technical Section: 4b, Flexible and Metallic Pipe

Release: Group 2 (June 2017)

1. SCOPE

1.1. This specification covers the requirements and methods of test for corrugated polyethylene (PE) pipe, couplings, and fittings for use in subsurface drainage systems, storm sewers, and in surface drainage (culverts), where soil support is given to the pipe’s flexible walls in all applications.

1.1.1. Nominal sizes of 75 to 250 mm (3 to 10 in.) are included.

1.1.2. Materials, workmanship, dimensions, pipe stiffness, environmental stress-crack resistance, perforations, joining systems, brittleness and forms of marking are specified.

Note 1—When PE pipe is to be used in locations where the ends may be exposed, consideration should be given to combustibility of the PE and the deteriorating effects of prolonged exposure to ultraviolet radiation.

1.2. Units—The values stated in SI units are to be regarded as standard. Within the text, the U.S. Customary units are shown in parentheses, and may not be exact equivalents.

1.3. The following precautionary caveat pertains only to the test method portion, Section 9.3 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. AASHTO Standard:

- R 16, Regulatory Information for Chemicals Used in AASHTO Tests

2.2. ASTM Standards:

- D618, Standard Practice for Conditioning Plastics for Testing
- D883, Standard Terminology Relating to Plastics
- D1693, Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
- D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
- D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
- D4218, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
3. TERMINOLOGY

3.1. The terminology used in this standard is in accordance with the definitions given in ASTM D883 and ASTM F412 unless otherwise specified.

3.2. **buckling**—During pipe flattening testing, any decrease or downward deviation in the pipe load-deflection test curve shall be considered a buckling point.

3.2.3. **crack**—Any break or split that extends through the wall or liner.

3.2.3.4. **crease**—An visible irrecoverable indentation, generally associated with wall buckling.

3.5. **reworked material**—A plastic from a processor’s own production that has been reground, pelletized, or solvated after having been previously processed by molding, extrusion, etc. (ASTM D883).

3.5.6. **delamination**—A separation between the liner and outer corrugated wall of Type S pipe as evidenced by a visible gap extending completely through at least one corrugation valley at any point around the circumference of the pipe.

4. CLASSIFICATION

4.1. The corrugated PE pipe covered by this specification is classified as follows:

4.1.1. **Type C**—This pipe shall have a full circular cross section, with a corrugated surface both inside and outside. Corrugations may be either annular or helical.

4.1.1.1. **Type CP**—This pipe shall be Type C with Class 2 perforations.

4.1.2. **Type S**—This pipe shall have a full circular cross section, with an outer corrugated pipe wall and a smooth inner liner. Corrugations may be either annular or helical. Type S pipe is not available in nominal sizes of less than 100 mm (4 in.).

4.1.2.1. **Type SP**—This pipe shall be Type S with either Class 1 or Class 2 perforations.

4.2. Class 1 and Class 2 perforations are as described in Sections 7.4.1 and 7.4.2.

5. ORDERING INFORMATION

5.1. Orders using this specification shall include the following information as necessary to adequately describe the desired product:

5.1.1. AASHTO designation and year of issue;

5.1.2. Type of pipe (Section 4.1);

5.1.3. Diameter and length required, either total length or length of each piece and number of pieces;
Note 2—Type C and CP pipe less than 200 mm (8 in.) in diameter may be supplied coiled; coiling of Type C and CP pipe 200 mm (8 in.) in diameter or greater is not recommended; Type S and SP pipe is not supplied in coils.

5.1.4. Number of couplings;

5.1.5. For Type SP pipe, class of perforations (Class 2 is furnished if not specified) (Section 7.4); and

5.1.6. Certification, if desired (Section 12.1).

6. MATERIALS

6.1. Basic Materials:

6.1.1. Extruded Pipe and Blow Molded Fittings—Pipe and fittings shall be made of virgin PE resin compounds meeting the requirements of ASTM D3350 and cell classification 424420C, except that the carbon black content shall not exceed 5 percent when tested in accordance with D4218. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.1.2. Rotational Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE resins meeting the requirements of ASTM D3350 and cell classification 213320C, except that the carbon black content shall not exceed 5 percent when tested in accordance with D4218. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.1.3. Injection Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE resins meeting the requirements of ASTM D3350 and cell classification 314420C, except that the carbon black content shall not exceed 5 percent when tested in accordance with D4218. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.2. Reworked Material—In lieu of virgin PE, clean reworked material may be used, provided that it meets the cell class requirements as described in Section 6.1.

7. REQUIREMENTS

7.1. Workmanship—The pipe and fittings shall be free of foreign inclusions and visible defects as defined herein. The ends of the pipe shall be cut squarely and cleanly so as not to adversely affect joining or connecting.

7.1.1. Visible Defects—Cracks, creases, delamination and unpigmented or non-uniformly pigmented pipe are not permissible in the pipe or fittings as furnished. There shall be no evidence of cracking or delamination when tested in accordance with Section 9.2.

7.1.2. Inner Liner—For Type S and SP pipe, the inner liner shall be fused to the outer corrugated wall at all internal corrugation crests.

7.2. Pipe Dimensions:

7.2.1. Nominal Size—The nominal size for the pipe and fittings is based on the nominal inside diameter of the pipe. Nominal diameters shall be sized for Type C and CP pipe in not less than 25-mm
(1 in.) increments from 75 to 250 mm (3 to 10 in.). Nominal sizes shall be sized for Type S and SP pipe in not less than 50-mm (2 in.) increments from 100 to 250 mm (4 to 10 in.).

7.2.2. **Inner Liner Thickness**—For Type S and SP pipe, the inner liner shall have a minimum thickness of 0.5 mm (0.02 in.) for pipe of 100 mm (4 in.) and 150 mm (6 in.) nominal size and a minimum thickness of 0.6 mm (0.025 in.) for pipe of 200 mm (8 in.) and 250 mm (10 in.) nominal size, when measured in accordance with Section 9.5.4.

7.2.3. **Inside Diameter Tolerances**—The tolerance on the specified inside diameter shall be +4.5, –1.5 percent when measured in accordance with Section 9.5.1.

7.2.4. **Length**—Corrugated PE pipe is an extruded product and may be sold in any length agreeable to the user. Lengths shall not be less than 99 percent of the stated quantity when measured in accordance with Section 9.5.2.

7.3. **Fitting and Coupling Dimensions**:

7.3.1. The maximum allowable gap between fitting or coupling and pipe shall not exceed 3 mm (0.1 in.) unless otherwise specified.

7.3.2. All fittings and couplings shall be within an overall length dimensional tolerance of ±12 mm (0.5 in.) of the manufacturer’s specified dimensions.

7.4. **Perforations**—When perforated pipe is specified, the perforations shall conform to the requirements of Class 2, unless otherwise specified in the order. Class 2 perforations are for pipe intended to be used for subsurface drainage or combination storm and underdrain. Class 2 perforations are for pipe intended to be used for subsurface drainage only. The perforations shall be cleanly cut so as not to restrict the inflow of water. Where circular perforations are preferred, the drill shall not penetrate the side walls of the corrugations. Pipe connected by couplings or bands may be unperforated within 100 mm (4 in.) of each end of each length of pipe.

**Note 3**—Pipe ordered under Class 1 perforations has no requirement as to inlet area because it specifies size, number, and location of holes. Alternate perforation patterns should be agreed to between the purchaser and manufacturer.

7.4.1. **Class 1 Perforations**—The perforations shall be approximately circular and shall have nominal diameters of not more than 5 mm (0.2 in.) for 100- and 150-mm (4- and 6-in.) diameter pipe and not greater than 10 mm (0.4 in.) for 200- and 250-mm (8- and 10-in.) diameter pipe. The holes shall be arranged in rows parallel to the axis of the pipe. The location of the perforations shall be in the valley of the outside corrugation and in each corrugation. The rows of perforations shall be arranged in two equal groups placed symmetrically on either side of the lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance of the centerlines of the uppermost rows above the bottom of the invert and the inside chord lengths of the unperforated segments illustrated in Figure 1 shall be as specified in Table 1. All measurements shall be made in accordance with Section 9.5.3.

<table>
<thead>
<tr>
<th>Nominal Diameter, mm (in.)</th>
<th>Rows of Perforations</th>
<th>Height $H$, mm (in.)</th>
<th>Chord Length $L$, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 (3)</td>
<td>2</td>
<td>35 (1.4)</td>
<td>50 (2)</td>
</tr>
<tr>
<td>100 (4)</td>
<td>2</td>
<td>45 (1.75)</td>
<td>65 (2.5)</td>
</tr>
<tr>
<td>150 (6)</td>
<td>4</td>
<td>70 (2.75)</td>
<td>95 (3.75)</td>
</tr>
<tr>
<td>200 (8)</td>
<td>4</td>
<td>94 (3.7)</td>
<td>130 (5.1)</td>
</tr>
<tr>
<td>250 (10)</td>
<td>4</td>
<td>120 (4.7)</td>
<td>160 (6.3)</td>
</tr>
</tbody>
</table>
7.4.2. Class 2 Perforations—Circular and slotted perforations shall conform to the maximum dimensions as shown in Table 2. Perforations shall be placed uniformly in the outside valleys of the corrugations. The water inlet area shall be a minimum of 20 cm²/m (1 in.²/ft) of pipe. All measurements shall be made in accordance with Section 9.5.3.

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter, mm (in.)</th>
<th>Drilled Hole Diameter, mm (in.)</th>
<th>Width, mm (in.)</th>
<th>Length, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 (3)</td>
<td>4.75 (0.19)</td>
<td>3 (0.12)</td>
<td>25 (1)</td>
</tr>
<tr>
<td>100 (4)</td>
<td>4.75 (0.19)</td>
<td>3 (0.12)</td>
<td>25 (1)</td>
</tr>
<tr>
<td>150 (6)</td>
<td>4.75 (0.19)</td>
<td>3 (0.12)</td>
<td>25 (1)</td>
</tr>
<tr>
<td>200 (8)</td>
<td>6.25 (0.25)</td>
<td>3 (0.12)</td>
<td>30 (1.2)</td>
</tr>
<tr>
<td>250 (10)</td>
<td>8.00 (0.3)</td>
<td>3 (0.12)</td>
<td>30 (1.2)</td>
</tr>
</tbody>
</table>

7.5. Pipe Stiffness—Type C pipe, as described in Section 4.1.1, shall have a minimum pipe stiffness (PS) of 240 kPa (35 psi) at 5 percent deflection; and Type S pipe, as described in Section 4.1.2, shall have a minimum PS of 340 kPa (50 psi) at 5 percent deflection when tested in accordance with Section 9.1. The pipe tested shall contain perforations, if specified.

7.6. Pipe Flattening—There shall be no visual evidence of wall buckling (a decrease or downward deviation in the load-deflection curve), cracking, splitting, or delamination, or decrease or downward deviation in the load-deflection curve when the pipe is tested in accordance with Section 9.2.
7.7. Environmental Stress Cracking—There shall be no cracking of the pipe when tested in accordance with Section 9.3.
Brittleness—There shall be no cracking of the pipe wall or liner when tested in accordance with Section 9.4 except as specified in Sections 7.8.1 and 7.8.2.

Note 4—The brittleness test is similar to that described in ASTM F405.

7.8.1. Cracks with a maximum chord length of 10 mm (0.4 in.) that originate at a perforation or at either end of the sample shall not be cause for rejection.

7.8.2. Splitting along a seam or mold parting line is not caused by brittleness and should be evaluated as a workmanship defect as described in Section 7.1.1 if no split exceeds 50 mm (2 in.) in chord length.

7.9. Fitting and Coupling Requirements:

7.9.1. The fittings and couplings shall not reduce or impair the overall integrity or function of the pipe line.

7.9.2. Common corrugated fittings include reducers, tees, wyes, and end caps.

Note 5—Only fittings and couplings supplied or recommended by the pipe manufacturer should be used.

7.9.3. Fittings and couplings shall not reduce the inside diameter of the pipe being joined by more than 5 percent of the nominal inside diameter. Reducer fittings shall not reduce the cross-sectional area of the smaller size.

7.9.4. Pipe connected by in-line couplers shall not separate when tested in accordance with Section 9.6.1.

7.9.5. The coupling shall not crack or crease when tested in accordance with Section 9.6.2.

7.9.6. The design of the couplers shall be such that when connected with the pipe, the axis of the assembly will be level and true when tested in accordance with Section 9.6.3.

8. CONDITIONING

8.1. Conditioning—Condition the specimen prior to test at 23 ± 2°C (73.4 ± 3.6°F) for not less than 24 hours in accordance with Procedure A in ASTM D618 for those tests where conditioning is required, and unless otherwise specified.

8.2. Conditions—Conduct the test in a laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F) unless otherwise specified herein.

9. TEST METHODS

9.1. Pipe Stiffness—Select a pipe specimen and test for PS as described in ASTM D2412, with the following exceptions.

9.1.1. The test specimen shall be 300 ± 10 mm (12 ± 0.4 in.) long, cut to include full corrugations.

9.1.2. Locate the specimen in the loading machine with an imaginary line connecting the two seams formed by the corrugation mold (end view) parallel to the loading plates. The specimen must lie flat on the plate within 1 mm (0.04 in.) and may be straightened by hand bending at room temperature to accomplish this.

9.1.3. The deflection indicator shall be readable and accurate to ±0.03 mm (0.001 in.).
9.1.4. The residual curvature found in corrugated pipe, especially that furnished in coils, frequently results in an erratic load-deflection curve. When this occurs, the beginning point for deflection measurements shall be at a load of 20 ± 5 N (4.5 ± 1 lbf). This point shall be considered as the origin of the load-deflection curve.

**Note 6**—The parallel plates must exceed the length of the test specimen as specified above.

**Note 7**—Additional pipe specimens may be tested at other orientations for PS and flattening if desired.

9.2. **Pipe Flattening**—Flatten the pipe specimen from Section 9.1 until the vertical inside diameter is reduced by 20 percent. The rate of loading shall be the same as in Section 9.1. The specimen shall fail if wall buckling *(a decrease or downward deviation in load-deflection curve)*, cracking, splitting, or delamination is observed with the unaided eye or if there is a decrease or downward deviation in load-deflection curve at 20 percent or less deflection. Immediately after the specimen has started to unload, check for visible evidence of cracking, splitting or delamination. The load-deflection curve shall be carried beyond 20 percent deflection so that the shape of the curve at 20 percent deflection can be determined.

9.3. **Environmental Stress Cracking**—Test sections of the pipe for environmental stress cracking in accordance with ASTM D1693, except for the following modification:

9.3.1. Two specimens shall be tested.

9.3.2. Each specimen shall consist of a 90-degere arc length of pipe without perforations as shown in Figure 2.

[Figure 2: Specimen Configuration for Environmental Stress Cracking]

9.3.3. Bend the specimens to shorten the inside chord length 20 ± 1 percent and retain in this position using a suitable holding device. Determine the arc chord dimension (B) of the specimen under test as follows:

\[ B = 0.84A \]  

where:

- \( A \) = the inside chord dimension before bending, and
- \( B \) = the same dimension taken after bending (see Figure 2).

9.3.4. Place the bent specimen in a container of suitable size and cover completely with the preheated wetting agent 100 percent “Igepal CO-630,” a trade name for nonylphenoxypoly(ethyleneoxy)ethanol, at 50 ± 2°C (122 ± 3.6°F). Maintain this temperature for 24 h, and then remove the sample and inspect immediately. For recommended practices on using specific chemicals to test plastic pipe, refer to R 16.
9.4. **Brittleness**—Test two samples of pipe at an impact of 45 J (35 ft-lbf) between two flat parallel plates using the apparatus depicted in Figure 3.
9.4.1. Cut the sample specimens 150 mm (6 in.) long from one continuous length.

9.4.2. Condition specimens at –4 ± 2°C (25 ± 3.6°F) for a minimum of 1 h.

9.4.3. Set the 9.5-kg (20-lb) top plate for a free fall of 500 mm (20 in.) to the uppermost surface of the specimen.

9.4.4. Locate the specimen on the bottom plate with the plane of the corrugated seam/the longitudinal pipe axis parallel to the plate slot. Rotate the pipe sample such that the imaginary plane through the two longitudinal seams formed by the corrugation mold is parallel to the plate.

9.4.5. Drop the upper plate and impact test the specimen within 30 s of removal from the conditioning environment.

9.4.6. Remove and inspect in accordance with the requirements of Section 7.8.

9.5. Pipe Dimensions:

9.5.1. Inside Diameter—Measure the inside diameter of two sections of pipe with a tapered plug in accordance with ASTM D2122. Alternatively, measure the inside diameter of two sections.
with a suitable device accurate to ±0.2 mm (0.008 in.) the mold part-line and 90 degrees to it, and average the measurements.

9.5.2. **Length**—Measure pipe with any suitable device accurate to 0.2 percent. Make all measurements on the pipe while it is stress-free and at rest on a flat surface in a straight line. The length measurements may be taken at ambient temperature.

9.5.3. **Perforations**—Measure dimensions of perforations on a straight specimen with no external forces applied. Make linear measurements with instruments accurate to 0.2 mm (0.008 in.).

9.5.4. **Inner Liner Thickness**—Measure the thickness of the inner liner with a digital micrometer or ultrasonic thickness gauge in accordance with ASTM D2122.

9.6. **Couplings**:

9.6.1. **Joint Integrity**—This test is limited to Type C and Type CP pipe supplied in coils. Assemble couplings to appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 150 mm (6 in.) in length. Vertically suspend two pipe lengths connected by the joint couplings along their longitudinal axis. Then hang a tare mass from the lower end of the assembled pipe specimen for 3 min. Apply the test mass gently. Verify that the joint will support a mass along the pipe axis equal to 0.090 kg/mm (60 lb/ft) of the nominal inside diameter, without separating. Test two couplings of each type.

9.6.2. **Strength**—Assemble each coupling to the appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 150 mm (6 in.) in length. Load the connected pipe and coupling between parallel plates at the rate of 12.5 mm/min (0.5 in./min) until the vertical inside diameter is reduced by at least 20 percent of the nominal diameter of the coupling. Inspect for damage while at the specified deflection and after load removal, and report the results of this inspection.

9.6.3. **Alignment**—Assure that the assembly or joint is correct and complete; if the pipe is bent, it should be hand-straightened prior to performing this test. Lay the assembly or joint on a flat surface and verify that it will accommodate straight-line flow.

10. **INSPECTION AND RETEST**

10.1. **Inspection**—Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

10.2. **Retest and Rejection**—If any failure to conform to these specifications occurs, the pipe or fittings or couplings may be retested to establish conformity in accordance with agreement between the purchaser and seller. Individual results, not averages, constitute failure.

11. **MARKING**

11.1. All pipe shall be clearly marked at intervals of not more than 3.5 m (10 ft), and fittings and couplings shall be clearly marked, as follows:

11.1.1. Manufacturer’s name or trademark,

11.1.2. Nominal size,

11.1.3. The specification designation AASHTO M 252,
11.1.4. The plant designation code, and

11.1.5. The date of manufacture or an appropriate code. If a date code is used, a durable manufacturer sticker that identifies the actual date of manufacture shall be adhered to the inside of each length of pipe.

Note 8—A durable sticker is one that is substantial enough to remain in place and be legible through installation of the pipe.

12. QUALITY ASSURANCE

12.1. A manufacturer’s certification that the product was manufactured, tested, and supplied in accordance with this specification shall be signed by a person authorized by the manufacturer.

13. KEYWORDS

13.1. Crack; corrugated; crease; drainage; Polyethylene pipe; reworked material.
Standard Specification for

Polypropylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter

AASHTO Designation: M 330-13 (2017)¹
Technical Section: 4b, Flexible and Metallic Pipe
Release: Group 2 (June 2017)
1. SCOPE

1.1. This specification covers the requirements and methods of tests for corrugated polypropylene (PP) pipe, couplings, and fittings for use in surface and subsurface drainage application.

1.1.1. Nominal sizes of 300 to 1500 mm (12 to 60 in.) are included.

1.1.2. Materials, workmanship, dimensions, pipe stiffness, environmental stress crack resistance, joining systems, brittleness, perforations and form of markings are specified.

1.2. Corrugated polypropylene pipe is intended for surface and subsurface drainage applications where soil provides support to its flexible walls. Its major use is to collect or convey drainage water by open gravity flow, as culverts, storm drains, sewers, etc. This standard does not cover applications that require polypropylene pipe over 600 mm (24 in.) with a minimum pipe stiffness over 314 kPa (46 psi) and low-pressure watertight joints (7.6 m (25 ft) of constant head), such as required in sanitary sewer applications.

1.3. This specification does not include requirements for bedding, backfill, or earth cover load. Successful performance of this product depends on proper type of bedding and backfill, and care in installation. The structural design of thermoplastic pipe and the proper installation procedures are given in the AASHTO LRFD Bridge Design Specifications, Section 12, and AASHTO LRFD Bridge Construction Specifications, Section 30, respectively. Upon request of the user or engineer, the manufacturer shall provide profile wall section detail required for a full engineering evaluation.

1.4. The values stated in SI units are to be regarded as standard. Within the text the U.S. Customary units are shown in parentheses and may not be exact equivalents.

1.5. The following precautionary caveat pertains only to the test method portion, Section 9.4 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. AASHTO Standards:

   - R 16, Regulatory Information for Chemicals Used in AASHTO Tests
2.2. ASTM Standards:
- D618, Standard Practice for Conditioning Plastics for Testing
- D638, Standard Test Method for Tensile Properties of Plastics
- D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- D792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D883, Standard Terminology Relating to Plastics
- D1238, Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- D1505, Standard Test Method for Density of Plastics by the Density-Gradient Technique
- D1600, Standard Terminology for Abbreviated Terms Relating to Plastics
- D1928, Standard Practice for Preparation of Compression-Molded Polyethylene Test Sheets and Test Specimens (withdrawn 2001)
- D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
- D2444, Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
- D2990, Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
- D3895, Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
- D4101, Standard Terminology for Plastic Piping Systems
- D6992, Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
- F412, Standard Terminology Relating to Plastic Piping Systems
- F2136, Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

3. TERMINOLOGY

3.1. The terminology used in this standard is in accordance with the definitions given in ASTM D883, D1600, and F412 unless otherwise specified.

3.1.1. Buckling—during pipe stiffness and flattening testing, any decrease or downward deviation in the pipe stiffness test curve at or below the calculated buckling deflection limit shall be considered a buckling point.
3.1.2. crack—any break or split that extends through the corrugations/ribs wall or inner wall (liner).
3.1.3. crease—a visible irrecoverable indentation, generally associated with wall buckling.
3.1.4. delamination—a separation between the inner-inner wall (liner) and the outer corrugated Type S pipe as evidenced by a visible gap extending completely through at least one corrugation valley at any point around the circumference of the pipe. For Type D pipe, delamination is a separation of the inner wall (liner) and outer corrugation/rib wall or a separation of the exterior corrugation/rib wall as evidenced by a visible gap extending completely between the interior supports/corrugation/ribs and inner wall (liner) or outer exterior wall at any point around pipe.
3.1.5. polypropylene (PP)—a polymer prepared by the polymerization of propylene as the sole monomer (ASTM D883).
3.1.6. reworked plastic—a plastic from a processor’s own production that has been reground, pelletized, or solvated after having been previously processed by molding, extrusion, etc. (ASTM D883).
3.1.7. slow crack growth—a phenomenon by which a stress crack may form. A stress crack is an external or internal crack in plastic caused by tensile stresses less than its short-time mechanical strength.
3.1.8. virgin polypropylene material—PP plastic material in the form of pellets, granules, or powder that has not been subject to use or processing other than required for initial manufacture.

