Designation: A 964/A 964M – 03

Standard Specification for Corrugated Steel Box Culverts[1]

This standard is issued under the fixed designation A 964/A 964M; 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 specification covers material, geometric, and wall section properties of steel box culverts manufactured from corrugated plate or sheet, with or without attached stiffeners, for field assembly. Appropriate fasteners and optional materials such as steel invert plates and headwalls are also described. Applications for steel box culverts include conduits for gravity flow drainage of surface water such as culverts and storm drains, as well as for small bridges and grade separation structures such as pedestrian or vehicular underpasses, and utility tunnels.

1.2 This specification does not include requirements for foundations, backfill, or the relationship between earth cover or live loads and strength requirements. These important design considerations are described in the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units).

1.3 This specification does not include requirements for the hydraulic design of these structures. Hydraulic design, placement of footings or inverts, and end treatments to resist scour are described in FHWA HDS No. 5.

1.4 Appendix X1 lists nominal dimensions of box culvert sizes commonly available. Also listed are cross-sectional area and hydraulic design parameters for these sizes.

1.5 Appendix X2 lists manufacturers' suggested design properties for the box culvert types described in this specification, and for the spacing classes and material thicknesses typically available.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A 36/A 36M Specification for Carbon Structural Steel

A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches

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 902 Terminology Relating to Metallic Coated Steel Products

2.2 *AASHTO Standard:*

LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units)[3]

2.3 *FHWA Standard:*

HDS No. 5, Hydraulic Design of Highway Culverts, Report No. FHWA-IP-85-15[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms related to metallic coated steel products refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *box culvert, n*—a generally rectangular conduit having a cross section symmetric about a vertical axis, with a long radius crown segment, short radius haunch segments, and straight side segments, with or without stiffeners, footing plates, or invert plates.

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[1] This specification 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, 444 N. Capitol St. N.W., Suite 225, Washington, DC 20001.

[4] Available from the National Technical Information Service, Springfield, VA 22161.

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3.2.2 *cross-corrugations*, *n*—shallow corrugations formed transverse to the main corrugations on the inside of deep corrugated haunch plates to facilitate curving (see Fig. 8).

3.2.3 *crown*, *n*—the long radius top arc segment of a box culvert cross section (see Fig. 1).

3.2.4 *haunch*, *n*—the short radius segments at the upper corners of a box culvert cross section, making the transition between the long radius crown segment and the straight side segments (see Fig. 1).

3.2.5 *shell*, *n*—the continuous, structural enclosure of the box culvert consisting of modular, field assembled and bolted, corrugated plate members forming the crown, haunch and side segments (see Fig. 1).

3.2.6 *stiffeners*, *n*—spaced, hot rolled or cold formed structural members, curved to the shape of the transverse cross section of box culverts and attached by field bolting to the corrugated plate shell (see Fig. 1).

3.2.7 *rise*, *n*—the clear inside vertical dimension from the bottom of the straight side segments of a box culvert to the crown, measured at the axis of symmetry (see Fig. 1).

3.2.8 *span*, *n*—the clear inside horizontal dimension of a box culvert, measured at the bottom of the straight side segments (see Fig. 1).

3.2.9 *unit weight*, *n*—the force resulting from gravitational attraction on a mass having a unit volume.

4. Classification

4.1 Steel box culverts are furnished in five types. Each type represents an alternate means of providing the required structural strength. The shell thickness and, where applicable, the stiffener thickness and spacing class at the crown and haunch of the box culvert are permitted to differ, provided they satisfy the ordering information and the design properties (see 5.1 and 6.1). Furthermore, while the box culvert structure shall be supplied in a consistent type throughout its length, the shell thickness and, where applicable, the stiffener thickness and spacing class also are permitted to be varied along the length, in accordance with cover and loading requirements, as agreed upon between the purchaser and the fabricator.

4.1.1 *Type I Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with spaced, cold formed, corrugated plate stiffeners as detailed in Fig. 2. Stiffener spacing classes shall be as defined below and as illustrated in Fig. 3.

