



Designation: B 746/B 746M – 012

# Standard Specification for Corrugated Aluminum Alloy Structural Plate for Field-Bolted Pipe, Pipe-Arches, and Arches<sup>1</sup>

This standard is issued under the fixed designation B 746/B 746M; 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.

*This standard has been approved for use by agencies of the Department of Defense.*

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.08 on Aluminum Culvert.

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## 1. Scope

1.1 This specification covers corrugated aluminum alloy structural plate used in the construction of pipe, pipe-arches, arches, underpasses, box culverts, and special shapes for field assembly. Appropriate fasteners are also described. The pipe, arches, and other shapes are generally used for drainage purposes, pedestrian and vehicular underpasses, and utility tunnels. Aluminum box culvert shapes are covered in Specification B 864/B 864M.

1.2 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and plate thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of plate thickness, type of bedding and backfill, controlled manufacture in the plant, and care in the installation. The purchaser must correlate the above factors and also the corrosion and abrasion requirements of the field installation with the plate thickness. The structural design of corrugated aluminum structural plate pipe and the proper installation procedures are given in Practices B 790/B 790M and B 789/B 789M, respectively. A procedure for using life-cycle cost analysis techniques to evaluate alternate drainage system designs using corrugated metal pipe is given in Practice A 930.

~~1.3 This specification is applicable to orders~~

~~1.3 The values stated in either inch-pound units (as B 746) or SI units (as B 746M). Inch-pound units and SI units are not necessarily equivalent. SI units are shown to be regarded separately as standard. The values stated in parentheses in the text; they each system are not exact equivalents; therefore, each system shall be used independently of the applicable values when the material is ordered to B 746M. other.~~

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength<sup>3</sup>

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength<sup>3</sup>

A 449 Specification for Quenched and Tempered Steel Bolts and Studs<sup>3</sup>

A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>

A 563M Specification for Carbon and Alloy Steel Nuts [Metric]<sup>3</sup>

A 930 Practice for Life-Cycle Cost Analysis of Corrugated Metal Pipe Used for Culverts, Storm Sewers, and Other Buried Conduits<sup>2</sup>

B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate<sup>4</sup>

B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]<sup>4</sup>

B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes<sup>4</sup>

B 221M Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes [Metric]<sup>4</sup>

B 666/B 666M Practice for Identification Marking of Aluminum and Magnesium Products<sup>4</sup>

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.08.

<sup>4</sup> Annual Book of ASTM Standards, Vol 02.02.

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>5</sup>

B 789/B 789M Practice for Installing Corrugated Aluminum Structural Plate Pipe for Culverts and Sewers<sup>4</sup>

B 790/B 790M Practice for Structural Design of Corrugated Aluminum Pipe, Pipe-Arches, and Arches for Culverts, Storm Sewers, and Other Buried Conduits<sup>4</sup>

B 864/B 864M Specification for Corrugated Aluminum Box Culverts<sup>4</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>

F 467 Specification for Nonferrous Nuts for General Use<sup>3</sup>

F 467M Specification for Nonferrous Nuts for General Use [Metric]<sup>3</sup>

F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use<sup>3</sup>

F 468M Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use [Metric]<sup>3</sup>

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners ~~[Metric]~~<sup>3</sup>

F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs<sup>3</sup>

F 594 Specification for Stainless Steel Nuts<sup>3</sup>

F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs ~~[Metric]~~<sup>3</sup>

F 836M Specification for Style 1 Stainless Steel Metric Nuts ~~[Metric]~~<sup>3</sup>

2.2 *American National Standards:*<sup>7</sup>

B18.2.1 Square and Hex Bolts and Screws, Inch Series

B18.2.2 Square and Hex Nuts

B18.2.3.6M Bolts, Metric, Heavy Hex

B18.2.4.6M Hex Nuts, Heavy, Metric

### 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *arch*—a part circle shape spanning an open invert between the footings on which it rests.

3.1.2 *box culvert*—a rectangular box with short-radius in upper corners and a long-radius crown. It can be with full invert or with footing pads.

3.1.3 *fabricator*—the producer of the components for the finished product.

3.1.4 *flat plate*—sheet or plate used to fabricate structural plate.

3.1.5 *manufacturer*—the producer of the flat plate and accessories.

3.1.6 *pipe*—a conduit having full circular shape; also, in a general context, all structure shapes covered by this specification.

3.1.7 *pipe-arch*—an arch shape with an approximate semicircular crown, small-radius corners, and large-radius invert.

3.1.8 *pipe, horizontal ellipse*—an elliptically shaped pipe with the horizontal diameter approximately 20 % greater than the nominal diameter.