4. CLASSIFICATION

4.1. The corrugated polypropylene pipe covered by this specification is classified as follows:

4.1.1. Type C—This pipe shall have a full circular cross section, with a corrugated surface both inside and outside. Corrugations shall be annular.

4.1.1.1. Type CP—This pipe shall be Type C with perforations.

4.1.2. Type S—This pipe shall have a full circular cross section, with an outer corrugated pipe wall and a smooth inner liner. Corrugations shall be annular.

4.1.2.1. Type SP—This pipe shall be Type S with perforations.

4.1.3. Type D—This pipe shall consist of an essentially smooth waterway inner wall (liner) braced circumferentially or spirally with projections-corrugations or ribs joined to an essentially smooth outer-exterior wall. Both walls shall be fused to, or continuous with, the internal

4.2. Two classes of perforations are as described in Sections 7.3.1 and 7.3.2.
5. **ORDERING INFORMATION**

5.1. Orders using this specification shall include the following information as necessary to adequately describe the desired product:

5.1.1. AASHTO designation and year of issue;

5.1.2. Type of pipe (see Section 4.1);

5.1.3. Diameter and length required, either total length or length of each piece and number of pieces;

5.1.4. Number of couplings;

5.1.5. Class of perforations (Class 2 is furnished if not specified) (see Section 7.3); and

5.1.6. Certification, if desired (see Section 12.1).

---

**Figure 1**—Types of Corrugated Polypropylene Pipe
6. **MATERIALS**

6.1. **Basic Materials**:

6.1.1. **Extruded Pipe and Fittings**—Pipe and fittings shall be made of virgin polypropylene compounds meeting or exceeding the requirements in Table 1. Polypropylene compounds shall be comprised of the base polypropylene resin and all additives, colorants, UV inhibitors, and stabilizers. Conditioning, sampling, preparation, and testing of specimens shall be in accordance with the requirements in ASTM D4101.

<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Test Method</th>
<th>Units (SI Units)</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Flow Rate (@446°F (230°C))</td>
<td>D1238</td>
<td>g/10 min</td>
<td>0.15</td>
<td>1.50</td>
</tr>
<tr>
<td>Density</td>
<td>D792, D1505</td>
<td>g/cm³ (lb/in.³)</td>
<td>0.900 (0.0325)</td>
<td>0.95 (0.0343)</td>
</tr>
<tr>
<td>Tensile Strength at Yield</td>
<td>D638</td>
<td>N/mm² (psi)</td>
<td>24 (3500)</td>
<td>31 (4500)</td>
</tr>
<tr>
<td>Elongation at Yield</td>
<td>D638</td>
<td>% (%)</td>
<td>5 (5)</td>
<td>25 (25)</td>
</tr>
<tr>
<td>Flexural Modulus (1% secant)</td>
<td>D970</td>
<td>N/mm² (psi)</td>
<td>1200 (175,000)</td>
<td>1900 (275,000)</td>
</tr>
<tr>
<td>IZOD Impact Strength (73°F (23°C))</td>
<td>D256</td>
<td>kJ/m² (ft-lb/in.²)</td>
<td>50 (23.8)</td>
<td>No Break</td>
</tr>
<tr>
<td>Oxidative-Induction Time (392°F (200°C))</td>
<td>D3895</td>
<td>min</td>
<td>25</td>
<td>200</td>
</tr>
</tbody>
</table>

6.1.2. **Injection Blow Molded Fittings and Couplings**—Fittings and couplings shall be made of virgin polypropylene resins that conform with the requirements of PP 0500 H 464 as defined and described in ASTM D4101 in Table 1. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.2. **Color and Ultraviolet Stabilization for Pipe and Fittings**—The pipe shall be colored or black. Black polypropylene compounds shall have between 2.0 and 4.0 percent carbon black. Colored polypropylene compounds shall be protected from ultraviolet (UV) degradation with UV stabilizers.

6.3. **Reworked Plastic**—In lieu of virgin PP, clean reworked plastic may be used by the manufacturer, provided that it meets the requirements as described in Section 6.1 and as defined in Section 3.5.

6.4. **Slow Crack Growth**—For slow-crack-growth resistance of the pipe corrugation, PP resins pipe liner specimens shall be evaluated using the notched constant ligament stress test according to the procedure described in Section 9.4. The average failure time of the five test specimens shall exceed 100 h with no single test specimen’s failure time less than 71 h.

6.5. **Long-Term Material Properties**—When tested in accordance with the procedure described in Section 9.8, the 75-year material properties for modulus of elasticity and tensile strength for polypropylene pipe shall be a minimum of 186 MPa (27,000 psi) and 7 MPa (1,000 psi), respectively.

7. **REQUIREMENTS**

7.1. **Workmanship**—The pipe and fittings shall be free of foreign inclusions and visible defects as defined herein. The ends of the pipe shall be cut squarely and cleanly so as not to adversely affect joining or connecting.
7.1.1. **Visible Defects**—Cracks, creases, delaminations, and unpigmented or non-uniformly pigmented pipe are not permissible in the pipe or fittings as furnished. There shall be no evidence of cracks, splits or delamination when tested in accordance with Section 9.2.

7.1.2. For Type S pipe, the inner wall (liner) shall be fused to the outer corrugation crest. For Type D pipe, both inner wall (liner) and exterior walls shall be fused to or continuous with the internal support corrugations or ribs.

7.2. **Pipe Dimensions:**

7.2.1. **Nominal size**—The nominal size for the pipe and fittings is based on the nominal inside diameter of the pipe. Nominal diameters shall be 300, 375, 450, 525, 600, 675, 750, 900, 1050, 1200, 1350, and 1500 mm (12, 15, 18, 21, 24, 27, 30, 36, 42, 48, 54, and 60 in.).

7.2.2. **Exterior wall and inner wall (Liner) Thickness**—The inner wall (liner) of Type S pipe and both inner wall (liner) and exterior walls of Type D pipe, shall have the following minimum thicknesses, when measured in accordance with Section 9.6.4.

<table>
<thead>
<tr>
<th>Diameter, mm (in.)</th>
<th>Inner Wall Thickness, Min. mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>0.9 (0.35)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>1.0 (0.04)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>1.3 (0.05)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>675 (27)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>750 (30)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>900 (36)</td>
<td>1.7 (0.07)</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>1.8 (0.07)</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1.8 (0.07)</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>2.0 (0.08)</td>
</tr>
<tr>
<td>1500 (60)</td>
<td>2.0 (0.08)</td>
</tr>
</tbody>
</table>

* For Type D profile, the minimum inner wall thickness shall also apply to the outer wall.

7.2.3. **Inside Diameter Tolerances**—The tolerance on the specified inside diameter shall be 3 percent oversize and 1.5 percent undersize, but not more than 30 mm (1.2 in.) oversize when measured in accordance with Section 9.6.1.

7.2.4. **Length**—Corrugated PP pipe may be sold in any length agreeable to the user. Lengths shall not be less than 99 percent of the stated quantity when measured in accordance with Section 9.6.2.

7.3. **Perforation**—When perforated pipe is specified, the perforations shall conform to the requirements of Class 2, unless otherwise specified in the order. Class 1 perforations are for pipe intended to be used for subsurface drainage or combination storm and underdrain. Class 2 perforations are for pipe intended to be used for subsurface drainage only. The perforations shall be cleanly cut so as not to restrict the inflow of water. Pipe connected by couplings or bands may be unperforated within 100 mm (4 in.) of each end of each length of pipe. Pipe connected by bell and spigot joints may not be perforated in the area of the bells and spigots.

7.3.1. **Class 1 Perforations**—The perforations shall be approximately circular and shall have nominal diameters of not less than 5 mm (0.2 in.) nor greater than 10 mm (0.4 in.) and shall be arranged in rows parallel to the axis of the pipe. The perforations shall be located in the external valleys with perforations in each row for each corrugation. The rows of perforations shall be arranged in two
equal groups placed symmetrically on either side of the lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance between the center lines of the rows shall not be less that 25 mm (1 in.). The minimum number of longitudinal rows of perforations, the maximum height of the center lines of the uppermost rows of perforations above the bottom of the invert, and the inside chord lengths of the unperforated segments illustrated in Figure 1 shall be as specified in Table 2.

7.3.2. **Class 2 Perforations**—Circular perforations shall be a minimum of 5 mm (0.2 in.) and shall not exceed 10 mm (0.4 in) in diameter. The width of slots shall not exceed 3 mm. The length of slots shall not exceed 70 mm (2.75 in.) for 300-mm (12-in.) and 375-mm (15-in.) pipe and 75 mm (3 in.) for 450-mm (18-in.) and larger pipe. Perforations shall be placed in the external valleys and uniformly spaced along the length and circumference of the pipe. The water inlet area shall be a minimum of 30 cm²/m (1.5 in.²/ft) for pipe sizes 300 to 450 mm (12 to 18 in.) and 40 cm²/m (2 in.²/ft) for pipe sizes larger than 450 mm (18 in.). All measurements shall be made in accordance with Section 9.6.3.

---

**Figure 2**—Location of Perforations

**Table 2**—Rows of Perforations, Height \(H\) of the Centerline of the Uppermost Rows above the Invert, and Chord Length \(L\) of Unperforated Segment, for Class 1 Perforations

<table>
<thead>
<tr>
<th>Nominal Diameter, mm (in.)</th>
<th>Rows of Perforations(^a)</th>
<th>(H), Max,(^b) mm (in.)</th>
<th>(L), Min,(^b) mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>6</td>
<td>138 (5.4)</td>
<td>192 (7.5)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>6</td>
<td>184 (6.75)</td>
<td>256 (9.5)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>6</td>
<td>207 (8.15)</td>
<td>288 (11.3)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>6</td>
<td>230 (9.5)</td>
<td>320 (13.2)</td>
</tr>
<tr>
<td>600 (24) and larger</td>
<td>8</td>
<td>(c)</td>
<td>(c)</td>
</tr>
</tbody>
</table>

\(^a\) Minimum number of rows. A greater number of rows for increased inlet area shall be subject to agreement between purchaser and manufacturer. Note that the number of perforations per meter in each row (and inlet area) is dependent on the corrugation pitch.

\(^b\) See Figure 2 for location of dimensions \(H\) and \(L\).

\(^c\) \(H\) (max) = 0.46\(D\); \(L\) (min) = 0.64\(D\), where \(D\) = nominal diameter of pipe, mm.
7.4. Pipe Stiffness—The pipe shall have a minimum pipe stiffness at 5 percent deflection as follows when tested in accordance with Section 9.1:
<table>
<thead>
<tr>
<th>Diameter, mm (in.)</th>
<th>Pipe Stiffness, kPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>450 (65)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>375 (54)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>350 (50)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>340 (49)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>300 (44)</td>
</tr>
<tr>
<td>675 (27)</td>
<td>265 (38)</td>
</tr>
<tr>
<td>750 (30)</td>
<td>250 (36)</td>
</tr>
<tr>
<td>900 (36)</td>
<td>200 (29)</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>185 (27)</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>170 (25)</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>150 (22)</td>
</tr>
<tr>
<td>1500 (60)</td>
<td>135 (19)</td>
</tr>
</tbody>
</table>

* For diameters 675 mm (27 in.) and larger the stiffness test is conducted at a higher loading rate than ASTM D2412 as described in Section 9.1.

7.5. **Pipe Flattening**—There shall be no evidence of inner (liner) or exterior wall cracking, splitting, cracks, splits, or delamination, when the pipe is tested in accordance with Section 9.2.

7.6. **Brittleness**—Pipe specimens shall not crack or split when tested in accordance with Section 9.3. Five nonfailures out of six impacts will be acceptable.

7.7. **Fitting Requirements**:

7.7.1. The fittings shall not reduce or impair the overall integrity or function of the pipe line.

7.7.2. Common fittings include in-line joint fittings, such as couplings and reducers, and branch or complementary assembly fittings such as tees, wyes, and end caps. These fittings are installed by various methods.

**Note 1**—Only fittings supplied or recommended by the pipe manufacturer should be used. Fabricated fittings made from pipe meeting the requirements of the pipe specification should be acceptable providing that the joints are adequately lapped or reinforced. Joints are not intended to be watertight. Soiltightness is a function of opening size, channel length, and backfill particle size. 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 soiltightness criteria can be found in AASHTO LRFD Bridge Construction Specifications, Section 30.

7.7.3. All fittings shall be within an overall length dimensional tolerance ± 12 mm (0.5 in.) of the manufacturer’s specified dimensions when measured in accordance with Section 9.6.2.

7.7.4. Fittings shall not reduce the inside diameter of the pipe being joined by more than 12 mm (0.5 in.). Reducer fittings shall not reduce the cross-sectional area of the small size.

7.7.5. Couplings shall be corrugated to match the pipe corrugations and shall provide sufficient longitudinal strength to preserve pipe alignment and prevent separation at the joints. Couplings shall be bell and spigot or split collar. Split couplings shall engage at least two full corrugations on each pipe section.

7.7.6. Pipe connections shall not separate to create a gap exceeding 5 mm (0.2 in.) when measured in a radial direction between pipe and coupling, or between bell and spigot portions of pipe, when tested according to Section 9.5.1. Fittings shall not crack or delaminate.

7.7.7. The design of the fittings shall be such that when connected with the pipe, the axis of the assembly will be level and true when tested in accordance with Section 9.5.2.
7.7.8. Other types of coupling bands or fastening devices that are equally effective as those described, and which comply with the joint performance criteria of AASHTO LRFD Bridge Construction Specifications, Section 30, may be used when approved by the purchaser.

7.8. Delamination—There shall be no delamination nor separation of the structural components of the pipe wall when tested in accordance with Section 9.7.

7.9. Stub Compression Test for Finished Pipe—Profile compression capacity in any specimen in the stub compression test shall not be less than 50 percent of the gross cross-sectional area times the minimum specified yield strength when tested in accordance with Section 9.9. The stub compression test shall be run twice a year on each profile for each diameter of pipe.

Note 2—Computing the minimum capacity requires determining the cross-sectional area of the pipe wall and liner profile. This can be accomplished conveniently by optically scanning the profile and determining the section properties using a computer drafting program.

8. CONDITIONING

8.1. Conditioning—Condition the specimen prior to test at 21 to 25°C (70 to 77°F) for not less than 24 h in accordance with Procedure A in ASTM D618 for those tests where conditioning is required, and unless otherwise specified.

8.2. Conditions—Conduct all tests at a laboratory temperature of 21 to 25°C (70 to 77°F) unless otherwise specified herein.

9. TEST METHODS

9.1. Pipe Stiffness—Select a minimum of two pipe specimens and test for pipe stiffness (PS), as described in ASTM D2412 except for the following:

9.1.1. The test specimens shall be a minimum of one diameter length for 300-mm (12-in.) to 600-mm (24-in.) diameter pipe, and one-half diameter length for pipe diameters greater than 600 mm (24 in.).

9.1.2. Locate the first specimen in the loading machine with an imaginary line connecting the two seams formed by the corrugation mold (end view) parallel to the loading plates, when applicable. The specimen must lie flat on the plate within 3 mm (0.12 in.) and may be straightened by hand bending at room temperature to accomplish this. Use the first location as a reference point for rotation and testing of the other specimen. Rotate the pipe 90 degrees from the first orientation and test. Test each specimen in one position only.

9.1.3. The deflection indicator shall be readable and accurate to ±0.02 mm (0.001 in.).

9.1.4. The residual curvature found in tubing frequently results in an erratic initial load/deflection curve. When this occurs, the beginning point for deflection measurement shall be at a load of 20 ± 5 N (4.5 lbf ± 1.1 lbf). The point shall be considered as the origin of the load deflection curve.

9.1.5. The crosshead speed shall be the faster of 12.7 mm/min (0.5 in./min) or 2 percent of the nominal diameter per minute.

Note 3—The parallel plates must exceed the length of the test specimen as specified above.

Note 4—Additional pipe specimens may be tested at other orientations for pipe stiffness and flattening if desired.
9.2. **Pipe Flattening**—Flatten the two (2) pipe specimens from Section 9.1 until the vertical inside diameter is reduced by 40 percent. The rate of loading shall be the same as in Section 9.1. Immediately after the specimen has started to unload, examine the specimen with the unaided eye for cracking, splitting, or delamination.

9.3. **Brittleness**—Test pipe sections in accordance with ASTM 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 degrees for impacts made on one circle, or at least 300 mm (12 in.) longitudinally for impacts made on one element. Impact points shall be at least 150 mm (6 in.) from the end of the specimen. Tup B shall be used, with a mass of 4.5 kg (10 lb). The height of drop shall be 3.0 m (10 ft). Use a flat plate specimen holder. Condition the specimens for 24 h at a temperature of 23 ± 2°C (73.4 ± 3.6°F). The center of the falling tup shall strike on a corrugation crown for all impacts.

9.4. **Slow Crack Growth Resistance of PP Pipe**—Five pipe test specimens shall be taken from extruded pipe in the pipe liner area and tested for stress crack resistance in accordance with the ASTM F2136 test except for the following modifications:

9.4.1. If it is not possible, due to pipe size limitations, to take specimens from the liner, five test specimens shall be compression molded from material taken directly from the pipe wall according to ASTM D1928, Procedure C. The thickness of the plaque shall be 1.9 ± 0.2 mm (0.075 ± 0.008 in.). The test specimens shall be taken from the molded plaque along the same orientation and tested per ASTM F2136 in accordance with the applied stress in Section 9.4.2.

9.4.2. The applied stress for the NCLS test shall be 4.14 MPA (600 psi).

9.5. **Fittings**:

9.5.1. **Joint Integrity**—Assemble each fitting or coupling to the appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 300 mm in length. Assemble a specimen at least 600 mm (24 in.) in length with the connection at the center. Load the connected pipe and fitting between parallel plates at the rate of 12.5 mm (0.5 in.) per minute until the vertical inside diameter is reduced by at least 20 percent of the nominal diameter of the pipe. Inspect for damage while at the specified deflection and after load removal. Measure the maximum radial distance between pipe and fittings, or between bell and spigot, during test and after load removal.

9.5.2. **Alignment**—Assure that the assembly or joint is correct and complete. If the pipe is bent, it should be straightened prior to performing this test. Lay the assembly or joint on a flat surface and verify that it will accommodate straight-line flow.

9.6. **Dimensions**:

9.6.1. **Inside Diameter**—Measure the inside diameter of the pipe with a tapered plug in accordance with ASTM D2122. As an alternative, measure the inside diameter with a suitable device accurate to ±3.0 mm (±0.12 in.) on two sections. Take 2 measurements at the mold seam and 90 degrees around the circumference of each section and average these 16 measurements. The average inside diameter shall meet the requirements of Section 7.2.3.

9.6.2. **Length**—Measure pipe with any suitable device accurate to ±6.0 mm (±0.25 in.) in 3 m (10 ft). Make all measurements on the pipe while it is stress-free and at rest on a flat surface in a straight line.

9.6.3. **Perforations**—Measure dimensions of perforations on a straight specimen with no external forces applied. Make linear measurements with instruments accurate to 0.2 mm (0.008 in.).
9.6.4. **Inner Wall (Liner) and Exterior Wall Thickness**—Measure the inner wall (liner) and exterior wall (Type D pipe) thickness in accordance with ASTM D2122.

9.7. **Delamination**—Examine Type S pipe for evidence of delamination as defined and described in Section 3.1.4 by cutting the pipe at the corrugation crest as shown in Figure 3 and attempting to insert a feeler gauge between the liner and corrugation valley as shown in Figure 4. The feeler gauge should not pass through the corrugation valley into the void beyond at any location along the circumference of the pipe.

Examine Type D pipe for evidence of delamination as defined and described in Section 3.1.4 by cutting the pipe at the corrugation crest as shown in Figure 3 and attempting to insert a feeler gauge between the inner support corrugations/ribs and the liner and outer exterior wall as shown in Figure 4. The feeler gauge should not pass between the internal support corrugation rib and the inner or wall at any location along the circumference of the pipe.

![Figure 3—Location of Pipe Cut](image-url)
9.8. **Long-Term Material Properties:**

9.8.1. **Creep Rupture Strength**—Determine creep rupture strength at 23°C (73°F) in accordance with the tensile creep test methods in ASTM D2990, except as follows. Test shall include an additional stress level selected so as to produce rupture at approximately 10,000 h. Alternately, use time-temperature superposition methods.

9.8.2. **Creep Modulus**—Determine creep modulus superposition method in ASTM D2990, except as follows. Test duration shall be 10,000 h. Tests shall include a minimum of 5 stress levels that are selected in approximately even increments up to and including 3.45 MPa (500 psi). Alternately, use time-temperature superposition methods.

**Note 5**—The time-temperature superposition method in ASTM D6992 may be used to determine the tensile creep modulus and the tensile creep rupture strength. These tests are intended to validate a material’s proof-of-performance qualification and are not standard quality assurance tests.

9.9. **Stub Compression Capacity**—Determine the stub compression capacity of the pipe section in accordance with T 341 (Appendix G). Conduct four tests on specimens cut from the same ring of pipe at 90-degree intervals around the circumference. The stub compression test, T 341, shall be a material and wall profile design qualification test conducted twice a year or whenever there are changes in wall profile design.

10. **INSPECTION AND RETEST**

10.1. **Inspection**—Inspection of the material shall be made as agreed on by the purchaser and the seller as part of the purchase contract.

10.2. **Retest and Rejection**—If any failure to conform to these specifications occurs, the pipe or fittings may be retested to establish conformity in accordance with agreement between the purchaser and seller. Individual results, not averages, constitute failure.
11. MARKING

11.1. All pipes shall be clearly marked at intervals of no more than 3.5 m (11.4 ft) as follows:

11.1.1. Manufacturer’s name or trademark,
11.1.2. Nominal size,
11.1.3. This specification designation, AASHTO M 330,
11.1.4. The plant designation code, and
11.1.5. The date of manufacture or an appropriate code.

11.2. Fittings shall be marked with the designation number of this specification, AASHTO M 330, and with the manufacturer’s identification symbol.

12. QUALITY ASSURANCE

12.1. A manufacturer’s certificate that the product was manufactured, tested, and supplied in accordance with this specification, together with a report of the test results, and the date each test was completed, shall be furnished on request. Each certification so furnished shall be signed by a person authorized by the manufacturer.

