Designation: A998/A998M – 18

Standard Practice for Structural Design of Reinforcements for Fittings in Factory–Made Corrugated Steel Pipe for Sewers and Other Applications[1]

This standard is issued under the fixed designation A998/A998M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the structural design of reinforcement for fittings in factory-made, round corrugated steel pipe, conforming to Specifications A760/A760M or A762/A762M, for use as storm and sanitary sewers and other buried applications. This practice is for fittings on pipe installed in a trench or embankment and subjected to earth loads and live loads. It must be recognized that a buried corrugated pipe is a composite structure made up of the steel ring and the soil envelope, and both elements play a vital part. Both main and branch pipe shall be designed in accordance with Practice A796/A796M and installed in accordance with Practice A798/A798M.

1.2 This practice covers the structural design of reinforcement for fittings such as those for branch pipes. Refer to Section 5 for design limitations.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel
A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A307 Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
A760/A760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains
A762/A762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains
A796/A796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications
A798/A798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications
A902 Terminology Relating to Metallic Coated Steel Products
A929/A929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe
F568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners (Metric) (Withdrawn 2012)[3]

2.2 *AASHTO Standard:*[4]

Standard Specifications for Highway Bridges
LRFD Bridge Design Specifications

2.3 *AREMA Document:*[5]

AREMA Manual

2.4 *SAE Document:*[6]

J78 Steel Self-Drilling Tapping Screws

[1] This practice is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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

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

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

[5] Available from American Railway Engineering and Maintenance-of-Way Association (AREMA), 8201 Corporate Drive, Suite 1125, Landover, MD 20785–2230.

[6] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

3. Terminology

3.1 For definitions of general terms used in this standard, refer to Terminology A902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *branch pipe*—corrugated pipe with a diameter smaller than or equal to that of the main pipe, carrying a portion of the flow and connected to the main pipe through a fitting welded in place.

3.2.2 *fittings*—sections of main pipe fabricated to accommodate branch pipes or manhole pipes.

3.2.3 *main pipe*—corrugated pipe carrying the primary flow.

3.2.4 *reinforcement*—sheets, bars, or structural members connected to the main pipe to strengthen a fitting.

4. Symbols

4.1 The symbols used in this practice have the following significance:

a = distance of saddle plate extension onto main pipe, in. [mm].
A_{li} = incremental required minimum cross section area of each longitudinal reinforcement, in^2/ft [mm^2/m].
A_{rc} = required minimum cross section area of each circumferential reinforcement, in^2 [mm^2].
A_{rcs} = cross section area of circumferential reinforcement actually selected, in^2 [mm^2].
A_{rl} = required minimum cross section area of each longitudinal reinforcement, in^2 [mm^2].
A_{rls} = cross section area of longitudinal reinforcement actually selected, in^2 [mm^2].
d = branch diameter, in. [mm].
d_b = nominal bolt diameter, in. [mm].
d_e = effective branch diameter, in. [mm].
d_m = maximum branch pipe diameter for which no circumferential reinforcement is required in. [mm].
d_s = nominal screw diameter, in. [mm].
D = main pipe diameter, in. [mm].
H = depth of fill above top of pipe, ft [m].
H_e = equivalent depth of fill, ft [m].
H_{nlr} = fill height for which no longitudinal reinforcement is required, ft [m].
L = total length of each longitudinal reinforcement, in. [mm].
L_w = length of weld, in. [mm].
LL = live load pressure (see Practice A796/A796M), lbf/ft^2 [kPa].
N_c = minimum total number of fasteners required to attach each circumferential reinforcement.
N_l = minimum total number of fasteners required to attach each longitudinal reinforcement.
q = allowable load for each fastener, lbf [N].
t_{np} = bare steel thickness of pipe, in. [mm].
t_{nr} = bare steel thickness of reinforcement in contact with pipe, in. [mm].
t_x = bare steel thickness of pipe or reinforcement, whichever is less, in. [mm].
w = unit force derived from 1 ft^3 [1 m^3] of fill material above the pipe, lbf/ft^3 [kN/m^3]. When actual fill material is not known use 120 lbf/ft^3 [19 kN/m^3].
α = acute angle between main and branch pipe, degrees.