3.1.9 *pipe, vertically elongated*—an elliptically shaped pipe with the vertical diameter up to 10 % greater than the nominal diameter.

3.1.10 *purchaser*—the purchaser of the finished product.

3.1.11 *special shape*—a shape, other than described elsewhere in this section, suitable for fabrication with structural plate.

3.1.12 *structural plate*—a corrugated and curved plate which is field assembled with other structural plates to form the required structure.

3.1.13 *vehicular underpass*—a high arch shape with an approximate semicircular crown, large-radius sides, small-radius corners between sides and invert, and large-radius invert.

### 4. Ordering Information

4.1 Orders for material under this specification shall include the following information as necessary to adequately describe the desired product:

4.1.1 Name of material (aluminum alloy structural plate and accessories),

4.1.2 Description of structure (see Section 3),

4.1.3 Number of structures,

4.1.4 ASTM designation and year of issue, as B 746—\_\_\_ for inch-pound units or B 746M—\_\_\_ for SI units.

4.1.5 Dimensions of structure (diameter or span and rise, and length, etc.) (see 7.2),

4.1.6 Thickness of plate (see 7.1),

4.1.7 Type of bolts; whether aluminum, stainless steel, or steel bolts are required or permitted. If not specified, steel bolts and nuts shall be furnished (see 5.3 and Note 2),

4.1.8 End treatment (bevel, skew, grade or slope corrections, or other special provision if required by the project plans or specifications),

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>7</sup> Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

- 4.1.9 Special requirements (including extrusion reinforcement locations and shapes), if required, and  
 4.1.10 Certification, if required.

NOTE 1—Typical ordering descriptions are as follows: (1) Structural plates and fasteners for two aluminum alloy structural plate pipes, per ASTM B 746—, 180-in. dia., 0.100-in. plate thickness, each 140-ft nominal centerline length with end treatment as shown on plans. (2) Structural plates and fasteners for one aluminum alloy structural plate pipe arch, per ASTM B 746—, 3860 mm span by 2460 mm rise, 3.81 mm plate thickness, 27.0 m nominal centerline length with square ends.

## 5. Materials

5.1 *Flat Plate*—Insofar as applicable, flat plate shall conform to the requirements of Specification B 209 or B 209M. The plates shall be fabricated from alloy 5052-H141. The mechanical properties for alloy 5052-H141 shall conform to the requirements of Table 1.

5.2 *Extrusions*—The extrusions for circumferential or longitudinal stiffeners, or secondary structural components, shall be fabricated from aluminum alloys 6061-T6 or 6063-T6 conforming to Specification B 221 or B 221M.

5.3 *Assembly Fasteners*—Except as provided elsewhere in this section, bolts and nuts shall conform to the requirements specified in Table 2 and Table 3. The bearing surface of both bolts and nuts shall be shaped to a 1-in. (25-mm) radius spherical surface, or to a uniform taper of approximately 22° to form a conical surface. In lieu of bolts and nuts with the special bearing surface, standard type bolts and nuts with special washers may be used. The number of nuts and bolts of each size and length furnished shall be 2 % in excess of the theoretical number required to field erect the structure or structures. Bolt lengths shall be such as to result in at least “full nut” engagement when tightened in place.

NOTE 2—Aluminum bolts and nuts, due to lower strength properties than steel bolts, have lower allowable design seam strengths in pipe with all plate thicknesses, but especially so for plate thicknesses greater than 0.175 in. (4.44 mm). The purchaser should indicate which bolts and nuts are acceptable or required based on his design calculations. Corrosion should be considered in selecting bolt types for use in corrosive environments.

## 6. Fabrication

6.1 Structural plates shall be fabricated from flat sheets or plates, corrugated in accordance with 6.2, punched for bolted lap seams in accordance with 6.3 and curved to the required radius.

6.2 *Corrugations*—Corrugations shall form smooth continuous curves and tangents. Corrugations shall form annular rings (complete or partial) about the axis of the structure. The dimensions of the corrugations shall be in accordance with Table 4.

6.3 *Bolt Holes*—The bolt holes shall be punched so that all plates having like dimensions, curvature, and same number of bolts per foot of seam shall be interchangeable. Longitudinal seams shall have holes for four bolts per corrugation, with two holes in each valley and two holes in each crest, with the holes placed 1¾ in. (45 mm) apart. Circumferential seams in the finished product shall provide for a bolt spacing of not more than 10 in. (250 mm). The diameter of the bolt holes in the longitudinal seams shall not exceed the bolt diameter by more than ⅛ in. (3 mm) except those in the plate corners. Bolt holes in circumferential seams, including plate corners, may be slotted with a width equal to the bolt diameter plus ¼ in. (3 mm) and a length equal to the bolt diameter plus ⅜ in. (10 mm). The minimum distance from the center of a hole to the edge of a plate shall be 1¾ times the diameter of the bolt. Holes shall be provided as required for connecting headwall anchors, bearings, and miscellaneous attachments.