13. KEYWORDS

13.1. Delamination; pipe; polypropylene; reworked plastic.

Standard Specification for

Polyethylene (PE) Liner Pipe, 300-to 1600-mm Diameter, Based on Controlled Outside Diameter

AASHTO Designation: M 326-08 (2017)
Technical Section: 4b, Flexible and Metallic Pipe
Release: Group 2 (June 2017)
1. SCOPE

1.1. This specification covers the requirements and methods of tests for outside diameter dimension controlled polyethylene liner pipe (PE liner pipe), jointing, and fittings for use in pipe relining and culvert rehabilitation for industrial wastes, sanitary sewer, and surface and subsurface drainage applications.

1.1.1. Nominal sizes of 300 to 1600 mm are included.

1.1.2. Materials, workmanship, dimensions, pipe stiffness, joining systems, and form of markings are specified.

1.2. This specification is intended for rehabilitation of industrial waste, sanitary sewer, and surface and subsurface drainage applications by the insertion of PE liner pipe through existing pipe. PE liner pipe is designed to minimize traffic disruption and subsurface damage, and rehabilitate existing sewers and culverts with little or no interruption in service or traffic.

Note 1—When polyethylene pipe is to be used in locations where the ends may be exposed, consideration should be given to protection of the exposed portions due to combustibility of the polyethylene and the effects of prolonged exposure to ultraviolet radiation.

1.3. For the PE liner pipe to perform properly, the annular space between existing and PE liner pipe must be filled. This specification does not include methods to fill the annular space between the existing pipe and the PE liner pipe, insertion techniques, and termination techniques. Construction and installation procedures are described in ASTM F585.

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

2. REFERENCED DOCUMENTS

2.1. ASTM Standards:

- D618, Standard Practice for Conditioning Plastics for Testing
- D883, Standard Terminology Relating to Plastics
The PE liner pipe covered by this specification is classified by the Standard Dimension Ratio (SDR) system. The relationship between SDR, outside diameter, and minimum wall thickness is as follows:

\[ SDR = \frac{D}{t} \]  

where:

\[ SDR = \text{ Standard Dimension Ratio}; \]
\[ D_o = \text{Average Outside Diameter, mm}; \text{ and} \]
\[ t = \text{minimum wall thickness, mm}. \]

4.2. Standard Dimension Ratios covered by this specification are SDR 41, SDR 32.5, and SDR 26.

4.3. Where existing conditions or special requirements make other SDR classifications necessary, other sizes or dimension ratios or both shall be acceptable for engineering applications when mutually agreed on by the customer and the manufacturer. This is provided that the pipe is manufactured from plastic compounds meeting the material requirement of this specification.

5. ORDERING INFORMATION

5.1. Orders using this specification shall include the following information as necessary to adequately describe the desired product:

5.2. AASHTO designation and year of issue;

5.2.1. Type of pipe (Section 4.2);

5.2.2. Diameter and length required, either total length or length of each piece and number of pieces;

5.2.3. Certification, if desired (Section 12.1).

6. MATERIALS

6.1. Basic Materials:

6.1.1. Extruded Pipe and Fittings—Pipe and fittings shall be made of virgin PE conforming with the requirements of cell class 345464C as defined and described in ASTM D3350. Resins that have higher cell classifications in one or more properties are acceptable provided that product requirements are met.

6.1.2. Rotational Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE resins that conform with the requirements of cell classification 213320C as defined and described in ASTM D3350, except that the carbon black content shall not exceed 3 percent. Resins that have higher cell classifications in one or more properties are acceptable provided that product requirements are met.

6.2. Reworked Plastic—In lieu of virgin PE, clean reworked plastic may be used by the manufacturer, provided that it meets the cell class requirements as described in Section 6.1.

6.3. The manufacturer shall not blend resins to meet the cell classification specified in Section 6.1.1 or 6.1.2. Blending of reworked plastic and virgin plastic is allowed provided that both the reworked resin and the virgin resin meet the requirements of Section 6.1.

7. REQUIREMENTS

7.1. Workmanship—The pipe and fittings shall be free of foreign inclusions and visible defects as defined herein. The ends of the pipe shall be cut squarely and cleanly so as not to adversely affect joining or connecting. Field cuts shall be de-burred and free of defects.
7.2. **Visible Defects**—Cracks, creases, delaminations, and unpigmented or nonuniformly pigmented pipe are not permissible in the pipe or fittings as furnished. There shall be no evidence of cracking or delamination when tested in accordance with Section 9.2.

7.3. **Pipe Dimensions:**

7.3.1. **Nominal Size**—The nominal size for the pipe and fittings is based on the nominal outside diameter of the pipe. Nominal diameters, outside diameters, and tolerance shall be in accordance with Table 1, when measured in accordance with Section 9.5.1.

<table>
<thead>
<tr>
<th>Nominal Pipe Size, mm (in.)</th>
<th>Outside Diameter, mm (in.)</th>
<th>Tolerance, ± mm (± in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>323.8 (12.750)</td>
<td>1.5 (0.057)</td>
</tr>
<tr>
<td>325 (13)</td>
<td>339.7 (13.375)</td>
<td>1.5 (0.060)</td>
</tr>
<tr>
<td>350 (14)</td>
<td>355.6 (14.000)</td>
<td>1.6 (0.063)</td>
</tr>
<tr>
<td>400 (16)</td>
<td>406.4 (16.000)</td>
<td>1.8 (0.072)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>457.2 (18.000)</td>
<td>2.1 (0.081)</td>
</tr>
<tr>
<td>500 (20)</td>
<td>508.0 (20.000)</td>
<td>2.3 (0.090)</td>
</tr>
<tr>
<td>538 (21.5)</td>
<td>546.1 (21.500)</td>
<td>2.5 (0.097)</td>
</tr>
<tr>
<td>550 (22)</td>
<td>558.8 (22.000)</td>
<td>2.5 (0.099)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>609.6 (24.000)</td>
<td>2.7 (0.108)</td>
</tr>
<tr>
<td>650 (26)</td>
<td>660.4 (26.000)</td>
<td>3.0 (0.117)</td>
</tr>
<tr>
<td>700 (28)</td>
<td>711.2 (28.000)</td>
<td>3.2 (0.126)</td>
</tr>
<tr>
<td>750 (30)</td>
<td>762.0 (30.000)</td>
<td>3.4 (0.135)</td>
</tr>
<tr>
<td>800 (32)</td>
<td>812.5 (32.000)</td>
<td>3.7 (0.144)</td>
</tr>
<tr>
<td>850 (34)</td>
<td>863.6 (34.000)</td>
<td>3.9 (0.153)</td>
</tr>
<tr>
<td>900 (36)</td>
<td>914.4 (36.000)</td>
<td>4.1 (0.162)</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>1066.8 (42.000)</td>
<td>4.8 (0.189)</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1219.2 (48.000)</td>
<td>5.5 (0.216)</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>1371.6 (54.000)</td>
<td>6.2 (0.243)</td>
</tr>
<tr>
<td>1600 (63)</td>
<td>1600.2 (63.000)</td>
<td>7.20 (0.284)</td>
</tr>
</tbody>
</table>

7.3.2. **Wall Thickness**—The wall thickness shall have the minimum thicknesses in Table 2 for each standard dimension ratio, when measured in accordance with Section 9.5.3.
Table 2—Minimum Wall Thickness

<table>
<thead>
<tr>
<th>Nominal Pipe Size, mm (in.)</th>
<th>Outside Diameter, mm (in.)</th>
<th>SDR 41 Wall Thickness, mm (in.)</th>
<th>SDR 32.5 Wall Thickness, mm (in.)</th>
<th>SDR 26 Wall Thickness, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>323.8 (12.750)</td>
<td>7.9 (0.310)</td>
<td>10 (0.392)</td>
<td>12.4 (0.490)</td>
</tr>
<tr>
<td>325 (13)</td>
<td>339.7 (13.375)</td>
<td>8.2 (0.326)</td>
<td>10.4 (0.412)</td>
<td>13.1 (0.514)</td>
</tr>
<tr>
<td>350 (14)</td>
<td>355.6 (14.000)</td>
<td>8.0 (0.314)</td>
<td>10.9 (0.431)</td>
<td>13.6 (0.538)</td>
</tr>
<tr>
<td>400 (16)</td>
<td>406.4 (16.000)</td>
<td>9.9 (0.390)</td>
<td>12.5 (0.492)</td>
<td>15.6 (0.615)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>457.2 (18.000)</td>
<td>11.2 (0.439)</td>
<td>14.1 (0.554)</td>
<td>17.6 (0.692)</td>
</tr>
<tr>
<td>500 (20)</td>
<td>508.0 (20.000)</td>
<td>12.4 (0.488)</td>
<td>15.6 (0.615)</td>
<td>19.5 (0.769)</td>
</tr>
<tr>
<td>538 (21.5)</td>
<td>546.1 (21.500)</td>
<td>13.3 (0.524)</td>
<td>16.8 (0.662)</td>
<td>21.0 (0.827)</td>
</tr>
<tr>
<td>550 (22)</td>
<td>558.8 (22.000)</td>
<td>13.6 (0.537)</td>
<td>17.2 (0.677)</td>
<td>23.4 (0.846)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>609.6 (24.000)</td>
<td>14.9 (0.585)</td>
<td>18.7 (0.738)</td>
<td>23.4 (0.923)</td>
</tr>
<tr>
<td>650 (26)</td>
<td>660.4 (26.000)</td>
<td>16.1 (0.634)</td>
<td>20.3 (0.800)</td>
<td>25.4 (1.000)</td>
</tr>
<tr>
<td>700 (28)</td>
<td>711.2 (28.000)</td>
<td>17.4 (0.683)</td>
<td>21.9 (0.862)</td>
<td>27.4 (1.077)</td>
</tr>
<tr>
<td>750 (30)</td>
<td>762.0 (30.000)</td>
<td>18.6 (0.732)</td>
<td>23.4 (0.923)</td>
<td>29.3 (1.154)</td>
</tr>
<tr>
<td>800 (32)</td>
<td>812.5 (32.000)</td>
<td>19.8 (0.780)</td>
<td>25.0 (0.985)</td>
<td>31.3 (1.231)</td>
</tr>
<tr>
<td>850 (34)</td>
<td>863.6 (34.000)</td>
<td>21.1 (0.829)</td>
<td>26.6 (1.046)</td>
<td>33.2 (1.308)</td>
</tr>
<tr>
<td>900 (36)</td>
<td>914.4 (36.000)</td>
<td>22.3 (0.878)</td>
<td>28.1 (1.108)</td>
<td>35.2 (1.385)</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>1066.8 (42.000)</td>
<td>26.0 (1.024)</td>
<td>32.8 (1.292)</td>
<td>41.0 (1.615)</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1219.2 (48.000)</td>
<td>29.7 (1.171)</td>
<td>37.5 (1.477)</td>
<td>46.9 (1.846)</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>1371.6 (54.000)</td>
<td>33.4 (1.317)</td>
<td>42.2 (1.662)</td>
<td>52.8 (2.077)</td>
</tr>
<tr>
<td>1600 (63)</td>
<td>1600.2 (63.000)</td>
<td>Not Available</td>
<td>49.2 (1.938)</td>
<td>61.5 (2.423)</td>
</tr>
</tbody>
</table>

7.3.3. **Average Inside Diameter**—The average inside diameter (ID) shall be calculated as follows:

\[
AvgID = \frac{OD_{\text{min}} + OD_{\text{max}}}{2} - 2(t_{\text{min}} \times 1.06)
\]  

where:

- \( AvgID \) = Average inside diameter, mm (in.);
- \( OD_{\text{min}} \) = Minimum outside diameter from Table 1, mm (in.);
- \( OD_{\text{max}} \) = Maximum outside diameter from Table 1, mm (in.); and
- \( t_{\text{min}} \) = Minimum wall thickness from Table 2, mm (in.).

7.3.4. **Length**—PE liner pipe may be sold in any length agreeable to the user. The furnished length shall not be less than the shorter of 99 percent of the agreed length or 12 mm (1/2 in.), whichever is less.

7.4. **Pipe Stiffness**—The pipe shall have a minimum pipe stiffness at 5 percent deflection as follows when tested in accordance with Section 9.1. The minimum pipe stiffness shall be as follows:

- 41 SDR = 55.2 kPa (8 psi)
- 32.5 SDR = 110.3 kPa (16 psi)
- 26 SDR = 213.7 kPa (31 psi)
7.4.1. Pipe stiffness test for 600 mm (24 in.) and smaller diameters may be extrapolated to larger sizes of the same SDR classification, provided the manufacturer can document the following equation accurately predicts the pipe stiffness for all sizes and SDR:

\[ PS = \frac{C \times E}{(SDR - 1)^3} \]  

\(7.5\) Pipe Flattening—There shall be no evidence of wall buckling (decrease or downward deviation in the load deflection curve), cracking, or splitting when the pipe is tested in accordance with Section 9.2.

7.6. Fitting Requirements:

7.6.1. The fittings shall not reduce or impair the overall integrity or function of the PE liner pipe.

7.6.2. Common fittings include in-line joint fittings, reducers, and branch or complementary assembly fittings such as tees and wyes. These fittings shall be installed or coupled to the pipe by various methods in accordance with Section 7.7.

7.6.3. All fittings shall be within an overall length dimensional tolerance ±12 mm (1/2 in.) of the manufacturer’s specified dimensions when measured in accordance with Section 9.5.2.

7.6.4. Fittings shall not reduce the inside diameter of the pipe being joined by more than 12 mm (1/2 in.). Reducer fittings shall not reduce the cross-sectional area of the small size.

7.6.5. Fabricated fittings should be supplied with joints compatible with the overall system.

7.7. Jointing Requirements:

7.7.1. Joints shall provide sufficient longitudinal (or axial) strength to preserve pipe alignment, prevent separation at the joints, and maintain integrity while pushing or pulling pipe lengths into existing pipes or culverts. Joints shall be mechanical or male and female joint connections. Mechanical or male and female joint connections shall be an integral part of the PE liner pipe. Alternatively, the mechanical joint, male and female joints, or pipe ends may be heat fused provided that the fusion process meets the requirements of ASTM F2620 and that the fused connection meets the requirements of Section 7 of this standard.

7.7.2. Joints shall have sufficient longitudinal or axial compression strength to withstand a maximum compressive force of 17.5 N/mm (100 lbf/in.) of outside diameter circumference in compression while maintaining joint integrity when tested in accordance with Section 9.4.1.

7.7.3. Joints shall have sufficient pull-apart strength to withstand a maximum tensile force of 17.5 N/mm (100 lbf/in.) of outside diameter circumference in tension without joint disassembly when tested in accordance with Section 9.4.2.

7.7.4. Joints shall not reduce the inside diameter or enlarge the outside diameter of the pipe being joined by more than 6 mm (1/4 in.). When the pipe is coupled, the axis of the assembly will be level and true when tested in accordance with Section 9.4.3.
7.7.5. Other types of mechanical jointing, which are equally effective as those described and which comply with the joint performance criteria of Section 7.7, may be used when approved by the purchaser.

7.7.6. All joints shall meet the watertight joint requirements of Section 7.8 unless otherwise specified by the owner/designer.

7.8. *Watertight joints* must meet a 74 kPa (10.8 psi) laboratory test per ASTM D3212. Mechanical coupler or male and female joint design shall use a gasket meeting ASTM F477.

### 8. CONDITIONING

8.1. *Conditioning*—Unless otherwise specified, for those tests for which conditioning is required, condition the specimen for not fewer than 24 h prior to test at 21 to 25°C (70 to 77°F) in accordance with Procedure A in ASTM D618.

8.2. *Conditions*—Conduct all tests at a laboratory temperature of 21 to 25°C (70 to 77°F) unless otherwise specified herein.

### 9. TEST METHODS

9.1. *Pipe Stiffness*—Select a minimum of two pipe specimens and test for pipe stiffness, as described in ASTM D2412 except the test specimens shall be a minimum of 300 mm (12 in.) in length for pipe diameters 300 to 600 mm (12 to 24 in.), and one-half diameter length for diameters greater than 600 mm (24 in.). Use the first location as a reference point for rotation and testing of the other specimen. Rotate subsequent specimen 90 degrees from the original orientation. Test each specimen in one position only. The deflection indicator shall be readable and accurate to ±0.02 mm (0.0008 in.).

**Note 2**—The parallel plates must exceed the length of the test specimen as specified above.

9.2. *Pipe Flattening*—Flatten the two pipe specimens from Section 9.1 until the vertical inside diameter is reduced by 20 percent. The rate of loading shall be the same as in Section 9.1. The specimen shall fail if buckling (a decrease or downward deviation in load-deflection curve), cracking, splitting, or delamination is observed with the unaided eye at 20 percent deflection. Immediately after the specimen has started to unload, check for visible evidence of cracking or splitting or delamination examine the specimen with the unaided eye for cracking or splitting.

9.3. *Slow Crack Growth Resistance of Resin Compounds*—Test PE liner pipe basic resin compounds for stress crack resistance in accordance with ASTM F1473 PENT test with a minimum time to failure of 100 hours.

9.4. *Jointing Fittings:*

9.4.1. *Joint Integrity Longitudinal Compression*—Assemble each male and female joint to the appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 300 mm (12 in.) in length. Assemble a specimen at least 600 mm (24 in.) in length with the connection at the center. Load the coupled pipe lengths in axial compression at a rate not to exceed 25.4 mm (1 in.) per second until the total compressive load equals the circumference of the PE liner pipe outside diameter, measured in millimeters (inches), times 17.5 N (4 lb). The applied load shall be aligned with the longitudinal axis of the pipe. After 2 min, unload the pipe coupler assembly and inspect for damage such as splitting, cracking, tearing, or a reduction to the inside diameter of 6 mm (¼ in.) or greater. Any damage and/or reduction to the inside diameter by 6 mm (¼ in.) or greater is considered a failure.
9.4.2. **Joint Integrity Pull Apart**—Assemble each male and female jointing to the appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 300 mm (12 in.) in length. Assemble a specimen at least 600 mm (24 in.) in length with the connection at the center. Pull heads may be heat fused to the pipe lengths. Load the coupled pipe in axial tension at a rate not to exceed 25.4 mm (1 in.) per second until the total tensile load equals the circumference of the PE liner pipe outside diameter, measured in millimeters (inches), times 17.5 N (4 lb). After 2 min, unload the pipe lengths and inspect for damage. The applied load shall be aligned with the longitudinal axis of the pipe. Damage to the pipe such as splitting, cracking, tearing, or joint separation is considered a failure.

9.4.3. **Alignment**—Assure that the assembly or joint is correct and complete. If the pipe is bent, it should be straightened prior to performing this test. Lay the assembly or joint on a flat surface and verify that it will accommodate straight-line flow.

9.5. **Dimensions:**

9.5.1. **Outside Diameter**—Measure the outside diameter of the pipe with a tapered sleeve gauge or a circumferential wrap tape in accordance with ASTM D2122. As an alternative, measure the outside diameter with a suitable device accurate to ±3.0 mm (1/8 in.) on two sections. Take eight measurements equally spaced around the circumference of each section and average these 16 measurements. The average outside diameter shall meet the requirements of Section 7.3.1.

9.5.2. **Length**—Measure pipe with any suitable device accurate to ±6.0 mm (1/4 in.) in 3 m (10 ft). Make all measurements on the pipe while it is stress-free and at rest on a flat surface in a straight line.

9.5.3. **Wall Thickness**—Measure the wall thickness in accordance with ASTM D2122.

10. **INSPECTION AND RETEST**

10.1. **Inspection**—Inspection of the material shall be made as agreed on by the purchaser and the seller as part of the purchase contract.

10.2. **Retest and Rejection**—If any failure to conform to these specifications occurs, the pipe or fittings may be retested to establish conformity in accordance with agreement between the purchaser and seller. Individual results, not averages, constitute failure.

10.3. **Pipe Marking**—Pipe marking may include ASTM F714 marking. However, to ensure conformance with this specification, the PE liner pipe shall include markings described in Section 11 of this specification.

11. **MARKING**

11.1. **All pipe shall be clearly marked at intervals of no more than 3.5 m (12 ft) as follows:**

11.1.1. Manufacturer’s name or trademark,

11.1.2. Nominal outside size,

11.1.3. Dimensional ratio,

11.1.4. The specification designation, AASHTO M 326,

11.1.5. The plant designation code, and
11.1.6. The date of manufacture or an appropriate code.

11.1.6.1. If the date code is used, a temporary manufacturer sticker that identifies the actual date of manufacture shall be adhered to the inside of each length of pipe.

11.2. Fittings shall be marked with a designation number of this specification, AASHTO M 326 and with the manufacturer’s identification symbol.

12. QUALITY ASSURANCE

12.1. A manufacturer’s certificate that the product was manufactured, tested, and supplied in accordance with this specification, together with a report of the test results, and the date each test was completed, shall be furnished on request. Each certification so furnished shall be signed by a person authorized by the manufacturer.

13. KEYWORDS

13.1. Buckling; crack; crease; liner pipe; polyethylene (PE) plastics.

APPENDIX

(Nonmandatory Information)

X1. QUALITY CONTROL/QUALITY ASSURANCE PROGRAM

X1.1. Scope:

X1.1.1. As required in Sections 10 and 12, the acceptance of these products relies on the adequate inspection and certification agreed to between the buyer and the seller/producer. This appendix should serve as a guide for both the manufacturer and the user. It places the responsibility on producers to control the quality of the material they produce and to provide the quality control information needed for acceptance by the buyer/user. Producers are required to perform quality control sampling, testing, and record keeping on materials they ship. It also sets forth quality assurance sampling, testing, and record keeping that should be performed by the buyer/user to confirm the performance of the producer’s control plan.

X1.2. Program Requirements:

X1.2.1. The producing company must have a quality control plan approved by the specifying agency.

X1.2.2. The producing plant must have an approved quality control plan.

X1.2.3. The plant must have an approved laboratory, either within the company or an independent laboratory.

X1.2.4. The producing plant(s) must have a designated quality control technician.
X1.3. **Quality Control Plan:**

X1.3.1. The producer must supply to the specifying agency a written quality control plan that shows how the producer will control the equipment, materials, and production methods to ensure that the specified products are supplied. The following information must be included in the plan:

X1.3.1.1. Titles of the personnel responsible for production quality at the plant(s);

X1.3.1.2. The physical location of the plant(s);

X1.3.1.3. The methods of identification of each lot of material during manufacture, testing, storage, and shipment. The method of identification shall allow the specifying agency to trace the finished product to the material provider;

X1.3.1.4. The method of sampling and testing of raw materials and of finished product, including lot sizes and types of tests performed; and

X1.3.1.5. A plan for dealing with nonconforming product, including how the producer plans to initiate immediate investigation and how corrective action will be implemented to remedy the cause of the problem.

X1.4. **Approved Laboratory:**

X1.4.1. All tests must be conducted at laboratories approved by the specifier. Each manufacturer may establish and maintain its own laboratory for performance of quality control testing or may utilize an approved independent laboratory. Records of instrument calibration and maintenance and sample collection and analysis must be maintained at the laboratory.