5. Basis of Design

5.1 Reinforcement requirements depend upon pipe diameter, pipe wall profile, pipe wall thickness, density of fill material, height of cover, and live load. Main pipes with intersecting branch pipes shall be investigated in accordance with Section 6 to determine whether reinforcement is required. If reinforcement is required, it shall be designed in accordance with the provisions of Sections 9 and 10, unless one of the alternatives specified in Section 7 is met. Fittings in main pipes with a diameter less than 48 in. [1200 mm], subject to the limitations of 5.2 – 5.6, do not require reinforcement.

5.2 This practice does not apply to cases where there are two branch pipes on opposite sides of the main pipe, each with a diameter greater than 0.75D, unless the longitudinal distance between the centerlines of the branches measured along the main pipe is greater than D.

5.3 This practice is limited to pipe with a live load that can be described and quantified such as AASHTO H20 or HS20 and AREMA E80.

5.4 Reinforcement design shall be based on an equivalent depth of fill (H_e) that accounts for both earth load and live load (LL) as follows:

$$H_e = \frac{LL + wH}{120} \qquad \left[H_e = \frac{LL + wH}{19} \right] \tag{1}$$

This practice is limited to pipe with $H_e \leq 30$ ft [9 m].

5.5 Reinforcement design shall be based on an effective branch diameter (d_e) determined for the branch angle (α) as follows:

$$d_e = \frac{d}{\sin \alpha} \tag{2}$$

Calculated values of d_e shall be rounded up to the next 6 in. [150 mm] increment for design calculations. The value of d_e must not exceed 1.16*D*.

5.6 This practice is further limited to α from 30 to 90°, inclusive.

5.7 This practice applies where the branch pipe is welded to the main pipe and has a specified thickness based on the requirements of Practice A796/A796M.

5.8 This practice does not include the possible effects of dragdown loads on vertical risers (manholes) such as caused by settlement of deep fills.

5.9 Best practices dictate that risers and other fabrications should not be located over pipe sections that already have welded fabrications. Although permissible, it is best to locate risers, laterals, and any other fabricated connections away from areas with other fabrications such as elbow miters. If this cannot be avoided, additional structural support should be added to the fabricated piece by increasing the gauge thickness of the mainline pipe by a minimum of one increment of thickness or pouring a concrete collar around the fabricated riser junction. The design of the collar shall be determined by the project engineer.

6. Need for Reinforcement

6.1 The need for both longitudinal and circumferential reinforcement as illustrated in Fig. 1 shall be considered.

6.2 Longitudinal reinforcement needs shall be determined from Tables 1-48 as applicable for the main pipe diameter and wall profile under consideration.[7] These tables list, for indicated branch pipe diameters, values of fill height, H_{nlr}, for which no longitudinal reinforcement is required. If $H_e \le H_{nlr}$, no longitudinal reinforcement is required; otherwise, longitudinal reinforcement shall be designed in accordance with Section 9. For main pipe diameters not included in Tables 1-48, interpolation shall be permitted. Fittings for branch pipes with a diameter less than shown in Tables 1-48, subject to the limitations of 5.2 – 5.6, do not require longitudinal reinforcement.

6.3 Circumferential reinforcement needs shall be determined from Tables 49-54 as applicable for the wall profile under consideration.[7] These tables list, for indicated main pipe diameters and wall thicknesses, the maximum branch pipe diameters, d_m, for which no circumferential reinforcement is required. If $d_e \le d_m$, no circumferential reinforcement is required; otherwise, circumferential reinforcement shall be designed in accordance with Section 10. Branch diameters are listed for equivalent depths of fill (H_e) of 10, 20, and 30 ft [3, 6, and 9 m]. Use the 10 ft [3 m] column for $1 \le H_e \le 10$ ft [$1 \le H_e \le 3$ m]. For other H_e not listed, interpolate between the values listed.

7. Alternatives to Providing Reinforcement

7.1 As an alternative to providing required longitudinal or circumferential reinforcement, or both, an increase in the thickness of the main pipe shall be permitted. The increased thickness must be such that the pipe does not require reinforcement when checked in accordance with 6.2, if longitudinal reinforcement is omitted, and 6.3, if circumferential reinforcement is omitted.

[7] The diameter-thickness combinations listed in the tables do not necessarily meet the requirements of Practice A796/A796M.