6.4 *Special Plates*—Plates for forming skewed ends, beveled ends, or curved alignment shall be accurately cut to fit the order plans. Cut edges of plates shall be free of notches, gouges, or burrs and shall present a workmanlike finish. Legible identification shall be placed on each special plate to designate its proper position in the finished structure and referenced to the approved erection drawings.

6.5 *Extrusions*—Extrusions for longitudinal or circumferential structural reinforcing, if required, shall be as sized and located on the order plans, and fabricated from aluminum alloy 6061-T6. Extrusions for receiving angles or receiving channels on arches or other less critical structural members, if required, shall be as sized and located on the order plans, and shall be fabricated from aluminum alloy 6061-T6 or 6063-T6.

## 7. Dimensions

7.1 *Plate Thickness*—Plate thickness shall be as specified by the purchaser from the specified plate thickness listed in Table 5 (Note 3). For corrugated plate, the thickness shall be measured on the tangents of the corrugations.

NOTE 3—The purchaser should determine the required thickness according to the design criteria in Practice B 790/B 790M.

7.2 *Cross-Section Dimensions*—Cross-section dimensions, such as diameter, span and rise, and radius of curvature, shall be measured to the inside crest of corrugations. The average diameter of circular pipe, based on two measurements at 90° to each

**TABLE 1 Mechanical Properties of Aluminum Structural Plate, Alloy 5052-H141<sup>A</sup>**

Specified Thickness		Tensile Strength, min		Yield Strength (0.2 % offset), min		Elongation, % min in 2 in. or 50 mm
in.	mm	ksi	MPa	ksi	MPa	
0.100–0.150	2.54–3.81	35.5	245	24.0	165	6
0.175–0.250	4.44–6.35	34.0	235	24.0	165	8

<sup>A</sup> To determine conformance with this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi (1 MPa) and each value for elongation to the nearest 0.5%, both in accordance with the rounding method of Practice E 29.

**TABLE 2 (B 746) Bolt and Nut Requirements**

	Bolts	Nuts
General Dimensions	ANSI B18.2.1 Heavy Hex	ANSI B18.2.2 Heavy Hex
Steel Bolts and Nuts	A 307 <sup>A</sup>	A 563 Grade A
Zinc Coating	A 153/A 153M or B 695 Class 50	A 153/A 153M or B 695 Class 50
Stainless Steel Bolts and Nuts	F 593 Alloy Group 1, 2, or 3	F 594 Alloy Group 1, 2, or 3
Aluminum Bolts and Nuts	F 468 Alloy 6061-T6	F 467 Alloy 6061-T6
Nominal Diameter, in.	¾	¾

<sup>A</sup> Bolts conforming to Specifications A 325 or A 449 with suitable nuts may be substituted.

**TABLE 3 (B 746M) Bolt and Nut Requirements**

	Bolts	Nuts
General Dimensions	ANSI B18.2.3.6M Heavy Hex	ANSI B18.2.4.6M Heavy Hex
Steel Bolts and Nuts	F 568M Class 4.6 <sup>A</sup>	A 563M Class 5
Zinc Coating	A 153/A 153M or B 695 Class 50	A 153/A 153M or B 695 Class 50
Stainless Steel Bolts and Nuts	F 738M Alloy Group A1, A2, or A4	F 836M Alloy Group A1, A2, or A4
Aluminum Bolts and Nuts	F 468M Alloy 6061-T6	F 467M Alloy 6061-T6
Nominal Diameter, metric size	M 20	M 20

<sup>A</sup> Bolts through Class 8.8 with suitable nuts may be substituted.

**TABLE 4 Corrugation Requirements**

Nominal Size	Maximum Pitch <sup>A</sup>	Minimum Depth <sup>B</sup>	Inside Radius	
			Nominal	Minimum
B 746—All values in in.				
9 by 2½	9 ¾	2¾	2¼	2.0
B 746M—All values in mm				
230 by 64	238	60	57	51

<sup>A</sup> Pitch is measured from crest to crest of corrugations, at 90° to the direction of the corrugations.

<sup>B</sup> Depth is measured as the vertical distance from a straightedge resting on the corrugation crests parallel to the axis of the pipe, to the bottom of the intervening valley.

