Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications[1]

This standard is issued under the fixed designation A796/A796M; 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 corrugated steel pipe and pipe-arches, ribbed and composite ribbed steel pipe, ribbed pipe with metallic-coated inserts, closed rib steel pipe, composite corrugated steel pipe, and steel structural plate pipe, pipe-arches, and underpasses for use as storm sewers and sanitary sewers, and other buried applications. Ribbed and composite ribbed steel pipe, ribbed pipe with metallic-coated inserts, closed rib steel pipe, and composite corrugated steel pipe shall be of helical fabrication having a continuous lockseam. This practice is for pipe installed in a trench or embankment and subjected to earth loads and live loads. It must be recognized that a buried corrugated steel pipe is a composite structure made up of the steel ring and the soil envelope, and both elements play a vital part in the structural design of this type of structure. This practice applies to structures installed in accordance with Practices A798/A798M or A807/A807M.

1.2 Corrugated steel pipe and pipe-arches shall be of annular fabrication using riveted or spot-welded seams, or of helical fabrication having a continuous lockseam or welded seam.

1.3 Structural plate pipe, pipe-arches, underpasses, and arches are fabricated in separate plates that, when assembled at the job site by bolting, form the required shape.

1.4 Deep corrugated plates are covered in this standard as a means of providing design properties only. The structural design of deep corrugated structures is not supported by this standard.

1.5 *Units*—This specification is applicable to design in inch-pound units as A796 or in SI units as A796M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the design is done per A796M.

1.6 *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.*

1.7 *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]

A760/A760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains
A761/A761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches
A762/A762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains
A798/A798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications
A807/A807M Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications
A902 Terminology Relating to Metallic Coated Steel Products
A964/A964M Specification for Corrugated Steel Box Culverts
A978/A978M Specification for Composite Ribbed Steel Pipe, Precoated and Polyethylene Lined for Gravity Flow Sanitary Sewers, Storm Sewers, and Other Special Applications (Withdrawn 2020)[3]
A1019/A1019M Specification for Closed Rib Steel Pipe with Diameter of 36 in. [900 mm] or Less, Polymer

[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.

Current edition approved March 1, 2021. Published March 2021. Originally approved in 1982. Last previous edition approved in 2017 as A796/A796M – 17a. DOI: 10.1520/A0796_A0796M-21.

[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.

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

Precoated for Sewers and Drains (Withdrawn 2012)[3]
A1042/A1042M Specification for Composite Corrugated Steel Pipe for Sewers and Drains (Withdrawn 2015)[3]
D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
D2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth) (Withdrawn 2007)[3]
D2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method

2.2 *AASHTO Standard:*[4]
Standard Specifications for Highway Bridges

2.3 *FAA Standard:*[5]
AC No. 150/5320–5B Advisory Circular, "Airport Drainage," Department of Transportation, Federal Aviation Administration, 1970

3. Terminology

3.1 *General Definitions*—For definitions of general terms used in this practice, refer to Terminology A902. For definitions of terms specific to this standard, refer to 3.2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *arch, n*—a pipe shape that is supported on footings and does not have a full metal invert.

3.2.2 *bedding, n*—the earth or other material on which the pipe is laid, consisting of a thin layer of imported material on top of the in situ foundation.

3.2.3 *deep corrugated plate, n*—structural plate in Specification A761/A761M with a corrugation depth greater than 5 in.

3.2.4 *haunch, n*—the portion of the pipe cross section between the maximum horizontal dimension and the top of the bedding.

3.2.5 *invert, n*—the lowest portion of the pipe cross section; also, the bottom portion of the pipe.

3.2.6 *long span structures, n*—structures with dimensions exceeding those in subsection 5.2, special shapes of any size having a crown or side radius greater than 13.0 ft [4000 mm], or structures utilizing deep corrugated plate.

3.2.6.1 *Discussion*—Metal box culverts (rise/span ≤0.3) are not considered long-span structures and are discussed in Specification A964/A964M.