X1.5. **Quality Control Technician:**

X1.5.1. All samples must be taken and tested by quality control technicians designated by the producer. The designated quality control technicians will be responsible for overall quality control at the producing plant.

X1.6. **Annual Update:**

X1.6.1. An annual update may be required. If required, the annual update may be submitted by the manufacturer to the specifying agency by December 31st of each calendar year.

X1.7. **Plant Approval:**

X1.7.1. The plant approval process requires the manufacturer to submit an annual update to the specifying agency. The update must identify the specific product manufactured at the plant.

X1.7.2. The specifying agency will review the manufacturer’s written quality control plan and a plant inspection may be scheduled. This inspection will verify that the quality control plan has been implemented and is being followed and that at least one designated quality control technician is on-site and will be present when material is being produced under this program. The laboratory will be inspected and approved if it meets the requirements.

X1.8. **Sampling and Testing:**

X1.8.1. The quality assurance plan approved for each manufacturer, and/or manufacturer’s location, shall detail the methods and frequency of sampling and testing for all raw materials and products.
purchased or manufactured at that location. All testing shall be in accordance with current specifications and procedures referenced in M 326.

X1.8.2. Samples of materials and pipe may be taken by the specifying agency.

X1.8.3. The specifying agency may require an annual third-party independent assurance test.

X1.9. **Sample Identification and Record Keeping:**

X1.9.1. Manufacturer’s quality control samples are to be uniquely identified by the producing plant.

X1.9.2. Quality control and quality assurance data are to be retained by the manufacturer for 2 years and made available to the specifying agency on request.

X1.9.3. Quality control test reports shall include the lot identification.

X1.9.4. Unless requested at the time of ordering, test reports do not have to be filed for specific projects.

X1.9.5. Reports shall indicate the action taken to resolve nonconforming product.
Standard Specification for

Corrugated Polyethylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter

AASHTO Designation: M 294-17
Technical Section: 4b, Flexible and Metallic Pipe
Release: Group 2 (June 2017)

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001
Standard Specification for

Corrugated Polyethylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter

AASHTO Designation: M 294-17

Technical Section: 4b, Flexible and Metallic Pipe
Release: Group 2 (June 2017)

1. SCOPE

1.1. This specification covers the requirements and methods of tests for corrugated polyethylene (PE) pipe, couplings, and fittings for use in surface and subsurface drainage applications.

1.1.1. Nominal sizes of 300 to 1500 mm (12 to 60 in.) are included.

1.1.2. Materials, workmanship, dimensions, pipe stiffness, slow crack growth resistance, joining systems, brittleness, perforations and form of markings are specified.

1.2. Corrugated PE pipe is intended for surface and subsurface drainage applications where soil provides support to its flexible walls. Its major use is to collect or convey drainage water by open gravity flow, as culverts, storm drains, etc.

Note 1—When PE pipe is to be used in locations where the ends may be exposed, consideration should be given to protection of the exposed portions due to combustibility of the PE and the deteriorating effects of prolonged exposure to ultraviolet radiation.

1.3. Units—The values stated in SI units are to be regarded as standard. Within the text, the U.S. Customary units are shown in parentheses, and may not be exact equivalents.

1.4. This specification does not include requirements for bedding, backfill, or earth cover load. Successful performance of this product depends on proper type of bedding and backfill, and care in installation. The structural design of corrugated PE pipe and the proper installation procedures are given in AASHTO LRFD Bridge Design Specifications, Section 12, and LFRD Bridge Construction Specifications, Section 30, respectively. Upon request of the user or engineer, the manufacturer shall provide profile wall section detail required for a full engineering evaluation.

1.5. The following precautionary caveat pertains only to the test method portion, Section 9.4, 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. AASHTO Standards:

- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- T 341, Determination of Compression Capacity for Profile Wall Plastic Pipe by Stub Compression Loading
2.2. **ASTM Standards:**
- D618, Standard Practice for Conditioning Plastics for Testing
- D638, Standard Test Method for Tensile Properties of Plastics
- D883, Standard Terminology Relating to Plastics
- D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
- D2444, Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
- D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
- D3895, Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
- D4218, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
- D4703, Standard Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
- D4883, Standard Test Method for Density of Polyethylene by the Ultrasound Technique
- D412, Standard Terminology Relating to Plastic Piping Systems
- D477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
- F2136, Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe
- F3181, Standard Test Method for the Un-Notched Constant Ligament-Stress (UCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

2.3. **Other:**

3. **TERMINOLOGY**

3.1. The terminology used in this standard is in accordance with the definitions given in ASTM D883 and ASTM F412 unless otherwise specified.

3.2. **buckling**—During pipe flattening testing, any decrease or downward deviation in the pipe load-deflection test curve at or below the calculated buckling deflection limit shall be considered a buckling point.

3.2.3. **contaminant** - Inorganic particulate matter or other non-HDPE material that creates inclusions or stress risers in the crystalline structure of HDPE.
3.4. **crack**—any break or split that extends through the wall or liner.

3.5. Crack initiation—the portion of the slow crack growth mechanism associated with the initial development of a craze zone and micro-cracks around a contaminant, void or discontinuity; also referred to as slow crack growth initiation or stress crack initiation.

3.6. Crack propagation—the portion of the slow crack growth mechanism associated with successive yielding of HDPE material ahead of a crack tip; also referred to as slow crack growth propagation or stress crack propagation.

3.7. **crease**—a visible irrecoverable indentation.

4. **CLASSIFICATION**

4.1. The corrugated PE pipe covered by this specification is classified as follows:

4.1.1. **Type C**—This pipe shall have a full circular cross section, with a corrugated surface both inside and outside. Corrugations shall be annular.

4.1.1.1. **Type CP**—This pipe shall be Type C with perforations.

4.1.2. **Type S**—This pipe shall have a full circular cross section, with an outer corrugated pipe wall and a smooth inner liner. Corrugations shall be annular.
4.1.2.1. **Type SP**—This pipe shall be Type S with perforations.

4.1.3. **Type D**—This pipe shall consist of an essentially smooth liner braced circumferentially or spirally with projections or ribs joined to an essentially smooth outer wall.

4.1.3.1. **Type DP**—This pipe shall be Type D with perforations.

4.2. Two classes of perforations are as described in Sections 7.3.1 and 7.3.2.

5. **ORDERING INFORMATION**

5.1. Orders using this specification shall include the following information, as necessary, to adequately describe the desired product:

5.1.1. AASHTO designation and year of issue;

5.1.2. Type of pipe (Section 4.1);

5.1.3. Diameter and length required, either total length or length of each piece and number of pieces;

5.1.4. Number of couplings;

5.1.5. Class of perforations (Class 2 is furnished if not specified) (Section 7.3); and

5.1.6. Certification, if desired (Section 12.1).
6. MATERIALS

6.1. Basic Materials:

6.1.1. Extruded Pipe and Blow Molded Fittings—Pipe and fittings shall be made of virgin and/or recycled PE resin compounds meeting the requirements of ASTM D3350 and cell classification 435400C, except that the carbon black content shall not exceed 4.0 percent. The cell classification shall be based on the virgin PE resin compounds without carbon black when tested in accordance with D4218. Resins that have higher cell classifications in one or more properties, with the exception of density, are acceptable provided product requirements are met. For slow crack growth resistance, acceptance of resins shall be determined by using the notched constant ligament-stress (NCLS) test according to the procedure described in Section 9.4. For slow crack growth resistance, acceptance of pipes shall be determined by tests on the finished pipe using the NCLS test according to the procedure described in Section 9.4. The requirements in 6.1.1.2 and 6.1.1.2 shall be met. The average failure time of the pipe liner shall not be less than 18 h. If profile geometries do not have a flat portion of sufficient length to produce an NCLS tensile specimen of 25 mm (1 in.) length, usually 15 in. diameter or less, the pipe sample shall be ground and a test plaque made in accordance with ASTM D4703 Procedure C at a cooling rate of 15°C/min (27°F/min) and tested per ASTM F2136. The average failure time of test specimens from plaques shall not be less than 24 h.

6.1.1.1. To ensure adequate resistance to SCG propagation, Notched Constant Ligament Stress (NCLS) testing shall be conducted on specimens die cut either directly from the finished pipe liner or from ground-up pieces of pipe (from the liner and/or outer wall) that have been compression-molded into a plaque. Testing shall be conducted in accordance with ASTM F2136 and the procedures described in Section 9.4.

6.1.1.1.1. If testing is conducted on specimens taken directly from the finished pipe liner, the average failure time of five specimens shall not be less than 18 h.

6.1.1.1.2. If testing is conducted on specimens taken from ground-up pieces of pipe that have been compression molded into a plaque, the average failure time of five test specimens shall not be less than 24 h.

6.1.1.2. For pipes manufactured with recycled materials, Un-notched Constant Ligament Stress (UCLS) testing shall be conducted in accordance with ASTM F3181 and the procedures described in Section 9.4 to ensure the desired service life is met. The minimum UCLS failure time shall be prescribed based on the service conditions (temperature and factored design stress) and desired service life as detailed in A2 of the Annex. In the absence of design data, a service life of 100 years at a service temperature of 23 deg. C and factored tensile design stress of 500 psi shall be conservatively specified. For this condition, the average UCLS failure time for five specimens shall not be less than 34 hrs., with no single specimen failing in less than 18 hrs.

6.1.1.3. Pipes manufactured from recycled materials shall have an Oxidation Induction Time (OIT) of 20 minutes when tested in accordance with ASTM D3895 and a break strain of 150% when tested in accordance with ASTM D638. Density of pipe compounds containing recycled materials should be conducted by the ultrasound technique in accordance with ASTM D4883.

Note 2. The ultrasound density technique is not affected by colorants and other inorganic compounds that may be present in these materials.

6.1.2. Rotational Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE resins meeting the requirements of ASTM D3350 and cell classification 213320C, except that
carbon black content shall not exceed 5 percent. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.1.3. Injection Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE resins meeting the requirements of ASTM D3350 and cell classification 314420C, except that the carbon black content shall not exceed 5 percent. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.2. Reworked Plastic—In lieu of virgin PE, clean reworked plastic may be used by the manufacturer, provided that it meets the cell class requirements as described in Section 6.1.

6.3. Resin Blending—When blended resins are used, the components of the blend must be virgin PE and the final blend must meet all of the requirements of Section 6.1.1 for extruded pipe and blow molded fittings, Section 6.1.2 for rotational molded fittings and couplings, and Section 6.1.3 for injection molded fittings and couplings.

7. REQUIREMENTS

7.1. Workmanship—The pipe and fittings shall be free of foreign inclusions and visible defects as defined herein. The ends of the pipe shall be cut squarely and cleanly so as not to adversely affect joining or connecting.

7.1.1. Visible Defects—Cracks, creases, delaminations, and unpigmented or nonuniformly pigmented pipe are not permissible in the pipe or fittings as furnished. There shall be no evidence of delamination when tested in accordance with Section 9.7.

7.2. Pipe Dimensions:

7.2.1. Nominal Size—The nominal size for the pipe and fittings is based on the nominal inside diameter of the pipe. Nominal diameters shall be 300, 375, 450, 525, 600, 675, 750, 900, 1050, 1200, 1350, and 1500 mm (12, 15, 18, 21, 24, 27, 30, 36, 42, 48, 54, and 60 in.).

7.2.2. Liner Thickness—The liner of Type S pipe, and both liner and outer wall of Type D pipe shall have the following minimum thicknesses when measured in accordance with Section 9.6.4.

<table>
<thead>
<tr>
<th>Diameter, mm (in.)</th>
<th>Liner Thickness, Min*, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>0.9 (0.035)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>1.0 (0.04)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>1.3 (0.05)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>675 (27)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>750 (30)</td>
<td>1.5 (0.06)</td>
</tr>
<tr>
<td>900 (36)</td>
<td>1.7 (0.07)</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>1.8 (0.07)</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1.8 (0.07)</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>2.0 (0.08)</td>
</tr>
<tr>
<td>1500 (60)</td>
<td>2.0 (0.08)</td>
</tr>
</tbody>
</table>

* For Type D profile, the minimum liner thickness shall also apply to the outer wall.
7.2.3. **Inside Diameter Tolerances**—The tolerance on the specified inside diameter shall be 4.5 percent oversize and 1.5 percent undersize, but not more than 37 mm (1.5 in.) oversize when measured in accordance with Section 9.6.1.

7.2.4. **Length**—Corrugated PE pipe may be sold in any length agreeable to the user. Lengths shall not be less than 99 percent of the stated quantity when measured in accordance with Section 9.6.2.

7.3. **Perforations**—When perforated pipe is specified, the perforations shall conform to the requirements of Class 2, unless otherwise specified in the order. Class 1 perforations are for pipe intended to be used for subsurface drainage or combination storm and underdrain. Class 2 perforations are for pipe intended to be used for subsurface drainage only. The perforations shall be cleanly cut so as not to restrict the inflow of water. Pipe connected by couplings or bands may be unperforated within 100 mm (4 in.) of each end of each length of pipe. Pipe connected by bell and spigot joints may not be perforated in the area of the bells and spigots.

---

**Figure 1**—Requirements for Perforations

**Table 1**—Rows of Perforations, Height \( H \) of the Centerline of the Uppermost Rows above the Invert, and Chord Length \( L \) of Unperforated Segment, for Class 1 Perforations

<table>
<thead>
<tr>
<th>Nominal Diameter, mm (in.)</th>
<th>Rows of Perforations</th>
<th>( H ), Max, mm (in.)</th>
<th>( L ), Min, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>6</td>
<td>138 (5.4)</td>
<td>192 (7.5)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>6</td>
<td>172 (6.75)</td>
<td>240 (9.5)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>6</td>
<td>207 (8.15)</td>
<td>288 (11.3)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>6</td>
<td>241 (9.5)</td>
<td>336 (13.2)</td>
</tr>
<tr>
<td>600 and larger (24 and larger)</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Minimum number of rows. A greater number of rows for increased inlet area shall be subject to agreement between purchaser and manufacturer. Note that the number of perforations per meter in each row (and inlet area) is dependent on the corrugation pitch.

* See Figure 1 for location of dimensions \( H \) and \( L \).

* \( H_{\text{max}} = 0.64D, L_{\text{min}} = 0.64D \), where \( D \) = nominal diameter of pipe, mm.
7.3.1. **Class 1 Perforations**—The perforations shall be approximately circular and shall have nominal diameters of not less than 5 mm (0.2 in.) nor greater than 10 mm (0.4 in.) and shall be arranged in rows parallel to the axis of the pipe. For Type CP and SP pipe, the perforations shall be located in the external valleys with perforations in each row for each corrugation. (The perforations shall not cut into the corrugation sidewalls.) For Type DP pipe, perforations shall be located in the center of the cells. The perforations shall not cut into the vertical sections of the cells. The rows of perforations shall be arranged in two equal groups placed symmetrically on either side of the lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance between the centerlines of the rows shall not be less than 25 mm (1 in.). The minimum number of longitudinal rows of perforations, the maximum height of the centerlines of the uppermost rows of perforations above the bottom of the invert, and the inside chord lengths of the unperforated segments illustrated in Figure 1 shall be as specified in Table 1.

7.3.2. **Class 2 Perforations**—Circular perforations shall be a minimum of 5 mm (0.2 in.) and shall not exceed 10 mm (0.4 in.) in diameter. The width of slots shall not exceed 3 mm (0.1 in.). The length of slots shall not exceed 70 mm (2.75 in.) for 300 mm (12 in.) and 375 mm (15 in.) pipe and 75 mm (3 in.) for 450 mm (18 in.) and larger pipe. Perforations shall be placed in the external valleys for Type CP and SP pipe and in the center of the cells for Type DP pipe. Perforations shall be uniformly spaced along the length and circumference of the pipe. The water inlet area shall be a minimum of 30 cm²/m (1.5 in.²/ft) for pipe sizes 300 to 450 mm (12 to 18 in.) and 40 cm²/m (2 in.²/ft) for pipe sizes larger than 450 mm (18 in.). All measurements shall be made in accordance with Section 9.6.3.

7.4. **Pipe Stiffness**—The pipe shall have a minimum pipe stiffness at 5 percent deflection as follows when tested in accordance with Section 9.1.

<table>
<thead>
<tr>
<th>Diameter, mm (in.)</th>
<th>Pipe Stiffness, kPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>345 (50)</td>
</tr>
<tr>
<td>375 (15)</td>
<td>290 (42)</td>
</tr>
<tr>
<td>450 (18)</td>
<td>275 (40)</td>
</tr>
<tr>
<td>525 (21)</td>
<td>260 (38)</td>
</tr>
<tr>
<td>600 (24)</td>
<td>235 (34)</td>
</tr>
<tr>
<td>675 (27)</td>
<td>205 (30)*</td>
</tr>
<tr>
<td>750 (30)</td>
<td>200 (29)*</td>
</tr>
<tr>
<td>900 (36)</td>
<td>155 (22.5)*</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>145 (21)*</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>135 (20)*</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>120 (18)*</td>
</tr>
<tr>
<td>1500 (60)</td>
<td>105 (15)*</td>
</tr>
</tbody>
</table>

* For diameters 675 mm (27 in.) and larger, the stiffness test is conducted at a higher loading rate than ASTM D2412 as described in Section 9.1.

7.5. **Pipe Flattening**—Pipe specimens shall show no visible evidence of cracking, splitting, or delamination when tested in accordance with Section 9.2. Additionally, pipe specimens shall not exhibit a decrease or downward deviation in the load-deflection curve prior to the buckling deflection limit calculated in Section 9.2.1.

7.6. **Brittleness**—Pipe specimens shall not crack or split when tested in accordance with Section 9.3. Five nonfailures out of six impacts will be acceptable.

7.7. **Stub Compression Test**—Profile compression capacity in any specimen in the stub compression test shall not be less than 50 percent of the gross cross-sectional area times the minimum specified
yield strength when tested in accordance with Section 9.8. The stub compression test, AASHTO T 341, shall be a material and wall design qualification test conducted twice a year or whenever there are changes in wall design or material distribution. Computing the minimum capacity requires determining the cross-sectional area of the pipe wall. This can be accomplished conveniently by optically scanning the profile and determining the section properties using a computer drafting program.

7.8. **Fitting Requirements:**

7.8.1. The fittings shall not reduce or impair the overall integrity or function of the pipe line.

7.8.2. Common corrugated fittings include in-line joint fittings, such as couplings and reducers, and branch or complementary assembly fittings such as tees, wyes, and end caps. These fittings are installed by various methods.

7.8.3. All fittings shall be within an overall length dimensional tolerance ±12 mm (0.5 in.) of the manufacturer’s specified dimensions when measured in accordance with Section 9.6.2.

7.8.4. Fittings shall not reduce the inside diameter of the pipe being joined by more than 12 mm (0.5 in.). Reducer fittings shall not reduce the cross-sectional area of the smaller size.

7.8.5. Couplings shall be corrugated to match the pipe corrugations and shall provide sufficient longitudinal strength to preserve pipe alignment and prevent separation at the joints. Couplings shall be bell and spigot or split collar. Split couplings shall engage at least two full corrugations on each pipe section.

7.8.6. The design of the fittings shall be such that when connected with the pipe, the axis of the assembly will be level and true when tested in accordance with Section 9.5.2.

7.8.7. Other types of coupling bands or fastening devices that are equally effective as those described, and that comply with the joint performance criteria of AASHTO LRFD Bridge Construction Specifications, Section 30, may be used when approved by the purchaser.

7.8.8. Only fittings supplied or recommended by the pipe manufacturer shall be used. Fabricated fittings shall be manufactured from pipe meeting the requirements of this specification and all seams must be completely sealed with compatible PE material.

7.8.9. Fabricated fittings shall be supplied with joints compatible with the overall system.

7.9. **Joint Requirements:**

7.9.1. All joints shall meet the requirements of a siltight joint unless otherwise specified by the owner/designer.

7.9.2. **Siltight joints** are specified as a function of opening size, channel length, and backfill particle size. If the size of the opening exceeds 3 mm (0.12 in.), the length of the channel must 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 siltightness criteria can be found in AASHTO LRFD Bridge Construction Specifications, Section 30, “Thermoplastic Pipe.”

7.9.3. **Silt-tight joints** should be used where the backfill material has a high percentage of fines. Silt-tight bell and spigot joints will utilize an elastomeric rubber seal meeting ASTM F477. Silt-tight joints must be designated to pass a laboratory pressure test of at least 14 kPa (2 psi).
7.9.4. Watertight joints must meet a 74 kPa (10.8 psi) laboratory test per ASTM D3212 and utilize a bell and spigot design with a gasket meeting ASTM F477.

8. CONDITIONING

8.1. Conditioning—Condition the specimen prior to test at 21 to 25°C (70 to 77°F) for not fewer than 24 h in accordance with Procedure A in ASTM D618 for those tests for which conditioning is required, and unless otherwise specified.

8.2. Conditions—Conduct all tests at a laboratory temperature of 21 to 25°C (70 to 77°F) unless otherwise specified herein.

9. TEST METHODS

9.1. Pipe Stiffness—Select a minimum of two (2) pipe specimens and test for pipe stiffness (PS), as described in ASTM D2412 except for the following: (1) the test specimens shall be a minimum of one diameter length for 300-mm (12-in.) to 600-mm (24-in.) diameter pipe, and one-half diameter length for pipe diameters greater than 600 mm (24 in.); (2) locate the first specimen in the loading machine with an imaginary line connecting the two seams formed by the corrugation mold (end view) parallel to the loading plates, when applicable. The specimen must lie flat on the plate within 3 mm (0.12 in.) and may be straightened by hand bending at room temperature to accomplish this. Use the first location as a reference point for rotation and testing of the other specimen. Rotate the second specimen 90 degrees from the orientation of the first specimen and test. Test each specimen in one position only; (3) the deflection indicator shall be readable and accurate to ±0.02 mm (0.001 in.); (4) the residual curvature found in tubing frequently results in an erratic initial load-deflection curve. When this occurs, the beginning point for deflection measurement shall be at a load of 20 ± 5 N (4.5 lbf ± 1.1 lbf). The point shall be considered as the origin of the load-deflection curve; (5) the crosshead speed shall be the faster of 12.7 mm min (0.5 in./min) or 2 percent of the nominal inside diameter per minute.

Note 23—The loading plates must exceed the length of the test specimen as specified above.

Note 34—Additional pipe specimens may be tested at other orientations for pipe stiffness and flattening if desired.

9.2. Pipe Flattening—Flatten the two pipe specimens from Section 9.1 until the vertical inside diameter is reduced to 1.5 times the buckling deflection limit calculated in Section 9.2.1. The rate of loading shall be the same as in Section 9.1. Immediately after the specimen has started to unload, check for visible evidence of cracking, splitting, or delamination.

9.2.1. The buckling deflection limit shall be determined by the following equation:

$$\Delta b = \frac{6.15\% \times 0.5D}{D_i \times 0.6 \times hp}$$

which simplifies to:

$$\Delta b = \frac{1.20D}{hp}$$

where:

- $\Delta b$ = Minimum buckling deflection limit, percent (%)
- $D$ = Inside diameter of pipe, mm (in.)
- $D_i$ = Shape factor = 4.27
- $hp$ = Corrugation height, mm (in.)
Note 45—The constant value 6.15 percent in the equation is the factored combined strain limit for HDPE pipe per AASHTO LRFD Bridge Design Specifications, Section 12.