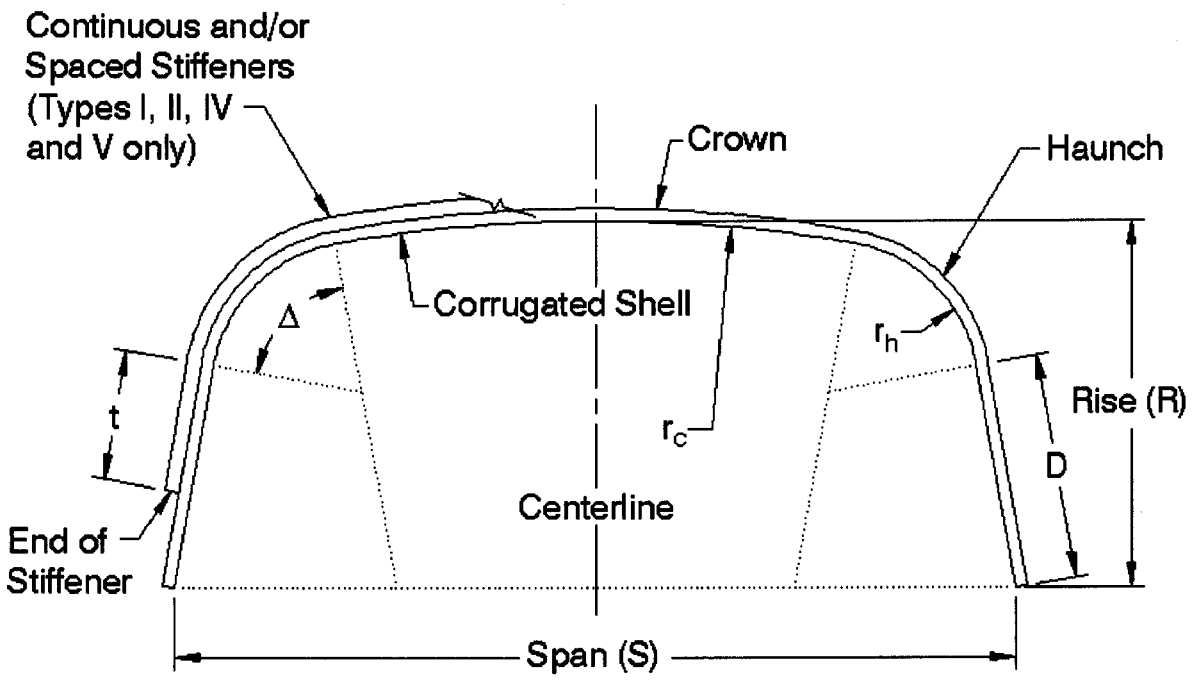
4.1.1.1 *Type I, Class A Spacing*, consisting of external stiffeners spaced at 24 in. [610 mm] center-to-center.

4.1.1.2 *Type I, Class B Spacing*, consisting of external stiffeners spaced at 12 in. [305 mm] center-to-center.

4.1.1.3 *Type I, Class C Spacing*, consisting of both external and internal stiffener groups, each spaced at 24 in. [610 mm] center-to-center, with the outer group offset 9 in. [229 mm] from the inner group.

4.1.2 *Type II Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with spaced, hot rolled, angle stiffeners as detailed in Fig. 4. Stiffener spacing classes shall be as defined below and as illustrated in Fig. 4.

4.1.2.1 *Type II, Class A Spacing*, consisting of external stiffeners spaced at 30 in. [762 mm] center-to-center.



NOTE - See Table 1 for explanation of notation.

FIG. 1 Box Culvert Geometry

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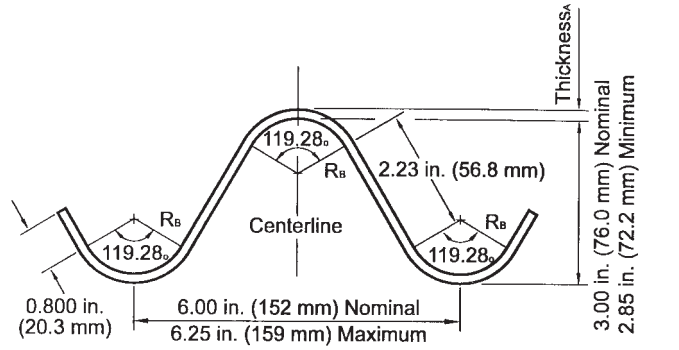
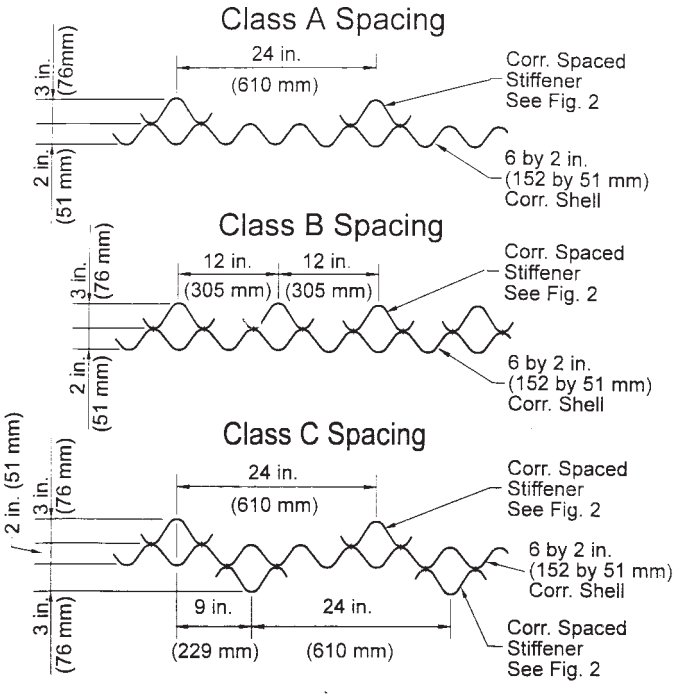


[A] Rib Stiffener Thickness: For thickness tolerances, see ASTM A 761/A 761M.