3.2.7 *pipe, n*—a conduit having a full circular shape, or in a general context, all structure shapes covered by this practice.

3.2.8 *pipe-arch, n*—a pipe shape consisting of an approximate semi-circular top portion, small radius corners, and large radius invert.

4. Symbols

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

A = required wall area, in.^{2}/ft [mm^2/mm]
(AL) = maximum highway design axle load, lbf [N]
C_l = longitudinal live load distribution factor for pipe arches
d = depth of corrugation, in. [mm]
E = modulus of elasticity = 29 by 10^6 lbf/in.^{2} [200 by 10^3 MPa]
(EL) = earth load, lbf/ft^2 [kPa]
(FF) = flexibility factor, in./lbf [mm/N]
f_y = specified minimum yield strength

For 6 by 2 in. [150 by 50 mm] corrugation
Type 33 = 33 000 lbf/in.^{2} [225 MPa]
Type 38 = 38 000 lbf/in.^{2} [260 MPa]
For 15 by 5½ in. [380 by 140 mm] and 16 by 6 in. [400 by 150 mm] corrugations = 44 000 lbf/in.^{2} [300 MPa]
For 20 by 9 ½ in. [500 by 237 mm] corrugation = 42 000 lbf/in.^{2} [290 MPa]
For all other corrugations = 33 000 lbf/in.^{2} [225 MPa]

f_u = specified minimum tensile strength

For 6 by 2 in. [150 by 50 mm] corrugation
Type 33 = 45 000 lbf/in.^{2} [310 MPa]
Type 38 = 48 000 lbf/in.^{2} [330 MPa]
For 15 by 15½ in. [380 by 140 mm], 16 by 6 in. [400 by 150 mm] and 20 by 9 ½ in. [500 by 237 mm] corrugations = 55 000 lbf/in.^{2} [380 MPa]
For all other corrugations = 45 000 lbf/in.^{2} [310 MPa]

f_c = critical buckling stress, lbf/in.^{2} [MPa]
h = height of cover, in. [mm] determined as follows: *(1)* highways—from top of pipe to top of rigid pavement, or to top of subgrade for flexible pavement; *(2)* railways—top of pipe to bottom of tie
H = depth of fill above top of pipe, ft [m]
H_{min} = minimum depth of fill, ft [m]
H_{max} = maximum depth of fill, ft [m]
I = moment of inertia of corrugated shape, in.^{4}/in. [mm^4/mm] (see Tables 2-35)
(IL) = pressure from impact load, lbf/ft^2 [kPa]
k = soil stiffness factor = 0.22 for good side-fill material compacted to 90 % of standard density based on Test Method D698
L_1, L_2, L_3 = loaded lengths, in. [mm] defined in 18.3
(LL) = pressure from live load, lbf/ft^2 [kPa]
P = total design load or pressure, lbf/ft^2 [kPa]
P_c = corner pressure, lbf/ft^2 [kPa]
P_f = factored crown pressure, lbf/ft^2 [kPa]
r = radius of gyration of corrugation, in. [mm] (see Tables 2-35)
r_c = corner radius of pipe-arch, in. [mm]
R_n = nominal resistance for each limit state, lbf/ft [kN/m]
R_f = factored resistance for each limit state, lbf/ft [kN/m]
r_t = radius at crown, in. [mm]

[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.
[5] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Publication No. SN-050-007-00149-5.

S	=	pipe diameter or span, ft [m]
s	=	pipe diameter or span, in. [mm]
(SF)	=	safety factor
(SS)	=	required seam strength, lbf/ft [kN/m]
T	=	thrust in pipe wall, lbf/ft [kN/m]
T_f	=	factored thrust in pipe wall, lbf/ft [kN/m]
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]
φ	=	resistance factor

5. Basis of Design

5.1 The safety factors and other specific quantitative recommendations herein represent generally accepted design practice. The design engineer should, however, determine that these recommendations meet particular project needs.