Note 56—The constant value 0.6 in the equation is based on the estimated distance from the centroid to the extreme fiber of the wall profile (0.6 \( hp \)) for typical profiles produced per this specification.

9.2.1.1. The corrugation height, \( hp \), shall be determined by the following equation:

\[
hp = \frac{(OD - ID)}{2}
\]

where:

- \( hp \) = Corrugation height, mm (in.)
- ID = Measured inside diameter of pipe, mm (in.)
- OD = Measured outside diameter of pipe, mm (in.)

OD shall be measured in accordance with Section 9.6.1. OD shall be measured with a circumferential wrap tape or other suitable device in accordance with ASTM D2122. Figure 2 shows an illustration of the corrugation height, and Figure 3 shows example measurements of the inside and outside diameters.
The diagram illustrates the following:

- **Cx**: Distance from Centroid to Extreme Fiber
- **C**: Distance from Centroid to Inner Wall
- **hp**: Corrugation Height or \((\text{OD} - \text{ID})/2\)

The comment on the page reads: "Commented [BWRIP(5): Change C = Distance from Centroid to inner wall to C = Distance from Centroid to inner liner.]"
9.2.2. It is permissible to run the pipe stiffness test in conjunction with the pipe flattening test as long as individual evaluations are made for their respective criteria as specified under Sections 7.4 and 9.1 (stiffness) and Sections 7.5, 9.2, and 9.2.1 (flattening).

9.3. Britleness—Test pipe specimens in accordance with ASTM 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 degrees for impacts made on one circle, or at least 300 mm (12 in.) longitudinally for impacts made on one element. Impact points shall be at least 150 mm (6 in.) from the end of the specimen. Tup B shall be used, with a mass of 4.5 kg (10 lb). The height of drop shall be 3.0 m (10 ft). Use a flat plate specimen holder. Condition the specimens for 24 h at a temperature of –4 ± 2°C (25 ± 3.6°F), 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.

9.4. Slow Crack Growth Resistance of Polyethylene Pipe—Test specimens from the pipe liner for stress crack propagation resistance in accordance with ASTM F2136, the NCLS test, except for the following modifications:

9.4.1. The applied stress for the NCLS test shall be 4100 kPa (600 psi). Note 67—The notched depth of 20 percent of the nominal thickness of the specimen is critical to this procedure.

9.4.1.1. If specimens are die cut directly from the finished pipe liner, they shall be die cut from the longitudinal direction and notched on the outer surface of the liner, perpendicular to the direction of flow, as shown below in Figure 4. Specimens die cut from the finished pipe liner shall be tested as noted in Section 6.1.1.

9.4.2. The liner NCLS test specimens shall be die cut longitudinally from the pipe liner and notched on the outer surface of the liner, perpendicular to the direction of flow, as shown below in Figure 2.
9.4.1.2 If specimens are die cut from ground-up pieces of pipe taken from the liner and/or outer wall that have been compression-molded into a plaque, the plaques shall be made per ASTM D4703 Procedure C. Specimens die cut from those plaques shall be tested as noted in Section 6.1.1.

9.4.3.4.2 When the pipe liner cannot be sampled, then a specimen may be taken from the profile wall of the pipe. Where the pipe wall profile does not have flat longitudinal sections of sufficient size to obtain a tensile specimen, a sample of the pipe wall shall be ground and made into plaques per ASTM D4703 Procedure C. Specimens die cut from those plaques shall be tested as noted in Section 6.1.1. For pipes manufactured from recycled materials, specimens shall be tested for stress crack initiation and propagation in accordance with ASTM F3181, the UCLS test. The test shall be conducted on specimens die cut or machined from pieces of pipe that have been compression-molded into a plaque in accordance with the procedures in ASTM F3181. The test shall be conducted at a temperature of 80 deg. C and at a stress of 650 psi.

9.5. Joints and Fittings:
9.5.1. Joint Integrity—Pipes that have a welded bell shall be tested to verify the strength of the weld as follows: Assemble the joint in accordance with the manufacturer’s recommendations. Use pipe samples at least 300 mm (12 in.) in length. Assemble a specimen at least 600 mm (24 in.) in length with the connection at the center. Load the connected pipe and joint between parallel plates at the rate of 12.5 mm/min (0.5 in./min) until the vertical inside diameter is reduced by at least 20 percent of the nominal diameter of the pipe. Inspect for damage while at the specified deflection and after load removal.

9.5.2. Alignment—Assure that the assembly or joint is correct and complete. If the pipe is bent, it should be straightened prior to performing this test. Lay the assembly or joint on a flat surface and verify that it will accommodate straight-line flow.

9.6. Dimensions:

9.6.1. Inside Diameter—Measure the inside diameter of the pipe with a tapered plug in accordance with ASTM D2122. As an alternative, measure the inside diameter with a suitable device accurate to ±3.0 mm (0.12 in.) by taking two inside diameter measurements, the first at the seam and the second 90 degrees from the seam, and averaging the two measurements. The average inside diameter shall meet the requirements of Section 7.2.3.

9.6.2. Length—Measure pipe with any suitable device accurate to ±6.0 mm in 3 m (0.25 in. in 10 ft). Make all measurements on the pipe while it is stress-free and at rest on a flat surface in a straight line. These measurements may be taken at ambient temperature.

9.6.3. Perforations—Measure dimensions of perforations on a straight specimen with no external forces applied. Make linear measurements with instruments accurate to 0.2 mm (0.008 in.).

9.6.4. Liner Thickness—Measure the liner thickness in accordance with ASTM D2122.

9.7. Delamination—Examine Type S pipe for evidence of delamination as defined and described in Section 3.9 by cutting the pipe at the corrugation crest as shown in Figure 3.5 and attempting to insert a feeler gauge between the liner and the corrugation valley as shown in Figure 4.5. The feeler gauge should not pass through the corrugation valley into a void at any location along the circumference of the pipe.

Examine Type D pipe for evidence of delamination as defined and described in Section 3.9 by cutting a section through the pipe as shown in Figure 3.5 and attempting to insert a feeler gauge between the internal supports and the liner and outer wall as shown in Figure 4.6. The feeler gauge should not pass between the internal support and the liner or outer wall at any point along the circumference of the pipe.
9.8. **Stub Compression Capacity**—Determine the stub compression capacity of the pipe section in accordance with T 341. Conduct four tests on specimens cut from the same ring of pipe at 90-degree intervals around the circumference.
10. **INSPECTION AND RETEST**

10.1. *Inspection*—Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

10.2. *Retest and Rejection*—If any failure to conform to these specifications occurs, the pipe or fittings may be retested to establish conformity in accordance with agreement between the purchaser and seller. Individual results, not averages, constitute failure.

11. **MARKING**

11.1. *All pipe shall be clearly marked at intervals of no more than 3 m (10 ft) as follows:*

11.1.1. Manufacturer’s name or trademark;

11.1.2. Nominal size;

11.1.3. This specification designation, M 294;

11.1.4. The plant designation code; and

11.1.5. If the pipe was manufactured with recycled content, it shall be designated accordingly with the phrase “Contains Recycled Resins”; and

11.1.6. The date of manufacture or an appropriate code. If a date code is used, a durable manufacturer sticker that identifies the actual date of manufacture shall be adhered to the inside of each length of pipe.

*Note 78*—A durable sticker is one that is substantial enough to remain in place and be legible through installation of the pipe.

11.2. Fittings shall be marked with the designation number of this specification, M 294, and with the manufacturer’s identification symbol.

12. **QUALITY ASSURANCE**

12.1. A manufacturer’s certificate that the product was manufactured, tested, and supplied in accordance with this specification, together with a report of the test results, and the date each test was completed, shall be furnished on request. Each certification so furnished shall be signed by a person authorized by the manufacturer.

12.2. *Manufacturer Records*—Manufacturers shall keep records of the following: (1) resin manufacturer’s data sheets and certification that the base resin meets minimum cell class requirements of the product specification; (2) manufacturer’s data sheets and quantities for all additives blended with the resin by the pipe manufacturer; (3) test results to demonstrate that, if resins of two different cell classifications are blended, the resulting mixture meets the requirements of the specified cell classification; (4) correlation of resin shipment source with pipe markings.

13. **KEYWORDS**

13.1. Buckling; crack; crease; delamination; corrugated pipe; pipe; polyethylene; recycled material.
ANNEX A

(Mandatory Information)

A1. GUIDELINES FOR PIPE MADE FROM NON-PPI CERTIFIED RESIN OR NON-PPI CERTIFIED BLENDED RESINS

A1.1. If pipe is made from a non-PPI certified resin or non-PPI certified blend of component resins, the pipe manufacturer should have a resin testing program in place that includes the testing of each component resin and resin blend lot for density and melt index and have the means of conducting (in-house or contract lab) the remaining cell class and NCLS testing as specified in this standard. The manufacturer shall test each resin or resin blend lot for full cell class and NCLS, unless a regular quality assurance program is in place to correlate cell class results to density and melt index. In any case, full cell class and NCLS testing should be performed on all approved/certified resin blends at least quarterly. Additionally, the pipe manufacturer shall have the resin blend independently tested and prequalified based on a "recipe" with component percentage tolerances of no more than ±1.5 percent substantiated by annual independent testing.

A1.2. When blends of virgin resins are used for pipe manufacture, the final blended resin must meet the requirements of the standard. It is not necessary for the individual components of the blend to meet the cell class or NCLS requirements of this standard, provided that the final blend meets all the requirements.

A1.2.1. Final resin blends shall have a minimum NCLS value of 33 h when tested in accordance with ASTM F2136 unless manufacturers have sufficient test data to show a lower resin NCLS value corresponds to a finished product liner NCLS value of at least 18 h.

A1.2.2. Sampling and testing of the final blended resin shall be performed as follows:

A1.2.2.1. The sample shall be prepared either by direct sampling from the feed hopper of the extruder (after the material has already been weigh-blended by the blenders or other means), or by manually weigh-blending the individual components to the specified finished blend ratios. The manufacturer shall have current calibration records for the automated or manual weigh-blending equipment.

A1.2.2.2. The blended sample shall not contain carbon black concentrate. If carbon black concentrate is present in the sampled material, the carbon black concentrate shall be removed prior to further sample preparation.

A1.2.2.3. The dry-blended sample shall be fully homogenized by melt blending via a twin screw lab extruder or other melt homogenization technique that has been verified to provide similar levels of homogenization prior to testing for physical properties.

A1.2.2.4. The melt-blended sample shall be tested for melt index, density, and NCLS in accordance with the number of hours per the requirements of the standard.

A2. PROCEDURE FOR DETERMINATION OF MINIMUM UCLS VALUES FOR PIPES MANUFACTURED WITH RECYCLED MATERIALS

A2.1. The complete procedure for determining the minimum UCLS values to ensure a desired service life at given design conditions for pipes manufactured with recycled materials is detailed in Appendix L of NCHRP Report 870, Standard Recommended Practice for Service Life.
Determination of Corrugated HDPE Pipes Manufactured with Recycled Materials. An abbreviated procedure is shown below.

**A2.2.** Using Equation A2.1 (Pluimer 2016), calculate the minimum UCLS failure time at the 80 deg. C / 650 psi stress test condition to ensure the desired service life (tSVC, yrs.) at the given service conditions [i.e. service stress (σSVC, psi) and service temperature (T, deg. C)].

\[
t = \left( \frac{SFt}{SFt} \right) \cdot \left( \frac{\sigma_{SVC}}{650} \right)^6
\]

(Eqn. A2.1)

where

- \( t \) = Minimum required average failure time at 80 deg. C, 650 psi condition, hrs.
- \( SFt \) = Poplar time shift factor = e0.109(80-T)
- \( SF\sigma \) = Poplar stress shift factor = e0.0116(80-T)
- \( T \) = Service temperature, deg. C
- \( \sigma_{SVC} \) = Design service stress, psi
- \( t_{SVC} \) = Required service life at service conditions, yrs.

**A2.3.** To ensure 95% confidence that the minimum average failure time calculated from Equation A2.1 will result in the desired service life, the failure time must be statistically adjusted to account for the scatter in the data. The average failure time needed to ensure 95% confidence is calculated from Equation A2.2.

\[
\bar{X}_{95\%} = 1.911 \cdot t
\]

(Eqn. A2.2)

where

- \( \bar{X}_{95\%} \) = Average failure time needed for 95% confidence, hrs.
- \( t \) = Minimum required average failure time from Eqn. A2.1, hrs.

**A2.4.** The average UCLS failure time of the 5 test specimens shall not be less than that calculated in Equation A2.2 (rounded up to the nearest integer), and no specimen shall fail in less than that calculated in Equation A2.1 (rounded up to the nearest integer).

**A2.5.** An example calculation is shown in Appendix X2.
APPENDIX

(Nonmandatory Information)

X1. QUALITY CONTROL/QUALITY ASSURANCE PROGRAM

X1.1. Scope:

X1.1.1. As required in Sections 10 and 12, the acceptance of these products relies on the adequate inspection and certification agreed to between the buyer and the seller/producer. This appendix should serve as a guide for both the manufacturer and the user. It places the responsibility on the producer to control the quality of the material it produces and to provide the quality control information needed for acceptance by the buyer/user. The producer is required to perform quality control sampling, testing, and record keeping on materials it ships. It also sets forth quality assurance sampling, testing, and record keeping that should be performed by the buyer/user to confirm the performance of the producer's control plan.

X1.2. Program Requirements:

X1.2.1. The producing company must have a quality control plan approved by the specifying agency.

X1.2.2. The producing plant must have a quality control plan approved by the specifying agency.

X1.2.3. The plant must have an approved laboratory, either within the company or an independent laboratory.

X1.2.4. The producing plant(s) must have a designated quality control technician.

X1.3. Quality Control Plan:

X1.3.1. The producer must supply to the specifying agency a written quality control plan that shows how the producer will control the equipment, materials, and production methods to ensure that the specified products are supplied. The following information must be included in the plan:

X1.3.1.1. Titles of the personnel responsible for production quality at the plant(s);

X1.3.1.2. The physical location of the plant(s);

X1.3.1.3. The methods of identification for each lot of material during manufacture, testing, storage, and shipment. The method of identification shall allow the specifying agency to trace the finished product to the material provider;

X1.3.1.4. The method of sampling and testing of raw materials and finished product, including lot sizes and types of tests performed; and
X1.3.1.5. A plan for dealing with nonconforming product, including how the producer plans to initiate immediate investigation and how corrective action will be implemented to remedy the cause of the problem.

X1.4. Approved Laboratory:

X1.4.1. All tests must be conducted at laboratories approved by the specifier. Each manufacturer may establish and maintain its own laboratory for performance of quality control testing or may utilize an approved independent laboratory. Records of instrument calibration and maintenance and sample collection and analysis must be maintained at the laboratory.

X1.5. Quality Control Technician:

X1.5.1. All samples must be taken and tested by the quality control technician designated by the producer. The designated quality control technicians will be responsible for overall quality control at the producing plant.

X1.6. Annual Update:

X1.6.1. An annual update may be required. If required, the annual update may be submitted by the manufacturer to the specifying agency by December 31st of each calendar year.

X1.7. Plant Approval:

X1.7.1. The plant approval process requires the manufacturer to submit an annual update to the specifying agency. The update must identify the specific product manufactured at the plant.

X1.7.2. The specifying agency will review the manufacturer’s written quality control plan and a plant inspection may be scheduled. This inspection will verify that the quality control plan has been implemented and is being followed and that at least one designated quality control technician is on-site and will be present when material is being produced under this program. The laboratory will be inspected and approved if it meets the requirements.

X1.8. Sampling and Testing:

X1.8.1. The quality assurance plan approved for each manufacturer, and/or manufacturer’s location, shall detail the methods and frequency of sampling and testing for all raw materials and products purchased or manufactured at that location. All testing shall be in accordance with current specifications and procedures referenced in M 294.

X1.8.2. Samples of materials and pipe may be taken by the specifying agency.

X1.8.3. The specifying agency may require an annual third-party independent assurance test.

X1.9. Sample Identification and Record Keeping:
X1.9.1. Manufacturer’s Quality Control samples are to be uniquely identified by the producing plant.

X1.9.2. Quality control and quality assurance data are to be retained by the manufacturer for 2 years and made available to the specifying agency on request.

X1.9.3. Quality control test reports shall include the lot identification.

X1.9.4. Unless requested at the time of ordering, test reports do not have to be filed for specific projects.

X1.9.5. Reports shall indicate the action taken to resolve nonconforming product.

X2. EXAMPLE CALCULATIONS FOR MINIMUM UCLS FAILURE TIME DETERMINATION

X2.1. Example 1: Consider a pipe installed in a condition where the maximum factored tensile design stress is 500 psi and the average in-ground service temperature is 23 deg. C. The desired service life is 100 years. To determine the minimum UCLS failure time, follow the procedure below.

X2.1.1. Calculate the Popelar time and stress multiplication factors to shift the failure times from the elevated temperature test condition to the service condition:

\[ t = e^{0.109(80-23)} = e^{6.213} = 499.2 \text{ hrs.} \]  
(Eqn. X2.1)

\[ S_{p} = e^{0.0116(80-23)} = e^{0.6612} = 1.937 \]  
(Eqn. X2.2)

X2.1.2. Calculate the minimum required UCLS failure time for the test condition to ensure the desired service life is met using Equation A2.1, as illustrated below.

\[ t = \left(\frac{8760 \cdot 100}{499.2}\right) \cdot \left(\frac{500}{650-1.937}\right)^5 = 17.3 \text{ hrs.} \]  
(Eqn. X2.3)

X2.1.3. Statistically adjust this minimum failure time to ensure 95% confidence using Equation A2.2, as illustrated below.

\[ X_{95\%} = 1.911 \cdot t = 1.911 \cdot 17.3 = 33.1 \text{ hrs.} \]  
(Eqn. X2.4)

X2.1.4. Rounding up to the nearest integer, the minimum average failure time for 5 specimens shall not be less than 34 hours, and no single specimen shall fail in less than 18 hours.

X2.2. Example 2: Consider a pipe installed in a condition where the maximum factored tensile design stress is 400 psi and the average in-ground service temperature is 20 deg. C. The desired service life is 100 years. To determine the minimum UCLS failure time, follow the procedure below.

X2.2.1. Calculate the Popelar time and stress multiplication factors to shift the failure times from the elevated temperature test condition to the service condition:
X2.2.2. \( SF_t = e^{0.109(80-20)} = e^{6.54} = 692.3 \) (Eqn. X2.5)

X2.2.3. \( SF_a = e^{0.0116(80-20)} = e^{6.696} = 2.006 \) (Eqn. X2.6)

X2.2.4. 

X2.2.5. Calculate the minimum required UCLS failure time for the test condition to ensure the desired service life is met using Equation A2.1, as illustrated below.

\[
t = \left( \frac{8760 \cdot 100}{692.3} \right) \times \left( \frac{400}{650-2.006} \right)^5 = 3.44 \text{ hrs.} \]  
(Eqn. X2.7)

X2.2.6. 

X2.2.7. Statistically adjust this minimum failure time to ensure 95% confidence using Equation A2.2, as illustrated below.

\[
\bar{X}_{95\%} = 1.911 \cdot t = 1.911 \cdot 3.44 = 6.57 \text{ hrs.} \]  
(Eqn. X2.7)

X2.2.8. 

X1.9.5-X2.3. Rounding up to the nearest integer, the minimum average failure time for 5 specimens shall not be less than 7 hours, and no single specimen shall fail in less than 4 hours.
Standard Specification for

Steel-Reinforced Polyethylene (PE) Ribbed Pipe, 300- to 1500-mm (12- to 60-in.) Diameter

AASHTO Designation: MP 20-13 (2017)¹
Technical Section: 4b, Flexible and Metallic Pipe
Release: Group 2 (June 2017)

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001
1. SCOPE

1.1. This specification covers the requirements and methods of tests for steel-reinforced polyethylene (PE) ribbed pipe, couplings, and fittings for use in surface and subsurface drainage applications.

1.1.1. Nominal sizes of 300 to 1500 mm (12 to 60 in.) are included.

1.1.2. Materials, workmanship, dimensions, pipe stiffness, impact resistance, tensile strength of seams, shape stability, joining systems, and form of markings are specified.

1.2. Steel-reinforced PE ribbed pipe is intended for surface and subsurface drainage applications where soil provides support to its flexible walls. Its major use is to collect or convey drainage water by open gravity flow as culverts, storm drains, etc.

Note 1—When PE pipe is to be used in locations where the ends may be exposed, consideration should be given to protection of the exposed portions due to combustibility of the PE and the effects of prolonged exposure to ultraviolet radiation.

1.3. This specification only deals with this pipe’s materials requirements. The structural design of steel reinforced thermoplastic culverts and the proper installation procedures are given in the AASHTO LRFD Bridge Design Specifications, Section 12, and AASHTO LRFD Bridge Construction Specifications, Section 26, respectively. Upon request of the user or engineer, the manufacturer shall provide profile wall section detail required for a full engineering evaluation.

1.4. Units—The values stated in SI units are to be regarded as standard. Within the text, the U.S. Customary units are shown in parentheses and may not be exact equivalents.

1.5. The following precautionary caveat pertains only to the test method portion, Section 9, 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. AASHTO Standards:

- M 288, Geosynthetic Specification for Highway Applications
2.2. **ASTM Standards:**
- A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
- D618, Standard Practice for Conditioning Plastics for Testing
- D638, Standard Test Method for Tensile Properties of Plastics
- D883, Standard Terminology Relating to Plastics
- D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
- D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
- D2444, Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
- D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
- F412, Standard Terminology Relating to Plastic Piping Systems
- F477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
- F2136, Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe

3. **TERMINOLOGY**

3.1. The terminology used in this standard is in accordance with the definitions given in ASTM D883 and ASTM F412 unless otherwise specified.

3.2. **Definitions:**

3.2.1. *crack*—any break or split that extends through the wall.

3.2.2. *crease*—an *a visible* irrecoverable indentation, generally associated with a loss in shape stability.

3.2.3. *delamination*—a gap extending through the welded lap seam between two adjacent wrap widths.

3.2.4. *encapsulation thicknesses*—the thicknesses of the high-density polyethylene (HDPE) covering on both sides of the steel reinforcement as well as the thickness of the closure at the top (outside) of the rib and the thickness of the profile directly under (inside) the reinforcement (see Figure 2).

3.2.5. *gravity flow*—a condition in which liquid flow through a piping system results from a downward pipeline slope, but flow is less than full, except during conditions when the system may become temporarily surcharged, in which case the system is subject to temporary internal hydrostatic pressure that is limited to 74 kPa.