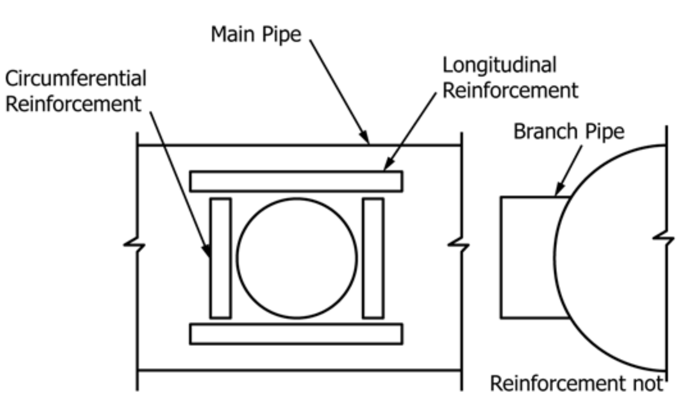

FIG. 1 Schematic of Reinforcements

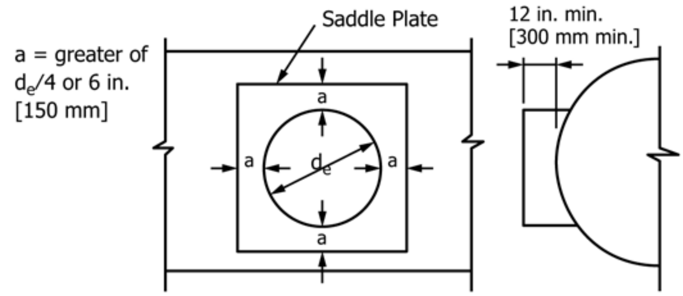

FIG. 2 Schematic of Saddle Plate

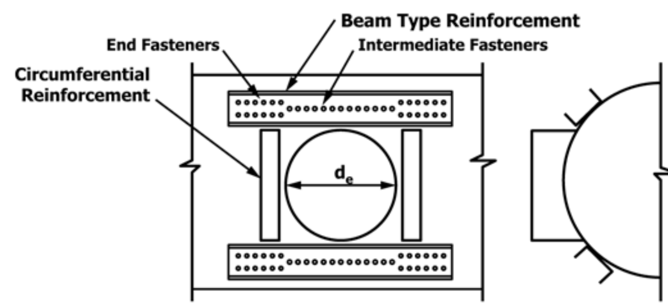

FIG. 3 Schematic of Beam Type Reinforcement

TABLE 1 Requirements for Longitudinal Reinforcement of Fittings in 48 in. Diameter Main Pipe with 2-⅔ by ½ in. Corrugations[A]

	Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, H_{nlr} and Incremental Longitudinal Reinforcement Area, A_{li}									
	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in	H_{nlr}, ft	A_{li}, in.^{2}/ft	H_{nlr}, ft	A_{li}, in.^{2}/ft	H_{nlr}, ft	A_{li}, in.^{2}/ft	H_{nlr}, ft	A_{li}, in.^{2}/ft	H_{nlr}, ft	A_{li}, in.^{2}/ft
24	37.4	0.05	48.2	0.04	69.1	0.04				
30	27.5	0.07	36.3	0.06	53.2	0.05				
36	22.2	0.10	29.6	0.09	39.2	0.07	50.0	0.06		
42	17.9	0.13	21.6	0.11	28.9	0.09	37.0	0.07	45.0	0.06
48	13.8	0.18	16.6	0.15	22.0	0.12	28.0	0.09	34.0	0.07

[A] Branch pipe of any profile with specified thickness as required by Practice A796/A796M.

7.2 As a second alternative to providing required longitudinal or circumferential reinforcement, or both, it is permissible to provide a saddle plate as illustrated in Fig. 2 with a thickness selected from Tables 55 and 56. Saddle plates that act as reinforcement must be of the same material and wall profile as the main pipe and must extend onto the main pipe on all sides from the branch pipe at a distance, a, of d_e/4 or 6 in. [150 mm], whichever is greater. The saddle plate must be continuously welded to a stub length of the branch pipe. The stub must have a full uncut section at least 12 in. [300 mm] long. The saddle plate must be connected to the main pipe with sufficient fasteners (welds, bolts, or screws) so that there are no large gaps and so that it will act together with the main pipe.

7.3 As an alternative to providing required longitudinal reinforcement, it is permissible to provide a beam type reinforcement as illustrated in Fig. 3, designed using recognized engineering principles.