5.2 This practice is not applicable for long-span structures and deep corrugated plate structures of any geometry. Such structures require additional design considerations for both the pipe and the soil envelope. The design of long-span and deep corrugated structures is described in the AASHTO LRFD Bridge Design Specification. In addition to meeting all other design requirements given herein, the maximum diameters or spans for structures designed by this practice are as follows:

Shape	Maximum Diameter or Span, ft [mm]
pipe, arch	26 [7920 mm]
pipe-arch, underpass	21 [6400 mm]

5.3 This practice is not applicable for pipe with a specified thickness less than 0.052 in. [1.32 mm] for installations under railways and airport runways.

6. Loads

6.1 The design load or pressure on a pipe is comprised of earth load (EL), live load (LL), and impact load (IL). These loads are applied as a fluid pressure acting on the pipe periphery.

6.2 For steel pipe buried in a trench or in an embankment on a yielding foundation, loads are defined as follows:

6.2.1 The earth load (EL) is the weight of the column of soil directly above the pipe:

$$(EL) = Hw \tag{1}$$

6.2.2 *Live Loads*—The live load (LL) is that portion of the weight of vehicle, train, or aircraft moving over the pipe that is distributed through the soil to the pipe.

6.2.2.1 *Live Loads Under Highway*—Live load pressures for H20 highway loadings, including impact effects, are:

Height of Cover, ft [m]	Live Load, lbf/ft^2 [kPa]
1 [0.30]	1800 [86.2]
2 [0.61]	800 [38.3]
3 [0.91]	600 [28.7]
4 [1.22]	400 [19.2]
5 [1.52]	250 [12.0]
6 [1.83]	200 [9.6]
7 [2.13]	175 [8.4]
8 [2.44]	100 [4.8]
over 8 [over 2.44]	neglect [–]

6.2.2.2 *Live Loads Under Railways*—Live load pressures for E80 railway loadings, including impact effects, are as follows:

Height of Cover, ft [m]	Live Load, lbf/ft^2 [kPa]
2 [0.61]	3800 [181.9]
5 [1.52]	2400 [114.9]
8 [2.44]	1600 [76.6]
10 [3.05]	1100 [52.7]
12 [3.66]	800 [38.3]
15 [4.57]	600 [28.7]
20 [6.10]	300 [14.4]
30 [9.14]	100 [4.8]
over 30 [over 9.14]	neglect [–]

6.2.2.3 Values for intermediate covers shall be interpolated.

6.2.2.4 *Live Loads Under Aircraft Runways*—Because of the many different wheel configurations and weights, live load pressures for aircraft vary. Such pressures must be determined for the specific aircrafts for which the installation is designed; see FAA Standard AC No. 150/5320-5B.

6.2.3 *Impact Loads*—Loads caused by the impact of moving traffic are important only at low heights of cover. Their effects have been included in the live load pressures in 6.2.2.

7. Design Method

7.1 Strength requirements for wall strength, buckling strength, and seam strength may be determined by either the allowable stress design (ASD) method presented in Section 8 or the load and resistance factor design (LRFD) method presented in Section 9. Additionally, the design considerations in other paragraphs shall be followed for either design method.

8. Design by ASD Method

8.1 The thrust in the pipe wall shall be checked by three criteria. Each considers the joint function of the steel pipe and the surrounding soil envelope.

8.1.1 *Required Wall Area:*

8.1.1.1 Determine the design pressure and the ring compression thrust in the steel pipe wall as follows:

$$P = EL + LL + IL \tag{2}$$

$$T = \frac{PS}{2} \tag{3}$$

TABLE 1 Resistance Factors for LRFD Design

Type of Pipe	Limit State	Resistance Factor, φ
Helical pipe with lock seam or fully welded seam	Minimum wall area and buckling	1.00
Annular pipe with spot-welded, riveted, or bolted seam	Minimum wall area and buckling	1.00
	Minimum seam strength	0.67
Structural plate pipe	Minimum wall area and buckling	1.00
	Minimum seam strength	0.67