3.2.6. *polyethylene (PE) plastics*—plastics based on polymers made with ethylene as essentially the sole monomer (ASTM D883).
3.2.7.  *reworked plastic*—a plastic from a processor’s own production that has been regrounded, pelletized, or solvated after having been previously processed by molding, extrusion, etc. (ASTM D883).

3.2.8.  *seam*—the portion of the helically wrapped strip that overlaps and is fused to adjacent helically wrapped strips (see Figure 1).

![Figure 1—Cross Section of Profile](image)

3.2.9.  *shape stability*—A general measure of the pipe’s ability to maintain geometric and structural stability while deflected and carrying a load equal to or greater than 75 percent of its peak load-carrying capability. Peak load-carrying capability is identified as the maximum load in the load/deflection curve as measured during the flattening test as described in Section 9.2.

3.2.10.  *steel-reinforced thermoplastic pipe*—Ribbed thermoplastic pipe with steel reinforcing strips encapsulated within the ribs (see Figure 1).

3.2.11.  *slow crack growth*—A phenomenon by which a stress crack may form. A stress crack is an external or internal crack in plastic caused by tensile stresses less than its short-term mechanical strength.

3.2.12.  *virgin polyethylene material*—PE plastic material in the form of pellets, granules, powder, floc, or liquid that has not been subject to use or processing other than required for initial manufacture.

3.2.13.  *wrap width*—The width the helically wrapped strip covers when measured across the strip, perpendicular to the ribs (see Figure 1).

3.2.14.  *waterway wall*—The minimum wall thickness separating the inner and outer surfaces of the pipe wall, which is measured between pipe ribs (see Figure 2).

### 4.  CLASSIFICATION

4.1.  The steel-reinforced PE ribbed pipe covered by this specification is classified as follows:

4.1.1.  *Type S*—This pipe shall have a full circular cross section with an essentially smooth inner wall.

4.1.2.  *Type SP*—This pipe shall be Type S with perforations.

4.2.  Perforations are described in Section 7.5.
5. ORDERING INFORMATION

5.1. Orders using this specification shall include the following information as necessary to adequately describe the desired product:

5.1.1. AASHTO designation and year of issue;

5.1.2. Perforation, if applicable (Section 7.5);

5.1.3. Diameter and length required, either total length or length of each piece and number of pieces;

5.1.4. Certification, if desired (Section 12.1); and

5.1.5. Type of pipe joint (Section 7.12.1).

6. MATERIALS

6.1. Polyethylene Materials:

6.1.1. Pipe and Fittings—Pipe and fittings shall be made of virgin PE, conforming to the requirements of ASTM D3350 and having a cell classification of 334452 C or E. Resins that have higher cell classifications in one or more properties are acceptable provided the product requirements are met.

6.1.2. Rotational Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE, conforming to the requirements of ASTM D3350 and having a cell classification of 213320 C or E. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met. For slow crack resistance, acceptance of resins shall be determined by using the notched, constant ligament-stress (NCLS) test according to the procedure described in Section 9.6. The average failure time of the five test specimens must exceed 24 h with no single test specimen’s failure time less than 17 h.

6.1.3. Injection Molded Fittings and Couplings—Fittings and couplings shall be made of virgin PE, conforming to the requirements of ASTM D3350 and having a cell classification of 324452 C or E. Resins that have higher cell classifications in one or more properties are acceptable provided product requirements are met.

6.1.4. Carbon Black Content—The carbon black content shall not exceed 4 percent of the total PE compound weight.

6.1.5. Other Materials—It is permissible to use materials other than the cell classification in Section 6.1.1 as part of the welding processes, provided these materials have higher cell classifications in one or more properties and in no way compromise the performance of the pipe products in the intended use.

6.1.6. Rework Plastics—In lieu of virgin PE, it is permissible to use clean reworked plastic generated from the manufacturer’s own pipe production, provided that it meets the cell class requirements as described in Section 6.1.1.

6.2. Steel Materials:

6.2.1. Steel Material—The steel material shall be cold- or hot-rolled, formable steel meeting the requirements of ASTM A653/A653M and the mechanical requirements for strength in Table 4 of ASTM A653/A653M for the grade defined by the manufacturer as required for their pipe’s design.
The steel shall have a galvanized coating. All steel materials shall be galvanized per the requirements of ASTM A653/A653M with a G60 minimum coating weight.

**Note 2**—The actual strength of the steel and the rib dimensions are dependent on the manufacturer’s design. If requested by the purchaser, the manufacturer shall provide before purchase and delivery their pipe design and certify with delivery that the grade of steel and rib dimensions in the pipe supplied conform to their design.

6.2.2.  
*Gaskets*—Elastomeric gaskets shall meet the requirements of ASTM F477.

6.2.3.  
*Industrial Sealant*—Sealants, such as moisture cure urethane or asphalt-based sealant materials used for repairs or assembly of the internal coupling joint, as recommended by the manufacturer, may be used.

### 7. REQUIREMENTS

7.1.  
*Workmanship*—The pipe and fittings shall be free of foreign inclusions and visible defects as defined herein. Visible defects shall not affect the wall integrity or the encapsulation of the steel reinforcement. The steel reinforcing materials shall not be exposed.

7.2.  
*Visible Defects*—Cracks, creases, delaminations, and unpigmented or nonuniformly pigmented pipe that are visible by the unaided eye are not permissible in the pipe or fittings.

7.3.  
There shall be no evidence of cracking or delamination when tested in accordance with Section 9.2.

7.4.  
*Pipe Dimensions and Tolerances*:

7.4.1.  
*Inside Diameter*—The tolerance on the inside diameter shall be ±2.0 percent, when measured in accordance with Section 9.8.1. Pipe dimensions (for both perforated and nonperforated pipe) shall comply with Table 1.

7.4.1.1.  
Other diameters that are within the range of pipe sizes shown in Table 1 are permissible. The minimum wall thickness and other properties shall be interpolated from the adjacent values given in Table 1.

### Table 1—Nominal Pipe Sizes, Inside Diameters, and Minimum Waterway Wall Thicknesses

<table>
<thead>
<tr>
<th>Nominal Pipe Size, mm (in.)</th>
<th>Inside Diameter, mm [in.]</th>
<th>Minimum Waterway Wall Thickness, $t_1$, mm [in.]</th>
<th>Minimum Encapsulation Thickness (Bottom), $t_2$, mm [in.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>300 [11.81]</td>
<td>1.1 [0.043]</td>
<td>0.9 [0.035]</td>
</tr>
<tr>
<td>375 (15)</td>
<td>375 [14.76]</td>
<td>1.2 [0.047]</td>
<td>1.0 [0.039]</td>
</tr>
<tr>
<td>450 (18)</td>
<td>450 [17.72]</td>
<td>1.3 [0.051]</td>
<td>1.3 [0.051]</td>
</tr>
<tr>
<td>600 (24)</td>
<td>600 [23.62]</td>
<td>1.5 [0.059]</td>
<td>1.5 [0.059]</td>
</tr>
<tr>
<td>750 (30)</td>
<td>750 [29.53]</td>
<td>1.5 [0.059]</td>
<td>1.5 [0.059]</td>
</tr>
<tr>
<td>900 (36)</td>
<td>900 [35.43]</td>
<td>1.7 [0.067]</td>
<td>1.7 [0.067]</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>1050 [41.34]</td>
<td>1.8 [0.071]</td>
<td>1.8 [0.071]</td>
</tr>
<tr>
<td>1200 (48)</td>
<td>1200 [47.24]</td>
<td>1.8 [0.071]</td>
<td>1.8 [0.071]</td>
</tr>
<tr>
<td>1350 (54)</td>
<td>1350 [53.15]</td>
<td>2.0 [0.079]</td>
<td>2.0 [0.079]</td>
</tr>
<tr>
<td>1500 (60)</td>
<td>1500 [59.06]</td>
<td>2.0 [0.079]</td>
<td>2.0 [0.079]</td>
</tr>
</tbody>
</table>

*Conversions of SI units to U.S. Customary units in this table are “soft” conversions; i.e., the metric measurement is mathematically converted to its exact (or nearly exact) equivalent in inch-pound measurement.*
7.4.2. *Waterway Wall*—Minimum waterway wall thickness shall be as required in Table 1 when measured in accordance with Section 9.8.2.

7.4.3. *Length*—The pipe shall be sold in any length agreeable to the user. Length shall not be less than 99 percent of the specified length, when measured in accordance with Section 9.8.3.

7.4.4. *Encapsulation Thickness*—The minimum thickness of the HDPE encapsulation at the sides, top (outside), and bottom (inside) of the reinforcement shall be as shown in Figure 2. Factory cut pipe ends shall have the cut rib ends encapsulated to meet the requirements of Figure 2 for the top (outside) of the ribs. Encapsulation thicknesses shall be measured in accordance with Section 9.8.4.

![Figure 2](image_url)—Schematic Representation of Steel-Reinforced Thermoplastic Pipe Profile

7.5. *Perforations*—When perforated pipe is specified, the perforations shall be cleanly cut and uniformly spaced along the length and circumference of the pipe. Circular perforations shall be a minimum of 5 mm (0.2 in.) and shall not exceed 10 mm (0.4 in.) in diameter. The water inlet area shall be a minimum of 30 cm²/m (1.5 in.²/ft) for pipe sizes 300 to 450 mm (12 to 18 in.) and 40 cm²/m (2.0 in.²/ft) for pipe sizes larger than 450 mm (18 in.). All measurements shall be made in accordance with Section 9.8.5. The perforations shall be cleanly cut so as not to restrict the inflow of water. Pipe connected by bell and spigot joints may not be perforated in the area of the bells and spigots. Perforations shall be located in the waterway wall portion of the pipe between the ribs and shall not cut into encapsulation of the reinforcement, the radius between this encapsulation and the waterway wall, or the fused seam. The reinforcing steel material shall not be exposed by these perforations.

7.6. *Pipe Stiffness*—The pipe shall have minimum pipe stiffness at 5 percent deflection as listed in Table 2. Pipe stiffness shall be tested in accordance with Section 9.1.

<table>
<thead>
<tr>
<th>Nominal Inside Diameter, mm (in.)</th>
<th>Pipe Stiffness, kPa [psi]*</th>
<th>Shape Stability Limit, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 (12)</td>
<td>345 [50]</td>
<td>20</td>
</tr>
<tr>
<td>375 (15)</td>
<td>290 [42]</td>
<td>20</td>
</tr>
<tr>
<td>450 (18)</td>
<td>276 [40]</td>
<td>20</td>
</tr>
<tr>
<td>600 (24)</td>
<td>234 [34]</td>
<td>20</td>
</tr>
<tr>
<td>750 (30)</td>
<td>193 [28]</td>
<td>20</td>
</tr>
<tr>
<td>900 (36)</td>
<td>152 [22]</td>
<td>20</td>
</tr>
<tr>
<td>1050 (42)</td>
<td>140 [20]</td>
<td>20</td>
</tr>
</tbody>
</table>
Note 3—The 5 percent deflection criterion was selected for testing convenience and should not be considered as a limitation with respect to in-use deflection.

7.7. **Pipe Flattening**—There shall be no visual evidence of splitting, or cracking, or breaking when tested in accordance with Section 9.2. Additionally, there shall be no separation or delamination of the spiral seam or the rib at the top of its junction with the waterway wall of the pipe when tested in accordance with Section 9.7.

7.8. **Shape Stability**—In the flattening test described in Section 9.2, the load shall not decrease with increasing deflection until after the percentage shape stability limit tabulated for the relevant diameter (in Table 2) has been exceeded. Additionally, if the peak load is reached before 20 percent deflection, the load at 20 percent deflection shall be a minimum of 75 percent of the peak load. Shape stability limit is calculated as follows:

\[
SSL = \frac{\Delta Y}{ID} \times 100\% 
\]

where:
- \(SSL\) = shape stability limit
- \(\Delta Y\) = change in vertical deflection
- \(ID\) = inside diameter of pipe

7.9. **Impact**—There shall be no evidence of splitting, cracking, or breaking when tested in accordance with Section 9.3. Additionally, there shall be no separation of the spiral seam or the rib at its junction with the waterway wall when tested in accordance with Section 9.7.

7.10. **Tensile Strength of Seam**—There shall be no breaking or separation of the weld when tested in accordance with Section 9.4.

7.11. **Fitting Requirements**:

7.11.1. Only fittings supplied or recommended by the manufacturer shall be used. Fabricated fittings shall be supplied with joints compatible with the overall system requirements. A bell-and-spigot joint is an example of a typical design.

7.11.2. All fittings shall be within an overall length dimensional tolerance ±12 mm (0.5 in.) of the manufacturer’s specified dimensions when measured in accordance with Section 9.8.3.

7.11.3. The fittings shall not impair the overall integrity or function of the pipe.

7.11.4. Common fittings include in-line joint fittings, reducers, and branch or complementary assembly fittings such as tees and wyes. These fittings shall be installed or coupled to the pipe by various methods.

7.11.5. Fittings shall not reduce the inside diameter of the pipe being joined by more than 12 mm (0.5 in.). Reducer fittings shall not reduce the cross-sectional area of the small size diameter by more than 3 percent.

7.12. **Jointing Requirements**:
7.12.1. Pipe joints and couplings shall be bell and spigot or screw-on collar. Only couplings supplied or recommended by the manufacturer shall be used. Couplings shall be supplied with joints compatible with the overall system requirements.

7.12.1.1. Other types of couplings or fastening devices that are equally effective as those described in Section 7.12.2.1 and that comply with the soiltight joint performance criteria of the AASHTO LRFD Bridge Construction Specifications, Article 26.4.2.4, may be used when approved by the purchaser. An example of another type of coupler is a split-collar coupling, which shall match the pipe profile and shall provide sufficient longitudinal strength to preserve pipe alignment and prevent separation at the joints. Split-collar couplings shall engage at least three full ribs on each pipe section.

7.12.1.2. Internal Coupling, Sealant Type—Joint seal is affected by applying an industrial sealant between the external surface of the coupling and the internal surface of the pipe. This jointing system may be used when approved by the purchaser.

7.12.1.3. Other types of jointing methods such as flanging, internal coupling (gasket type), extrusion welding, electro-fusion, butt fusion, and others may be used when approved by the purchaser.

7.12.2. Joint Tightness—The pipe or fitting joint shall meet the requirements defined as one of the following types:

7.12.2.1. Soiltight Joints—Soiltight joints are specified as a function of opening size (maximum dimension normal to the direction that soil may infiltrate), channel length (length of the path along which the soil may infiltrate), and backfill particle size. If the size of the opening exceeds 3 mm (1/8 in.), the length of the channel must be at least four times the size of the opening. No opening may exceed 25 mm (1 in.). 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.

7.12.2.2. Silt-Tight Joints—A silt-tight joint is resistant to infiltration of particles that pass the No. 200 sieve. Silt-tight joints are specified to provide protection against infiltration of backfill material containing a high percentage of fines, and typically utilize some type of filtering or sealing component, such as an elastomeric rubber seal or geotextile wrap. Geotextile wraps are manufactured to tolerances that assure silt will not pass through them. The successful performance of these wraps in the field is dependent on their installation. If a geotextile wrap is specified for use, the material specified should meet the requirements of M 288, with an Apparent Opening Size (AOS) > 70.

For joints that utilize an elastomeric rubber seal, silt-tight performance shall have been demonstrated in a laboratory test to meet the hydrostatic requirements of ASTM D3212, with the exception that the hydrostatic test pressure shall be a minimum of 14 kPa (2 psi).

7.12.2.3. Leak-Resistant Joints—Leak-resistant joints shall be bell and spigot and utilize an elastomeric rubber seal meeting the requirements of ASTM F477. Alternative methods of joining (e.g., external joint wraps) shall be allowed provided the requirements of Section 7.12.2.3.1 are achieved.

7.12.2.3.1. Leak resistance shall be verified in the lab by meeting all of the requirements of ASTM D3212. The hydrostatic test pressure and vacuum specified in the test method shall be 74 kPa (10.8 psi).

7.12.3. Special Design Joints—Special design joints shall include joints requiring special strength in bending or shear, pull-apart capabilities, or unusual features such as restrained joints placed on severe slopes, welded joints, flanged and bolted joints for high pressures, high heads, or velocities. Watertight joints that provide zero leakage for a specified head or pressure application are included in this type of joint.
7.13. **Stub Compression Test**—Profile compression capacity in any specimen in the stub compression test shall not be less than 50 percent of the gross cross section of the steel reinforcing area times the minimum specified yield strength of the steel when tested in accordance with Section 9.9. The stub compression test, T 341, shall be a material and wall design qualification test conducted twice a year or whenever there are changes in wall design or material distribution. Computing the minimum capacity requires determining the cross-sectional area of the pipe wall. This can be accomplished conveniently by optically scanning the profile and determining the section properties using a computer drafting program.

### 8. CONDITIONING

8.1. **Conditioning**—Condition the specimen prior to test at 21 to 25°C (70 to 77°F) for not less than 24 h in accordance with Procedure A in ASTM D618 for those tests where conditioning is required, and unless otherwise specified.

8.2. **Conditions**—Conduct all tests at a laboratory temperature of 21 to 25°C (70 to 77°F) unless otherwise specified herein.

### 9. TEST METHODS

9.1. **Pipe Stiffness**—Select a minimum of two pipe specimens and test for pipe stiffness $F/\Delta y$, as described in ASTM D2412, except for the following conditions:

1. The length of the test specimen shall be a whole number of wraps, with a minimum length of four wrap widths or half the pipe diameter, whichever is greater.
2. Randomly orient each specimen in the loading machine.
3. Testing speed of the specimens shall be 12.5 mm/min (0.5 in./min) for testing up to 5 percent deflection. For flattening beyond 5 percent deflection (see Section 9.2), it is permissible to increase test speeds up to 125 mm/min (5 in./min).
4. The deflection indicator shall be readable and accurate to ±0.02 mm (0.001 in.).
5. The beginning point for deflection measurement shall be at a load of 20 ± 5 N (4.5 ± 1.1 lbf). The point shall be considered as the origin of the load deflection curve.

9.2. **Flattening**—Flatten the two pipe samples from Section 9.1 until the vertical inside diameter is reduced by 20 percent. The length of the test specimen and the rate of loading shall be the same as in Section 9.1. Examine the specimen with the unaided eye for cracking, splitting, or delamination. It is permissible for the ribs to lean during this test only to the extent that neither the above requirements nor the shape stability requirements (Section 7.8) are failed.

9.3. **Impact**—Test pipe specimens in accordance with ASTM D2444 except that six specimens shall be tested. Specimens shall be at least four wrap widths in length and impact points shall be at least 152 mm (6 in.) from the end of the specimen. Impact resistance shall not be less than 136 J. Tup B and a flat plate specimen holder shall be used. Condition the specimens for 24 h at a temperature of 0 ± 1°C (32 ± 2°F), and conduct all tests within 60 s of removal from this atmosphere.

9.4. **Tensile Strength of Seam**—Test in accordance with ASTM D638, with the following conditions:

1. The sample shall be prepared according to the dimensions for Type I specimens, with the weld seam arranged centrally and perpendicular to the tensile test axis.
2. All steel reinforcement shall be removed from the profile.
3. It is permissible to reduce the height of the HDPE ribs to no less than 2.5 mm (0.1 in.) if required to facilitate testing.

9.5. **Joint Integrity**—Assemble each fitting or coupling to the appropriate pipe in accordance with the manufacturer’s recommendations. Use pipe samples at least 300 mm (12 in.) in length. Assemble a specimen at least 600 mm (24 in.) in length with the connection at the center. Load the connected pipe and fitting between parallel plates at the rate of 12.5 mm/min (0.5 in./min) until the vertical inside diameter is reduced by at least 20 percent of the nominal diameter of the pipe. Inspect for splitting, cracking, delamination, or other damage while at the specified deflection and after load removal.

9.6. **Slow Crack Growth Resistance of Resin Compounds**—Test basic resin compounds for stress crack resistance in accordance with the ASTM F2136, the NCLS test, except for the following modifications:

9.6.1. The applied stress for the NCLS test shall be 4100 kPa (600 psi).

9.6.2. Resin test specimens shall be plaques molded from the reground resin from the rotomolded or injection-molded parts.

**Note 4**—The notched depth of 20 percent of the nominal thickness of the specimen is critical to this procedure.

9.7. **Delamination**—Test the fusion of the weld between the inner and outer wall of the wrap width with a probe or knife point. It shall not be possible to separate cleanly the two walls at the lap seam weld. Test samples at eight equally spaced points around its circumference.

9.8. **Dimensions**:

9.8.1. **Inside Diameter**—Measure the inside diameter of three specimens, each a minimum of 300 mm (12 in.) long with any suitable device accurate to 0.8 mm (0.03 in.), at two positions, namely, any point in the circumferential direction and 90 degrees from this point, and average the six measurements. Inside diameter shall meet the requirements of Section 7.4.1.

9.8.2. **Waterway Wall**—Locate and measure the wall thickness between the ribs at four equally spaced locations around the circumference of the pipe, in accordance with ASTM D2122.

9.8.3. **Length**—Measure pipe with any suitable device accurate to ±6.0 mm in 3 m (±0.25 in. in 10 ft). Make all measurements on the pipe while it is resting on a relatively flat surface, in a straight line, with no external tensile or compressive forces exerted on the pipe. These measurements may be taken at ambient temperatures.

9.8.4. **Encapsulation Thickness**—Locate and measure the encapsulation thickness by cutting a cross section and measuring in accordance with ASTM D2122.

9.8.5. **Perforations**—Measure dimensions of perforations on a straight profile specimen with no external forces applied. Make linear measurements with instruments accurate to 0.2 mm (0.08 in.).

9.9. **Stub Compression Capacity**:

9.9.1. Determine the stub compression capacity of the pipe section in accordance with T 341. Conduct four tests on specimens cut from the same ring of pipe at 90-degree intervals around the circumference.
10. **INSPECTION AND RETEST**

10.1. *Inspection*—Inspection of the material shall be made as agreed on by the purchaser and the seller as part of the purchase contract.

10.2. *Retest and Rejection*—Retesting in the event of a test failure shall be conducted on samples from the failed lot only under an agreement between purchaser and seller. There shall be no changes to the test procedures or the requirements.

11. **MARKING**

11.1. *All pipe shall be clearly marked at intervals of no more than 3.5 m (11.5 ft) as follows:*

11.1.1. Manufacturer’s name or trademark.

11.1.2. AASHTO MP 20.

11.1.3. Nominal inside diameter.

11.1.4. The plant designation code.

11.1.5. The date and location of manufacture or an appropriate production code. If a date code is used, a durable manufacturer sticker that identifies the actual date of manufacture shall be adhered to the inside of each length of pipe.

*Note 5*—A durable sticker is one that is substantial enough to remain in place and be legible through installation of the pipe.

11.2. Fittings shall be marked with the designation number of this specification, AASHTO MP 20, and with the manufacturer’s identification symbol.

12. **QUALITY ASSURANCE**

12.1. A manufacturer’s certificate that the product was manufactured, tested, and supplied in accordance with this specification, together with a report of the test results and the date each test was completed shall be furnished on request. Each certification so furnished shall be signed by a person authorized by the manufacturer.