**TABLE 5 Plate Thickness<sup>A</sup>**

Specified Thickness		Minimum Thickness	
in.	mm	in.	mm
0.100	2.54	0.093	2.36
0.125	3.18	0.118	3.00
0.150	3.81	0.138	3.51
0.175	4.44	0.161	4.09
0.200	5.08	0.186	4.72
0.225	5.72	0.209	5.31
0.250	6.35	0.232	5.89

<sup>A</sup> Thickness is measured at any point on the plate not less than ¾ in. or 10 mm from an edge, and if corrugated, on the tangents of corrugations.

other, shall not vary more than  $\pm 2\%$  from the calculated inside diameter shown in Table 6. The span and rise of pipe arch, arch, underpass, and other noncircular structures shall be as specified within  $\pm 2\%$ .

NOTE 4—The purchaser should consult the fabricator to determine the standard dimensions for the various types of structures, other than circular structure.

## 8. Workmanship

8.1 Plates, fasteners, and accessories shall be of uniform quality consistent with good manufacturing and inspection practices.

## 9. Sampling and Testing

9.1 Sampling and testing of plate shall be according to Specification B 209 or B 209M. Sampling and testing of other materials shall be according to the specification referenced. The manufacturer shall make adequate tests and measurements to ensure that the material produced complies with this specification.

9.1.1 Test results including chemical composition and mechanical properties shall be maintained by the manufacturer for seven years and shall be made available to the fabricator and purchaser upon request, for examination at the manufacturer's facility unless otherwise agreed upon.

9.2 The fabricator or the purchaser may make such tests as are necessary to determine the acceptability of the material or to verify the correctness of a certification.



**TABLE 6 Diameter of Circular Pipe, 9 by 2.5 in. (230 by 65 mm),  
Corrugation**

Nominal Diameter Specified		Calculated Inside Diameter	
in.	mm	in.	mm
60	1525	58.7	1490
66	1675	64.8	1645
72	1830	70.9	1805
78	1980	77.0	1955
84	2135	83.2	2115
90	2285	89.3	2265
96	2440	95.4	2425
102	2590	101.6	2580
108	2745	107.7	2735
114	2895	113.8	2890
120	3050	119.9	3050
126	3200	126.1	3200
132	3355	132.2	3360
138	3505	138.3	3515
144	3660	144.4	3670
150	3810	150.6	3825
156	3960	156.7	3980
162	4115	162.8	4135
168	4265	169.0	4290
174	4420	175.1	4445
180	4570	181.2	4600
186	4725	187.3	4760
192	4875	193.5	4910
198	5030	199.6	5070
204	5180	205.7	5225
210	5335	211.8	5380
216	5485	218.0	5535
222	5640	224.1	5695
228	5790	230.2	5845
234	5945	236.3	6005
240	6095	242.5	6160
246	6250	248.6	6315
252	6400	254.7	6470
258	6555	260.9	6630
264	6705	267.0	6780
270	6860	273.1	6940
276	7010	279.2	7090
282	7165	285.4	7250
288	7315	291.5	7405
294	7470	297.6	7560
300	7620	303.7	7715
306	7770	309.9	7870
312	7925	316.0	8025

9.3 Mechanical properties shall be determined on plate prior to corrugating or other fabricating, except tests may be made after fabrication by the purchaser for tensile and yield strengths.

**10. Rejection and Rehearing**

10.1 Material that fails to conform to the requirements of this specification ~~may~~ shall be rejected. Rejection ~~should~~ shall be reported to the manufacturer or fabricator promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or fabricator may make claim for a rehearing.

**11. Certification**

11.1 When specified in the purchase order or contract, a manufacturer’s certification shall be furnished to the purchaser of the plate (fabricator), or manufacturer’s and fabricator’s certification shall be furnished to the purchaser of the finished pipe, stating that samples representing each lot have been tested and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the mechanical test results and the chemical composition limits shall be furnished.

NOTE 5—As the identity of the plate is not maintained from the original ingot production, if numerical results are required by the purchaser, tests should be performed on the finished plate.

**12. Product Marking**

12.1 Each plate shall be identified by showing the following:

12.1.1 Name or trademark of plate manufacturer,

12.1.2 Name of fabricator, if other than the manufacturer,

12.1.3 Alloy and temper,

12.1.4 Specified thickness,

12.1.5 Identification symbols showing date of fabricating by a six digit number indicating in order the year, month, and day of the month, and

12.1.6 ASTM designation number.

12.2 The remarking shall be so placed that when the structure is erected, the identification will appear on the inside.

12.3 The marking shall be applied to the plate by a permanent method such as coining in accordance with Practice B 666/B 666M.

### 13. Keywords

13.1 aluminum structural plate; arches; culverts; field bolted structures; pipe; pipe arches

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