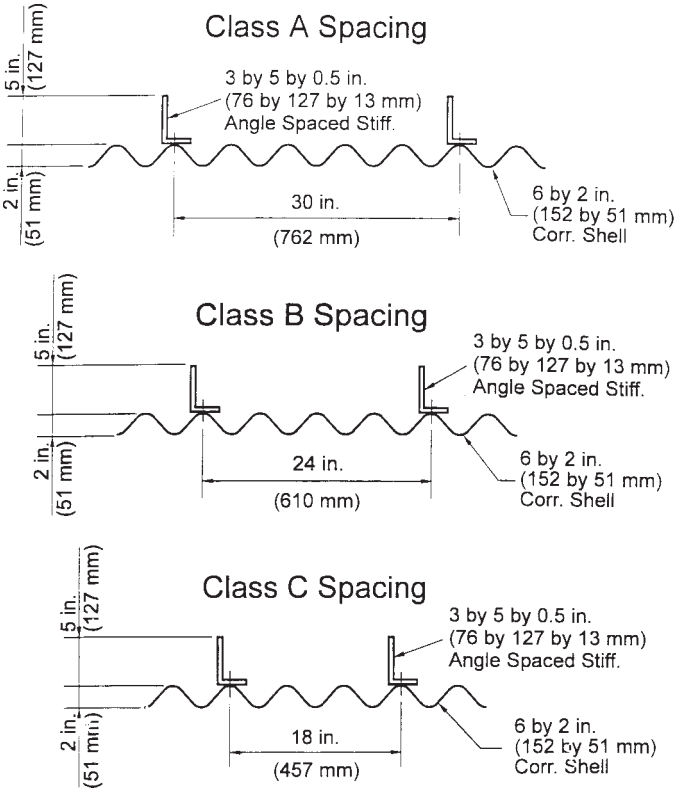
[B] Inside Radius: 1.00 in. (25.4 mm) nominal, 0.938 in. (23.8 mm) minimum.

FIG. 2 Type I Rib Stiffener Geometry



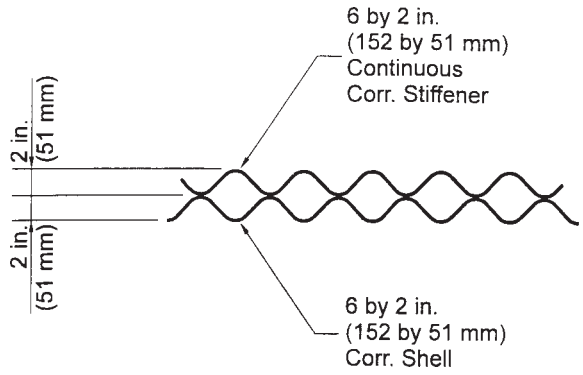
NOTE—All dimensions are nominal.

FIG. 3 Type I Rib Spacing Classes



NOTE—All dimensions are nominal.

FIG. 4 Type II Rib Spacing Classes



NOTE—All dimensions are nominal.

FIG. 5 Type IV Stiffener

4.1.2.2 *Type II, Class B Spacing*, consisting of external stiffeners spaced at 24 in. [610 mm] center-to-center.

4.1.2.3 *Type II, Class C Spacing*, consisting of external stiffeners spaced at 18 in. [457 mm] center-to-center.

4.1.3 *Type III Box Culvert*, consisting of a 15 by 5.5 in. [381 by 140 mm] corrugated plate shell without stiffeners.

4.1.4 *Type IV Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with continuous corrugated plate stiffeners. The stiffener placement and cross section shall be as detailed in Fig. 5.

4.1.5 *Type V Box Culvert*, consisting of a corrugated plate shell having 15 by 5.5 in. [381 by 140 mm] corrugations in combination with cold formed, corrugated plate stiffeners, continuous on the crown and, if required, spaced corrugated plate stiffeners on the haunches. The continuous crown stiffener placement and cross section shall be as detailed in Fig. 6. Where spaced haunch stiffeners are utilized, the stiffener spacing classes shall be as defined below and as illustrated in Fig. 7. Haunch stiffeners are not required to be continuous with the crown stiffeners around the periphery of the haunch and crown.

4.1.5.1 *Type V, Class A Spacing*, consisting of external haunch stiffeners spaced at 45 in. [1143 mm] center-to-center.