13. **KEYWORDS**

13.1. Crack; crease; delamination; gravity flow.

**APPENDIX**

(Nonmandatory Information)

**X1. QUALITY CONTROL/QUALITY ASSURANCE PROGRAM**

X1.1. *Scope:*
X1.1.1. As required in Sections 10 and 12, the acceptance of these products relies on the adequate inspection and certification agreed to between the buyer and the seller/manufacturer. This appendix should serve as a guide for both the manufacturer and the user. It places the responsibility on the manufacturer to control the quality of the material they produce and to provide the quality control.

X1.2. *Program Requirements:*

X1.2.1. The manufacturing company must have a quality control plan approved by the specifying agency.

X1.2.2. The manufacturing plant must have an approved quality control plan.

X1.2.3. The plant must have an approved laboratory, either within the company or an independent laboratory.

X1.2.4. The manufacturing plant(s) must have a designated quality control technician.

X1.3. *Quality Control Plan:*

X1.3.1. The manufacturer must supply to the specifying agency a written quality control plan that shows how the producer will control the equipment, materials, and production methods to ensure that the specified products are supplied. The following information must be included in the plan:

X1.3.1.1. Titles of the personnel responsible for production quality at the plant(s).

X1.3.1.2. The physical location of the plant(s).

X1.3.1.3. The methods of identification of each lot of material during manufacturing, testing, storage, and shipment. The method of identification shall allow the specifying agency to trace the finished product to the material provider.

X1.3.1.4. The method of sampling and testing of raw materials and of finished product, including lot sizes and types of tests performed.

X1.3.1.5. A plan for dealing with nonconforming product, including how the manufacturer plans to initiate immediate investigation and how corrective action will be implemented to remedy the cause of the problem.

X1.4. *Approved Laboratory:*

X1.4.1. All tests must be conducted at laboratories approved by the specifier. Each manufacturer may establish and maintain its own laboratory for performance of quality control testing or may utilize an approved independent laboratory. Records of instrument calibration and maintenance and sample collection and analysis must be maintained at the laboratory.
X1.5. Quality Control Technician:

X1.5.1. All samples must be taken and tested by quality control technicians designated by the manufacturer. The designated quality control technicians will be responsible for overall Quality Control at the manufacturing plant.

X1.6. Annual Update:

X1.6.1. An annual update may be required. The annual update may be submitted by the manufacturer to the specifying agency by December 31st of each calendar year.

X1.7. Plant Approval:

X1.7.1. The plant approval process requires the manufacturer to submit an annual update to the specifying agency. The update must identify the specific product manufactured at the plant.

X1.7.2. The specifying agency will review the manufacturer’s written quality control plan, and a plant inspection may be scheduled. This inspection will verify that the quality control plan has been implemented and is being followed and that at least one designated quality control technician is on-site and will be present when material is being produced under this program. The laboratory will be inspected and approved if it meets the requirements.

X1.8. Sampling and Testing:

X1.8.1. The quality assurance plan approved for each manufacturer, or manufacturer’s location, or both, shall detail the methods and frequency of sampling and testing for all raw materials and products purchased or manufactured at that location. All testing shall be in accordance with current specifications and procedures referenced in MP 20.

X1.8.2. Samples of materials and pipe may be taken by the specifying agency.

X1.8.3. The specifying agency may require an annual third-party independent assurance test.

X1.9. Sample Identification and Record Keeping:

X1.9.1. Manufacturer’s quality control samples are to be uniquely identified by the producing plant.

X1.9.2. Quality control and quality assurance data are to be retained by the manufacturer for 2 years and made available to the specifying agency on request.

X1.9.3. Quality control test reports shall include the lot identification.

X1.9.4. Unless requested at the time of ordering, test reports do not have to be filed for specific projects.
X1.9.5. Reports shall indicate the action taken to resolve nonconforming product.

1 This provisional standard was first published in 2010.
NCHRP Project 4-39 – Field Performance of Corrugated HDPE Pipes Manufactured with Recycled Content

AASHTO Technical Section 4B – Flexible and Metallic Pipe
Subcommittee on Materials
Phoenix, AZ
August 8, 2017

Michael Pluimer, PhD – Co-PI
Crossroads Engineering Services, LLC

Acknowledgements

TRI/Environmental
- Joel Sprague, PE – Co-PI; Rick Thomas, M.S.; Mario Paredes, PE; David Cuttino; Jay Sprague

Villanova University
- Leslie McCarthy, PhD, PE; Andrea Welker, PhD, PE; Eric Musselman, PhD; Jeffrey Cook

E.L. Robinson – Kevin White, PE

Ohio University
- Shad Sargand, PhD; Ehab Shaheen, Student
Acknowledgements

- NCHRP Panel
  - Cecil Jones, PE - Chair; Diversified Engineering Services, Inc.
  - Michael Fleming, PE; Washington DOT
  - Jon Griffith, PE; Georgia DOT
  - Dan Miller, PE; Ohio DOT
  - Victoria Woods, PE; Missouri DOT (Ingevity)
  - Dan Currence, PE; PPI
  - Carl Douglass, PE; DI Labs
  - Jim Goddard; JG3, LLC
- NCHRP Staff
  - Ed Harrigan, PhD – Senior Program Officer
  - Anthony Avery, PhD – Senior Prog. Assistant

Outline

- Background Information
- Key findings of NCHRP 4-39
  - UCLS test
  - Service life model
  - Railroad study
- Material recommendations
  - M294 revisions
  - Standard Recommended Practice for Service Life
- Summary and Conclusions
Project purpose was to evaluate the field performance of corrugated HDPE pipes manufactured with recycled materials – follow-up to 4-32

Both post-consumer (PCR) and post-industrial (PIR) recycled materials evaluated, but focus on post-consumer

Included both field and lab testing, as well as the development and validation of a service life prediction model

Resulted in the first true performance-based specification for thermoplastic pipes

Evaluated 28 different recycled resins (25 PCR, 3 PIR), 75 different blends of virgin and recycled materials, and 24 full-scale pipes (4 different manufacturers) manufactured with various blends of recycled materials

Service life model validated on 9 full-scale pipes containing a range of recycled material blends

Over 1000 different tests conducted

11 years of research (contract started in Feb. 2006), project budget of $950,000 ($350K for NCHRP 4-32, $600K for NCHRP 4-39)
Overview of Recycled Materials for Corrugated HDPE Pipe

- Post-industrial recycled (PIR) materials (pre-consumer)
  - UL Definition: “Material diverted from the waste stream during a manufacturing process that has never reached the end user.”
  - May include reject parts, regrinds, defective parts, etc. from another manufacturer

- In-plant regrind materials
  - Scrap or out-of-spec parts
  - Scrap materials from start-up

Overview of Recycled Materials for Corrugated HDPE Pipe

- Post-consumer recycled (PCR) PE materials
  - PE materials from products that have served a previous consumer purpose
  - Flake or reprocessed pellets
  - More readily available than PIR materials and more consistent in performance, though may have lower stress crack resistance
  - Approx. 5.5 billion pounds of these materials in agricultural and land drainage pipes over past 20 years!
Crack Initiation and Propagation

Creep:
\[ t_{CCG} = t_{CI} + t_{CP} \]

Fatigue:
\[ N_{FGG} = N_{GI} + N_{CP} \]

SCG Evaluation

Notched Tests

\[ t_{SCG} = t_{CI} + t_{CP} \]

where
- \( t_{SCG} \) = total time for slow crack growth
- \( t_{CI} \) = time for crack initiation
- \( t_{CP} \) = time for crack propagation
Constant Stress Testing – A New Test Method – UCLS Test

Invented to assess the crack initiation phase as well as the crack growth phase

Based on “BFF” test developed by Rick Thomas - NCHRP Report 696

Conducted in DI water at elevated temperatures

UCLS Test

<table>
<thead>
<tr>
<th>Description</th>
<th>Dimension and Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO – Overall length</td>
<td>≥ 170</td>
</tr>
<tr>
<td>L – Length of narrow section</td>
<td>57 ± 0.5</td>
</tr>
<tr>
<td>D – Distance between taper</td>
<td>100 ± 1</td>
</tr>
<tr>
<td>R – Radius of fillet</td>
<td>76.2 ± 1</td>
</tr>
<tr>
<td>G – Gage length</td>
<td>50.8 ± 0.3</td>
</tr>
<tr>
<td>WO – Overall width</td>
<td>19 ± 6</td>
</tr>
<tr>
<td>W – Width of narrow section</td>
<td>13 ± 0.5</td>
</tr>
<tr>
<td>TO – Overall thickness</td>
<td>≥ 2.3</td>
</tr>
<tr>
<td>T – Thickness of test section</td>
<td>1 ± 0.1</td>
</tr>
<tr>
<td>HC – Distance to hole center</td>
<td>9.5 ± 0.5</td>
</tr>
<tr>
<td>DH – Hole diameter</td>
<td>5.6 ± 0.5</td>
</tr>
</tbody>
</table>
NCLS vs. UCLS

Notched specimens, 2.5 in. long, 0.075 in. thick
Tested in 10% Igepal solution at 50 deg. C, 600 psi stress

Un-Notched specimens, 6.5 in. long, 0.040 in. thick
Tested in DI water at 80 deg. C, 650 psi stress

Predicting Service Life Relative to Brittle Cracking with the UCLS Test

Conduct UCLS test in water at at least 3 different temperature / stress conditions (E.G. 80 deg. C / 650 psi; 80 deg. C / 450 psi; 70 deg. C / 650 psi)

Use Popelar Shift Method (PSM) or Rate Process Method (RPM) to shift data from test temperature and stress to service temperature and stress:

**Popelar Shift Method:**

- Stress Shift Factor: $e^{0.0116(T2-T1)}$
- Time Shift Factor: $e^{0.109(T2-T1)}$

**Rate Process Method:**

$$\log t = A + \frac{B}{T} + C \frac{\log S}{T}$$
Illustration of Service Life Prediction
Pipe 4 – 49% PCR – UCLS Data

\[
SSF = e^{0.0116(T2-T1)}
\]

\[
TSF = e^{0.109(T2-T1)}
\]

Data point shifted to 23 deg. C

23 Deg. C Mastercurve

Illustration of Service Life Prediction
Pipe 4 – 49% PCR
UCLS Data Shifted to 23 deg. C

\[
y = -0.2175x + 4.1196 \quad R^2 = 0.9936
\]

500 psi

234 yrs.
Illustration of Service Life Prediction
Pipe 3 – Custom 98% PCR Pipe
UCLS Data Shifted to 23 deg. C

Model Validation
Model Validation – Constant Deflection Laboratory Test

- Full-scale 750 mm (30-in.) diameter pipes held at 20% deflection
- Laboratory temperature 23 deg. C
- Constant STRAIN test (vs. Constant STRESS in UCLS)

A = 35 in.; B = 30 in.; C = 24 in.

Simulated Field Test
Strain Analysis

- Peak local strain at 20% deflection = 3.75%
- Peak tensile strain in simulated field test on buried pipes = 3.5%

Equivalent Average Stress Determination

\[
\bar{\sigma}_{PP} = \frac{10^{1.6}}{10^{0.830}} = 1637 \text{ psi}
\]

\[
\bar{\sigma}_{Buried} = \frac{10^{1.6}}{10^{0.830}} = 1528 \text{ psi}
\]
Illustration of Service Life Prediction
Pipe 4 – 49% PCR
UCLS Data Shifted to 23 deg. C

Illustration of Service Life Prediction
Pipe 3 – Custom 98% PCR Pipe
UCLS Data Shifted to 23 deg. C
### Full Scale Pipe Validation Testing in Accelerated Loading Conditions

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Description</th>
<th>PCR</th>
<th>Predicted Time to Cracking</th>
<th>Actual Time to First Cracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe 1</td>
<td>30 in. M294 pipe</td>
<td>0%</td>
<td>&gt; 2 yrs.</td>
<td>&gt; 1 yr. - No cracks</td>
</tr>
<tr>
<td>Pipe 2</td>
<td>30 in. F2648 pipe</td>
<td>49%</td>
<td>&gt; 2 yrs.</td>
<td>&gt; 1 yr. - No cracks</td>
</tr>
<tr>
<td>Pipe 3</td>
<td>30 in. Custom pipe</td>
<td>98%</td>
<td>58 – 148 days</td>
<td>101 days</td>
</tr>
<tr>
<td>Pipe 4</td>
<td>30 in. F2648 pipe</td>
<td>49%</td>
<td>1.4 – 3.1 yrs.</td>
<td>&gt; 1 yr. - No cracks</td>
</tr>
<tr>
<td>Pipe 5</td>
<td>30 in. M294 pipe</td>
<td>0%</td>
<td>&gt; 2 yrs.</td>
<td>&gt; 1 yr. - No cracks</td>
</tr>
<tr>
<td>Pipe 6</td>
<td>30 in. Custom pipe</td>
<td>98%</td>
<td>71 – 220 days</td>
<td>185 days</td>
</tr>
<tr>
<td>Pipe 7</td>
<td>30 in. Custom pipe</td>
<td>98%</td>
<td>73 – 172 days</td>
<td>185 days</td>
</tr>
<tr>
<td>Pipe 8</td>
<td>30 in. F2648 pipe</td>
<td>54%</td>
<td>203 - 578 days</td>
<td>&gt; 306 d - No cracks</td>
</tr>
<tr>
<td>Pipe 9</td>
<td>30 in. F2648 pipe</td>
<td>59%</td>
<td>139 – 357 days</td>
<td>300 days</td>
</tr>
</tbody>
</table>

### Cracking in Pipe 3 – Custom 98% PCR Pipe
Highlights of Service Life Prediction Method

- Every pipe that was predicted to crack developed cracks within the predicted timeframe, both for the parallel plate test and the simulated field test.
- None of the pipes that were not predicted to crack developed cracks.
- Based on these test results, the service life prediction model based on the UCLS test was validated.
- The UCLS test provides the basis for a true performance-based specification for pipes manufactured with recycled materials.

3-Year Evaluation under Heavy Rail Loads

- Virgin and PCR 750 mm (30 in.) diameter pipes with bell and spigot watertight joint.
- 0.6 m (2.0 ft.) of cover to bottom of tie.
- Pipes instrumented with strain gages and extensometers.
3-Year Evaluation under Heavy Rail Loads

December Data Collection
Pipe 1 (virgin) Historical Performance

Pipe 2 (recycled) Historical Performance
Dynamic Wall Strain Comparison

Fatigue Evaluation
Fatigue Evaluation

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Spec.</th>
<th>PCR, %</th>
<th>Dynamic Grip Displacement, mm (in.)</th>
<th>Peak-Peak Dynamic Strain, microstrain</th>
<th>Number of Cycles, millions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-1</td>
<td>0</td>
<td>+/- 0.05 (0.002)</td>
<td>1200</td>
<td>1.0</td>
<td>No cracking</td>
</tr>
<tr>
<td>2</td>
<td>2-1</td>
<td>49</td>
<td>+/- 0.05 (0.002) +/- 0.13 (0.005)</td>
<td>1200 – 1st million 2700 – 2nd million</td>
<td>2.0</td>
<td>No cracking</td>
</tr>
<tr>
<td>4</td>
<td>4-1</td>
<td>49</td>
<td>+/- 0.05 (0.002)</td>
<td>1200</td>
<td>6.4</td>
<td>No cracking</td>
</tr>
<tr>
<td>4</td>
<td>4-1</td>
<td>49</td>
<td>+/- 0.05 (0.002)</td>
<td>1200</td>
<td>10.0</td>
<td>No cracking</td>
</tr>
</tbody>
</table>

Results of Railroad Field Study

- Specimens fatigue tested to 10 million cycles with no fatigue-related damage
- No significant difference in performance between virgin and recycled pipes
Deliverables

- Draft revisions to M294 were developed to include the incorporation of corrugated HDPE pipes manufactured with recycled content.
- Draft revisions to AASHTO Bridge Design Specifications to include material properties for pipes manufactured with recycled materials.
- An ASTM test method was developed for the UCLS test.
- An AASHTO Standard Recommended Practice was developed for establishing the service life of corrugated HDPE pipes manufactured with recycled content and for determining the minimum UCLS criteria to ensure the desired service life is met.

Proposed M294 Revisions

8.6. MATERIALS

8.1.6.1. Basic Materials:

6.1.1. Extruded Pipe and Blow Molded Fittings—Pipe and fittings shall be made of virgin and/or recycled virgin PE resin compounds meeting the requirements of ASTM D3359 and cell classification 41540C, except that the carbon black content shall not exceed 4.0 percent. The cell classification shall be based on the virgin PE resin compounds without carbon black. Resins that have higher cell classifications in one or more properties, with the exception of density, are acceptable provided product requirements are met. For slow crack growth resistance, the requirements in 6.1.1.1 and 6.1.1.2 shall be met.

6.1.1.1. acceptance of resins shall be determined by using the notched constant ligament stress (NCLS) test according to the procedure described in Section 9.4. For slow crack growth resistance, acceptance of pipes shall be determined by test. To ensure adequate resistance to SCC propagation, NCLS testing shall be conducted on specimens taken either directly from the finished pipe legs or from ground-up pieces of pipe that have been compression-molded into a plaque. To the finished pipe using the NCLS test. Testing shall be conducted in accordance with ASTM F2130 and the procedures described in Section 9.4.
6.1.1.1. If testing is conducted on specimens taken directly from the finished pipe inner liner, the average failure time of the pipe liner of five specimens shall not be less than 18 h.

6.1.1.2. If testing is conducted on specimens taken from ground up pieces of pipe that have been compression molded into a plaque, if profile geometries do not have a flat portion of sufficient length to produce an NCLS tensile specimen of 23 mm (1 in.) length, usually 15 in. diameter or less, the pipe sample shall be ground and a test plaque made in accordance with ASTM D5709. Procedure C at a cooling rate of 1.5°C/min (27°F/min) and tested per ASTM F2136. The average failure time of five test specimens from plaques shall not be less than 24 h.

6.1.2. For pipes manufactured with recycled materials, UCLS testing shall be conducted in accordance to ASTM F3181 and Section 9.4 to ensure the desired service life is met. The minimum UCLS failure time shall be prescribed based on the service conditions (temperature and factored design stress) and desired service life as detailed in A2 of the Annex. In the absence of design data, a service life of 100 years at a service temperature of 23 deg. C and factored tensile design stress of 580 psi shall be conservatively assumed. For this condition, the average UCLS failure time for five specimens shall not be less than 14 hrs, with no single specimen failing in less than 18 hrs.

6.1.1.3. Pipes manufactured from recycled materials shall have an Oxidation Induction Time (OIT) of 20 minutes when tested in accordance to ASTM D3895 and a break strain of 150% when tested in accordance to ASTM D638. Density of pipe compounds containing recycled materials should be conducted by the ultrasound technique in accordance with ASTM D4883 since ultrasonic density is not affected by colorants and other inorganic compounds that may be present in these materials.
Proposed M294 Revisions (Cont’d)

Using Equation A2.1, calculate the minimum UCLS failure time \( t \) at the 80 deg. C / 650 psi stress test condition to ensure the desired service life (\( f_{svc} \), yrs.) at the given service conditions (i.e., service stress (\( \sigma_{svc} \), psi) and service temperature (\( T \), deg. C)):

\[
t = \left( \frac{9766 - \sigma_{svc}}{SF_t} \right)^5 \frac{(\sigma_{svc})^5}{650 - SF_{st}}
\]

(Eqn. A2.1)

where

\( t \) = Minimum required average failure time at 80 deg. C, 650 psi condition, hrs.

\( SF_t \) = Popolar time shift factor = \( e^{(0.39(90 - T))} \)

\( SF_{st} \) = Popolar stress shift factor = \( e^{(0.39(650 - SF_{st}))} \)

\( T \) = Service temperature, deg. C

\( \sigma_{svc} \) = Design service stress, psi

\( f_{svc} \) = Required service life at service conditions, yrs.

AASHTO Bridge Specification
Revisions – Section 12.12.3.3-1

Appendix K – Proposed Revisions to
AASHTO LRFD Bridge Specifications for
Recycled Materials Incorporation

The following changes are recommended to Table 12.12.3.3-1 of the AASHTO LRFD Bridge Design Specifications:

<table>
<thead>
<tr>
<th>Type of Plan</th>
<th>Maximum Allowable Service Stress (psi)</th>
<th>Service Life (yrs.)</th>
<th>Table 12.12.3.3-1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fc, min (ksi)</td>
<td>Fc, min (ksi)</td>
<td>Fc, min (ksi)</td>
</tr>
<tr>
<td>Flexural</td>
<td>130</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>Compressive</td>
<td>180</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>Ultra High Performance</td>
<td>220</td>
<td>190</td>
<td>160</td>
</tr>
</tbody>
</table>
Standard Recommended Practice for Service Life Determination

- Details procedure for determining the service life of corrugated HDPE pipes manufactured with recycled materials.
- Provides equations to determine the minimum UCLS requirements to ensure service life at given conditions.

Determining Minimum UCLS

\[ t_T = \frac{10^C}{SF_t} \]

where

\[ C = \left[ \frac{\log(SF_\sigma \cdot \sigma_T) - \log(\sigma_{SVC})}{m} \right] + \log(t_{SVC}) \]

- \( t_T \) = time to failure @ test cond., hrs.
- \( m \) = slope of brittle curve
- \( SF_\sigma \) = Stress shift factor
- \( SF_t \) = Time shift factor
- \( t_{SVC} \) = service life, hrs.
- \( \sigma_{SVC} \) = design stress at service cond., psi
- \( \sigma_T \) = stress at UCLS test condition, psi
Summary and Conclusions

- Corrugated HDPE pipes have been manufactured with recycled materials and used in land drainage and private applications for over 40 years.

- The purpose of this research project was to evaluate the use of recycled materials in corrugated HDPE pipes for state DOT highway applications due to the sustainability and cost benefits associated with these materials.

- NCHRP Projects 4-32 and 4-39 were approved for this research and budgeted for $950,000; the research spanned 11 years.

- The research resulted in the development of the first true performance-based specification for plastic pipes.
Summary and Conclusions

- Based on this research, it is recommended that recycled materials be incorporated into AASHTO M294 provided the final blends meet the current cell class and NCLS requirements; In addition, they must meet minimum UCLS, OIT and break strain requirements.

- Fatigue due to live loads is not a concern for corrugated HDPE pipes manufactured with or without PCR materials.

