Designation: A 998/A 998M – 08

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 A 998/A 998M; 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 A 760/A 760M or A 762/A 762M, 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 A 796/A 796M and installed in accordance with Practice A 798/A 798M.

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 *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.*

1.4 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. SI units are shown in brackets in the text for clarity, but they are the applicable values when the design is to be performed using SI units.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 36/A 36M Specification for Carbon Structural Steel

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains

A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains

A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications

A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications

A 902 Terminology Relating to Metallic Coated Steel Products

A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners (Metric)

2.2 *AASHTO Standard:*[3]

Standard Specifications for Highway Bridges

LRFD Bridge Design Specifications

2.3 *American Railway Engineering and Maintenance-of-Way Association:*

AREMA Manual[4]

2.4 *Society of Automotive Engineers:*

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

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

J978, Steel Self-Drilling Tapping Screws[5]

3. Terminology

3.1 For definitions of general terms used in this standard, refer to Terminology A 902.

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 min 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 min 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 A 796/A 796M), 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 1.16D.

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 A 796/A 796M.

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.

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

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

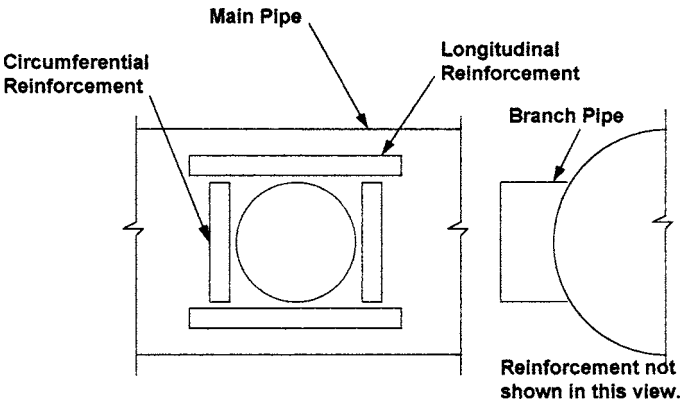

FIG. 1 Schematic of Reinforcements

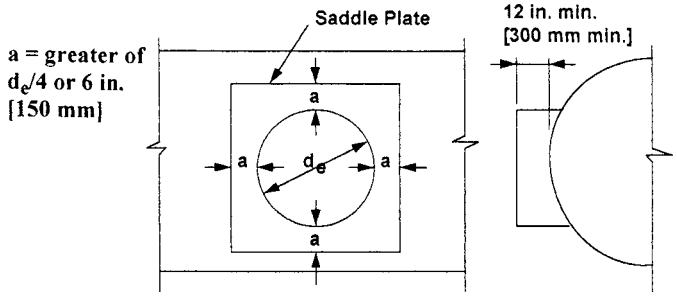

FIG. 2 Schematic of Saddle Plate

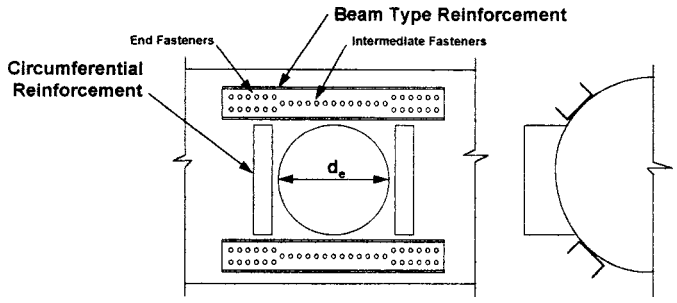

FIG. 3 Schematic of Beam Type Reinforcement

wall profile under consideration.[6] These tables list, for indicated branch pipe diameters, values of fill height, H_{nlr}, for which no longitudinal reinforcement is required. If $H_e \leq H_{nlr}$, 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.[6] 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 $d_e \leq d_m$, 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 $1 \leq H_e \leq 10$ ft [$1 \leq H_e \leq 3$ m]. For other H_e not listed, interpolate between the values listed.

[6] The diameter-thickness combinations listed in the tables do not necessarily meet the requirements of A 796.

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 A 796/A 796M.

TABLE 2 Requirements for Longitudinal Reinforcement of Fittings in 1200 mm Diameter Main Pipe with 68 by 13 mm Corrugations[A]

	Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, H_{nlr}, and Incremental Longitudinal Reinforcement Area, A_{li}									
	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	H_{nlr}, m	A_{li}, mm^2/m	H_{nlr}, m	A_{li}, mm^2/m	H_{nlr}, m	A_{li}, mm^2/m	H_{nlr}, m	A_{li}, mm^2/m	H_{nlr}, m	A_{li}, mm^2/m
600	11.4	106.	14.7	85.	21.1	85.				
750	8.4	148.	11.1	127.	16.2	106.				
900	6.8	212.	9.0	191.	11.9	148.	15.2	127.	18.6	106.
1050	5.5	275.	6.6	233.	8.8	191.	11.3	148.	13.7	127.
1200	4.2	381.	5.1	318.	6.7	254.	8.5	191.	10.4	148.

[A] Branch pipe of any profile with specified thickness as required by A 796/A 796M.

TABLE 3 Requirements for Longitudinal Reinforcement of Fittings in 60 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	29.9	0.06	38.6	0.05	55.3	0.04				
30	22.0	0.09	29.0	0.08	42.6	0.06				
36	17.7	0.12	23.6	0.10	31.4	0.09	40.0	0.08		
42	14.3	0.16	17.3	0.14	23.1	0.11	29.0	0.09	35.0	0.07
48	11.0	0.21	13.3	0.18	17.6	0.14	22.0	0.10	27.0	0.08
54	8.7	0.27	10.5	0.22	14.0	0.17	18.0	0.12	22.0	0.10
60	7.0	0.33	8.5	0.28	11.3	0.21	14.0	0.15	17.0	0.12

[A] Branch pipe of any profile with specified thickness as required by A 796/A 796M.