- The UCLS test is the basis for a performance-based specification for corrugated HDPE pipes manufactured with recycled content and is effective at predicting the service life of these pipes relative to Stage II SCG failures.
Steel Reinforced Polyethylene Corrugated Pipe – Materials and Design Method

American Association of State Highway Transportation Officials
Subcommittee on Materials, Technical Section 4b
August 8, 2017
Overview

• Introduction
  • ASTM F2435, Composite structure, bell and spigot, pipe stiffness

• Utah State Soil Cell Testing

• Structural Design Analysis
  • CANDE setup, mesh plot and assumptions
  • Material Design Properties
  • Design Criteria – Steel
  • Design Criteria – HDPE
    • Longitudinal Strain

• Burial Depth Table

• Future AASHTO Activities
Introduction

- Steel Reinforced Polyethylene (PE) Corrugated Pipe.
  - Meets the requirements of ASTM F2435-15.
  - Scope of ASTM standard specifies: “The steel reinforced polyethylene corrugated pipes governed by this standard are intended for use in non-pressure applications for sanitary sewers, storm sewers and drainage pipes.”
  - Product used globally for about 30-years.
Typical Pipe Corrugation Profile

• Steel Reinforced Polyethylene (PE) Corrugated Pipe.
  • ASTM Standard for materials specifies the following:
  • HDPE shall have a minimum Cell Class of 333430C. Slow crack growth resistance of 41 hours with no failures, when tested at 600 psi.
  • Steel Reinforcement shall conform to Specification A1008/A1008M or A653/A653M, and the minimum yield strength of the steel sheet shall not be less than 24.66 ksi (170 MPa). (Note: the product analyzed in this presentation used steel with a 52 ksi yield stress).
  • Pipe diameters range from 8-inch to 80” diameter However 12-inch to 72-inch is currently manufactured in the U.S.)
Bell and Spigot

- Pipe joint is watertight
  - All testing performed according to ASTM D3212. (Note: these joints exceed 20 psi)
- Bell and spigot are over molded onto the pipe.
- Gaskets are required to meet ASTM F477.
Pipe Stiffness

- Two types are available with two pipe stiffness's.
  - Type I: Constant pipe stiffness of 58 psi pipe stiffness
  - Type IV: Variable pipe stiffness ranging from 58 psi to 15 psi.

**TABLE 1 Dimensions and Pipe Stiffness for Single-Wall Pipe and Double-Wall Pipe – Type I (V-shaped profile)**

<table>
<thead>
<tr>
<th>Nominal Size</th>
<th>Inside Diameter (inch)</th>
<th>Outside Diameter (inch)</th>
<th>Pitch (inch)</th>
<th>Waterway Wall Thickness (inch)</th>
<th>Minimum Steel Thickness (inch)</th>
<th>Minimum Pipe Stiffness (psi)</th>
<th>Minimum Pipe Stiffness (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>200</td>
<td>8.0</td>
<td>203</td>
<td>9.1</td>
<td>213.1</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>10.0</td>
<td>254</td>
<td>10.95</td>
<td>278.1</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
<td>12.0</td>
<td>305</td>
<td>13.12</td>
<td>332.2</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>16</td>
<td>450</td>
<td>18.0</td>
<td>457</td>
<td>19.58</td>
<td>497.3</td>
<td>2.63</td>
<td>66.8</td>
</tr>
<tr>
<td>24</td>
<td>600</td>
<td>24.0</td>
<td>610</td>
<td>26.56</td>
<td>674.6</td>
<td>3.42</td>
<td>86.9</td>
</tr>
<tr>
<td>28</td>
<td>700</td>
<td>28.0</td>
<td>711</td>
<td>30.85</td>
<td>783.6</td>
<td>3.85</td>
<td>97.8</td>
</tr>
<tr>
<td>32</td>
<td>800</td>
<td>32.0</td>
<td>813</td>
<td>35.11</td>
<td>891.8</td>
<td>4.25</td>
<td>108.0</td>
</tr>
<tr>
<td>36</td>
<td>900</td>
<td>36.0</td>
<td>914</td>
<td>39.4</td>
<td>1000.8</td>
<td>4.68</td>
<td>124.0</td>
</tr>
<tr>
<td>40</td>
<td>1000</td>
<td>40.0</td>
<td>1016</td>
<td>47.2</td>
<td>1198.9</td>
<td>6.69</td>
<td>169.9</td>
</tr>
<tr>
<td>45</td>
<td>1125</td>
<td>44.0</td>
<td>1118</td>
<td>51.73</td>
<td>1313.9</td>
<td>7.48</td>
<td>190.0</td>
</tr>
<tr>
<td>48</td>
<td>1200</td>
<td>48.0</td>
<td>1219</td>
<td>56.42</td>
<td>1432.1</td>
<td>6.07</td>
<td>205.0</td>
</tr>
<tr>
<td>54</td>
<td>1375</td>
<td>54.0</td>
<td>1372</td>
<td>63.12</td>
<td>1603.2</td>
<td>8.65</td>
<td>224.8</td>
</tr>
<tr>
<td>61</td>
<td>1525</td>
<td>61.0</td>
<td>1524</td>
<td>70.41</td>
<td>1758.4</td>
<td>9.25</td>
<td>235.0</td>
</tr>
<tr>
<td>67</td>
<td>1675</td>
<td>67.0</td>
<td>1676</td>
<td>76.4</td>
<td>1940.6</td>
<td>9.25</td>
<td>235.0</td>
</tr>
<tr>
<td>73</td>
<td>1825</td>
<td>73.0</td>
<td>1829</td>
<td>82.98</td>
<td>2107.7</td>
<td>9.25</td>
<td>235.0</td>
</tr>
<tr>
<td>80</td>
<td>2000</td>
<td>80.0</td>
<td>2002</td>
<td>91.25</td>
<td>2317.8</td>
<td>9.25</td>
<td>235.0</td>
</tr>
</tbody>
</table>

**TABLE 4 Dimensions and Pipe Stiffness for Single-Wall Pipe and Double-Wall Pipe – Type IV (V-shaped profile)**

<table>
<thead>
<tr>
<th>Nominal Size</th>
<th>Inside Diameter (inch)</th>
<th>Outside Diameter (inch)</th>
<th>Pitch (inch)</th>
<th>Waterway Wall Thickness (inch)</th>
<th>Minimum Steel Thickness (inch)</th>
<th>Minimum Pipe Stiffness (psi)</th>
<th>Minimum Pipe Stiffness (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>200</td>
<td>8.0</td>
<td>203</td>
<td>9.1</td>
<td>213.1</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>10.0</td>
<td>254</td>
<td>10.95</td>
<td>278.1</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>12</td>
<td>300</td>
<td>12.0</td>
<td>305</td>
<td>13.12</td>
<td>332.2</td>
<td>2.16</td>
<td>54.9</td>
</tr>
<tr>
<td>15</td>
<td>375</td>
<td>15.0</td>
<td>381</td>
<td>16.3</td>
<td>413.0</td>
<td>2.36</td>
<td>60.0</td>
</tr>
<tr>
<td>20</td>
<td>450</td>
<td>18.0</td>
<td>457</td>
<td>19.3</td>
<td>489.0</td>
<td>2.44</td>
<td>62.0</td>
</tr>
<tr>
<td>24</td>
<td>600</td>
<td>24.0</td>
<td>610</td>
<td>25.7</td>
<td>653.0</td>
<td>2.76</td>
<td>76.0</td>
</tr>
<tr>
<td>30</td>
<td>750</td>
<td>30.0</td>
<td>762</td>
<td>32.2</td>
<td>817.0</td>
<td>3.54</td>
<td>100.0</td>
</tr>
<tr>
<td>40</td>
<td>900</td>
<td>36.0</td>
<td>915</td>
<td>38.2</td>
<td>970.0</td>
<td>3.94</td>
<td>129.0</td>
</tr>
<tr>
<td>48</td>
<td>1200</td>
<td>48.0</td>
<td>1220</td>
<td>52.0</td>
<td>1320.0</td>
<td>6.30</td>
<td>180.0</td>
</tr>
<tr>
<td>60</td>
<td>1500</td>
<td>60.0</td>
<td>1524</td>
<td>65.2</td>
<td>1650.0</td>
<td>7.68</td>
<td>235.0</td>
</tr>
</tbody>
</table>
Soil Cell Testing Results

• 24” Diameter pipe tested in soil cell
  • Two embedment soils were used for testing
    • Class I (Crushed Stone) Compacted to 95%
    • Class III (Silty Sand) Compacted to 75%
  • Class I maximum soil pressure equivalent to 102 feet of cover and vertical deflection of 0.82% with no visible sign of structural destress.
  • Class III maximum soil pressure equivalent to 32 feet of cover and vertical deflection of 18.5% with buckling near the springline.
Interior of pipe at maximum loading buckling seen on both sides slightly above spring line.
Buckling seen from the outside of the pipe.
Structural Design Analysis
Structural Design Analysis

• Structural design analysis evaluated corrugated pipe structure as outlined in the following slides.

• Design team included:
  • Dr. Michael Katona and
  • Tim Toliver, P.E.

• Design analysis was based on:
  • CANDE FEA and Analytical methods.

• Design Objective:
  • Determine maximum allowable burial depths with a variety of embedment materials in embankment conditions.
General Scope of Design Study

- Evaluate the structure response to loading with Culvert Analysis and Design (CANDE) FEA.
- 9 pipe diameters 12” – 60” manufactured in accordance with ASTM F2435
- Embankment Installation
- Utilize the AASHTO LRFD criteria
- Evaluate 10 embedment materials summarized in the table below:

<table>
<thead>
<tr>
<th>ASTM D2321</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>compacted</td>
<td>uncompacted</td>
<td>95%</td>
<td>90%</td>
<td>85%</td>
</tr>
<tr>
<td>CANDE Analysis</td>
<td>SW 100</td>
<td>SW 95</td>
<td>SW 90</td>
<td>SW 85</td>
</tr>
<tr>
<td></td>
<td>SW 90</td>
<td>ML 90</td>
<td>ML 85</td>
<td>CL 90</td>
</tr>
</tbody>
</table>

Notes: (1) Class IV is not recommended unless it is installed under the direction of a soils engineer to ensure proper placement and compaction. It is noted that the compaction densities used in the analysis are 5% lower than the corresponding ASTM D2321 values. This lower density is intended to compensate for contractor error associated with the difficulty of achieving proper compaction for these types of soils.
Background

• Corrugated Steel Reinforced Corrugated Polyethylene Pipe
  • HDPE bonded to steel
  • Helical corrugation pattern
  • Diameter range from 12” to 60”
  • Typical corrugation patterns are shown
The key assumption:

• Steel and plastic components work in tandem to resist bending and hoop deformation.

• CANDE model defined with two circular pipe groups which are assigned the same set of nodes tracing the pipe’s circumference:
  • one representing HDPE plastic; and
  • one representing steel.

• Both pipe groups undergo the same kinematic deformations.

• Resistance is generated in proportion to material and sectional stiffness.
Typical Mesh Plot and Setup
Material Properties

- Material properties are shown in the table below

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s Modulus (psi)</th>
<th>Yield Stress (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>29,000,000</td>
<td>52,000</td>
</tr>
<tr>
<td>HDPE</td>
<td>22,000</td>
<td>900</td>
</tr>
</tbody>
</table>

**Note:**
1. Standard AASHTO values for long-term loading were used for deep burial
2. Yield Stress for the steel was measured from actual tensile test specimens
Typical Pipe Section Properties
(24” pipe diameter)

Steel pipe section properties
Area = 0.0337 in^2/in
Moment of Inertia = 0.00247 in^4/in

Plastic pipe section properties
Area = 0.3236 in^2/in
Moment of Inertia = 0.0105 in^4/in
# Steel Pipe Design Criteria

<table>
<thead>
<tr>
<th>Design Criterion (Strength limits)</th>
<th>Factored Demand (Load factor = 2.05)</th>
<th>Factored Capacity (Resistance factors = 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) <strong>Thrust stress</strong> (psi)</td>
<td>$\sigma_{\text{max}} &lt; f_y$</td>
<td>$f_y = \text{yield strength} = 52,000 \text{ psi}$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{max}} = \text{maximum thrust in steel circumference.}$</td>
<td></td>
</tr>
<tr>
<td>(2) <strong>Global Buckling</strong> (psi)</td>
<td>$\sigma_{\text{max}} &lt; f_b$</td>
<td>$f_b = \text{buckling capacity, via AASHTO Eq. 12.7.2.4-1&amp;2}$</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{max}} = \text{maximum thrust in steel circumference.}$</td>
<td></td>
</tr>
<tr>
<td>Performance Limits (at Service Load)</td>
<td>Demand at service load (Load factor = 1.00)</td>
<td>Max allowable value</td>
</tr>
<tr>
<td>(3) <strong>Max deflection</strong> (%)</td>
<td>$\Delta_{\text{max}} &lt; 5% \text{ Diameter}$</td>
<td>$\text{Allowable} = 5% \text{ Diameter}$</td>
</tr>
<tr>
<td></td>
<td>$\Delta_{\text{max}} = \text{max vertical deflection as % of D}_{\text{avg}}$</td>
<td></td>
</tr>
<tr>
<td>(4) <strong>Max outer-fiber strain</strong></td>
<td>$\varepsilon_{\text{max}} &lt; \varepsilon_y$</td>
<td>$\text{Allowable} = \varepsilon_y = f_y/E_e = 0.163%$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{\text{max}} = \text{maximum outer-fiber strain (from diagnostics)}$</td>
<td>$E_e = E/(1-\nu^2) = 31,900,000 \text{ psi}$</td>
</tr>
</tbody>
</table>
# Plastic Pipe Design Criteria

<table>
<thead>
<tr>
<th>Design Criterion (Strength limits)</th>
<th>Factored Demand (Load factor = 2.05)</th>
<th>Factored Capacity (Resistance factors = 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Thrust stress (psi)</td>
<td>$\sigma_{\text{max}} &lt; f_u$</td>
<td>$f_u = \text{compressive strength} = 900 \text{ psi}$ (long-term value for deep burial)</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{max}} = \text{maximum thrust stress in HDPE pipe.}$</td>
<td></td>
</tr>
<tr>
<td>(2) Global Buckling (psi)</td>
<td>$\sigma_{\text{max}} &lt; f_b$</td>
<td>$f_b = \text{buckling capacity}$ AASHTO Eq. 12.12.3.5.2-1</td>
</tr>
<tr>
<td></td>
<td>$\sigma_{\text{max}} = \text{maximum thrust stress in HDPE pipe.}$</td>
<td></td>
</tr>
<tr>
<td>(3) Combined strain (in/in)</td>
<td>$\varepsilon_{\text{max}} &lt; \varepsilon_{\text{ult}}$</td>
<td>$\varepsilon_{\text{ult}} = \text{failure strain} = 0.0614 \text{ in/in}$ $= 1.5*(\text{long-term strength})/(\text{long-term modulus})$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{\text{max}} = \text{maximum outer-fiber strain}$</td>
<td></td>
</tr>
</tbody>
</table>

## Performance Limits (at Service Load)

<table>
<thead>
<tr>
<th>Demand (Load factor = 1)</th>
<th>Max allowable value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) Allowable in-plane tensile strain, $\varepsilon_{t\text{-max}} &lt; \varepsilon_{t\text{-allow}}$</td>
<td>$\varepsilon_{t\text{-allow}} = \text{allowable tensile strain} = 5%$</td>
</tr>
<tr>
<td>(5) Allowable deflection $\Delta_{\text{max}} &lt; \Delta_{\text{allow}}$</td>
<td>$\Delta_{\text{allow}} = 5% \text{ pipe diameter}$</td>
</tr>
<tr>
<td>(6) Allowable longitudinal tensile strain, $\varepsilon_{\text{long-max}} &lt; \varepsilon_{t\text{-allow}}$</td>
<td>$\varepsilon_{t\text{-allow}} = \text{allowable tensile strain} = 5%$</td>
</tr>
</tbody>
</table>
Longitudinal Tensile Strain

\[ \varepsilon_{\text{long}} = 0.5 \frac{p}{E} \left( \frac{L}{t} \right)^2 \leq \varepsilon_{\text{allow}} = 0.05 \]
### Recommended burial depths

<table>
<thead>
<tr>
<th>Diameter (in)</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compacted</td>
<td>Dumped</td>
<td>95%</td>
<td>90%</td>
</tr>
<tr>
<td>12</td>
<td>67</td>
<td>37</td>
<td>54</td>
<td>37</td>
</tr>
<tr>
<td>15</td>
<td>59</td>
<td>30</td>
<td>47</td>
<td>30</td>
</tr>
<tr>
<td>18</td>
<td>50</td>
<td>28</td>
<td>45</td>
<td>28</td>
</tr>
<tr>
<td>24</td>
<td>64</td>
<td>27</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>30</td>
<td>42</td>
<td>25</td>
<td>38</td>
<td>25</td>
</tr>
<tr>
<td>36</td>
<td>27</td>
<td>22</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>42</td>
<td>41</td>
<td>22</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td>48</td>
<td>31</td>
<td>18</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>60</td>
<td>28</td>
<td>19</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>
Future AASHTO Activities for Steel Reinforced Polyethylene Corrugated Pipe.

• Develop a draft AASHTO SOM Standard.
• Request AASHTO SOM consideration of the product.
• Develop draft changes to AASHTO LRFD Section 12 to address design.
• Request AASHTO Subcommittee on Bridges and Structures consideration of the product.
• Work simultaneously with AASHTO Subcommittee on Bridges and Structures and AASHTO SOM to develop a AASHTO Standard for Steel Reinforced Polyethylene Corrugated Pipe
Acknowledgment

Thanks to:

• Kevin Cornell (Kanaflex) – For funding the design study
• AASHTO SOM – Bill Bailey – For the opportunity to present this information
## TS 4B 2017 SOM & TS Ballot Items

<table>
<thead>
<tr>
<th>Item #</th>
<th>Ballot Item</th>
<th>Concurrent SOM &amp; TS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>There are four concurrent SOM &amp; TS ballot items on standards M 252, M 330, M 326 and M 294. There is also one SOM ballot item to adopt MP 20 as a full standard.</td>
<td></td>
</tr>
</tbody>
</table>
Based on TS4B 2017 Summer Ballot comments, Task Force 2017-2 reviewed and revised the definitions in Section 3 for crease, buckling and delamination to correlate with visual evaluations associated with performing the pipe flattening test in Section 9.2.  
See pages 2, 3 and 4 of TS 4b minutes for the comments and actions taken on M 252 by the Task Force 2017-02. | Concurrent SOM & TS |
| 2      | **Revise M330 Standard Specification for Polypropylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter**  
Based on TS4B 2017 Summer Ballot comments, Task Force 2017-2 reviewed and revised the definitions in Section 3 for crease and delamination. The Task force eliminated the definition for buckling because the pipe flattening test is run to a 40 percent deflection. The Task Force also attempted to clarify the terms; pipe liner and pipe wall in several places in the specification and updated several figures.  
See page 4 through 7 of TS 4b minutes for the comments and actions taken on M 330 by the Task Force 2017-02. | Concurrent SOM & TS |
| 3      | **Revise M 326-08 (2017) Standard Specification for Polyethylene (PE) Liner Pipe, 300- to 1600-mm Diameter, Based on Controlled Outside Diameter.**  
Based on TS4B 2017 Summer Ballot comments, Task Force 2017-3 reviewed and revised the definitions in Section 3 for crease and buckling to correlate with visual evaluations in section 7.5 associated with performing the pipe flattening test in Section 9.2. The task force also found a typographic error in Table 2 specifically the Minimum Wall Thickness is listed as 0.314” for 14” diameter SDR 41 pipe. The correct | Concurrent SOM & TS |
wall thickness should be 0.341”

See pages 7 through 8 of TS 4b minutes for the comments and actions taken on M 326 by the Task Force 2017-03.

**Attachment 4 M 326 for concurrent TS & COMP ballot.doc**

<table>
<thead>
<tr>
<th>4</th>
<th>Revise M294 Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The proposed revisions include revisions to numerous sections to incorporate the use of recycled materials into the manufacture of High Density Polyethylene pipe. The changes are a result of the research performed under NCHRP Project 4-39.</td>
</tr>
<tr>
<td></td>
<td>See pages 8 to 13, 15 and Appendix 17-19 of TS 4b minutes for the discussions and comments on revisions to M 294 from TS ballot results. Also see attachment 7 for the Presentation on NCHRP Project 4-39: “Field Performance of Corrugated HDPE Pipes Manufactured with Recycled Materials” and the unedited Final Report previously sent to SOM member Departments.</td>
</tr>
<tr>
<td></td>
<td><strong>Attachment 5 M 294 for concurrent TS &amp; COMP ballot.doc</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5</th>
<th>Move MP 20 Provisional Standard Specification for Steel-Reinforced Polyethylene (PE) Ribbed Pipe, 300- to 1500-mm (12- to 60-in.) Diameter to a full standard specification.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This provisional standard was first published in 2010. There have been no substantial changes to provisional practice since its adoption. The word visible was added to the crease definition for indentation and visual evidence was added to the evaluation for cracking and splitting after the pipe flattening test is performed.</td>
</tr>
<tr>
<td></td>
<td>See page 14 of TS 4b minutes for the discussion on MP 20 in the Task Force 2017-04 report.</td>
</tr>
<tr>
<td></td>
<td><strong>Attachment 6 MP 020 for COMP ballot.doc</strong></td>
</tr>
</tbody>
</table>
### Meeting Date:
8/8/2017

### Items approved by the TS for TS/Subcommittee/Concurrent Ballot

<table>
<thead>
<tr>
<th>Standard Designation</th>
<th>Summary of Proposed Changes</th>
<th>TS Only, Subcommittee Only or Concurrent? (TS / S / C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 252</td>
<td>Several editorial changes need to be made due to state comments.</td>
<td>Concurrent TS and SOM ballot</td>
</tr>
<tr>
<td>M 330</td>
<td>Several editorial changes need to be made due to state comments.</td>
<td>Concurrent TS and SOM ballot</td>
</tr>
<tr>
<td>M 326</td>
<td>Revisions needs to be made based on several state comments.</td>
<td>Concurrent TS and SOM ballot</td>
</tr>
<tr>
<td>M 294</td>
<td>Revisions will be made to include the &quot;recycled changes&quot;</td>
<td>Concurrent TS and SOM ballot</td>
</tr>
<tr>
<td>M 190</td>
<td>Method for using penetrometer will be included.</td>
<td>Concurrent TS and SOM ballot</td>
</tr>
<tr>
<td>MP 20</td>
<td>This standard will become a full standard.</td>
<td>Subcommittee Ballot</td>
</tr>
</tbody>
</table>

### New Task Forces Formed:

<table>
<thead>
<tr>
<th>Task Force Name</th>
<th>Summary of Task</th>
<th>Names of TF Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-05</td>
<td>Address Caltrans, FL, MI negative and comments by NY and PA for M 294</td>
<td>Mike Pluimer, NC, VA, MI, FL, CA, NY, PA</td>
</tr>
</tbody>
</table>

### Research Liaison:

1.) Chair: Will look into an answer to these two questions. If an explanation is found out before the meeting, the explanation will be shared with TS. PPI: The buckling is not a test for polypropylene. This comment refers to the calculated deflection limit for flattening. The Chair will be in touch with LA. (related to M 330)

2.) Chair: Will ask Task force 2017-02 to reconvene and consider each of the suggested comments and arrive at consensus. (related to M 252 and M 330)

3.) Task force 2017-01 was not able to update M 190 specification in time for a concurrent TS and SOM ballot. M 190 will be prepared for review and a technical section ballot in 2018.