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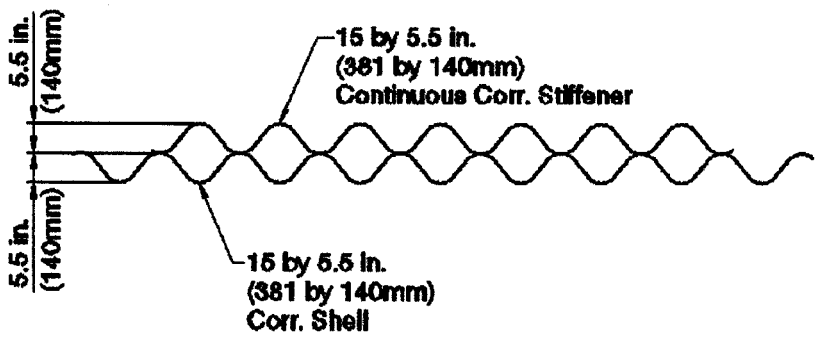

FIG. 6 Type V Continuous Crown Stiffener

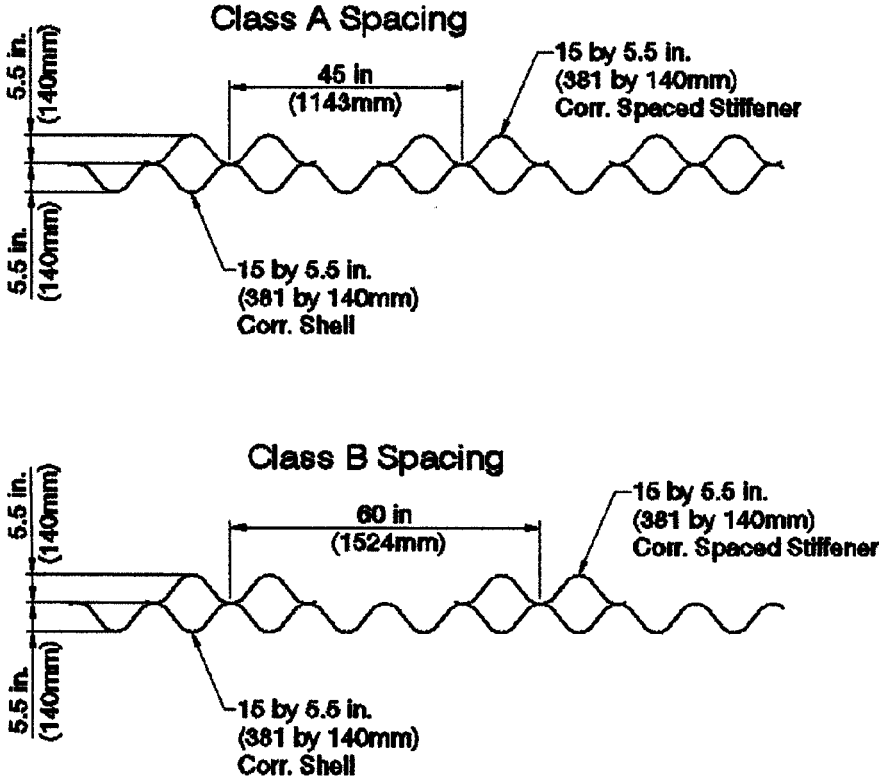

FIG. 7 Type V Spaced Haunch Stiffeners

4.1.5.2 *Type V, Class B Spacing*, consisting of external haunch stiffeners spaced at 60 in. [1524 mm] center-to-center.

5. Ordering Information

5.1 Orders for products specified herein shall include the following information required as necessary to adequately describe the desired product characteristics:

5.1.1 Name of product (corrugated steel box culvert),

5.1.2 ASTM designation and year of issue, as A 964- for inch-pound units or A 964M- for SI units,

5.1.3 Number of structures,

5.1.4 Nominal dimensions of each structure including the rise, span, length (measured along the bottom centerline), and the unobstructed cross sectional area required,

NOTE 1—The nominal length increment is 2 ft [0.61 m] for Types I, II and IV box culverts and 2.5 ft [0.76 m] for Types III and V box culverts. Also, structure types with internal stiffeners reduce the available cross sectional area below nominal values. Therefore, the unobstructed cross sectional area required by the hydraulic design may be important in some cases.

5.1.5 The design ground surface profile documenting the location and magnitude of the minimum and maximum cover height over structure top centerline (measured from the inside crest of the corrugated plate to the finished surface of the traveled way),

NOTE 2—The design specifications limit cover height to a range of between 1.4 ft and 5.0 ft [0.43 m and 1.52 m]. Small deviations in the height of cover can make a significant difference in the design. It is recommended that the purchaser specify the ground surface profile to the nearest 0.1 ft [30 mm].

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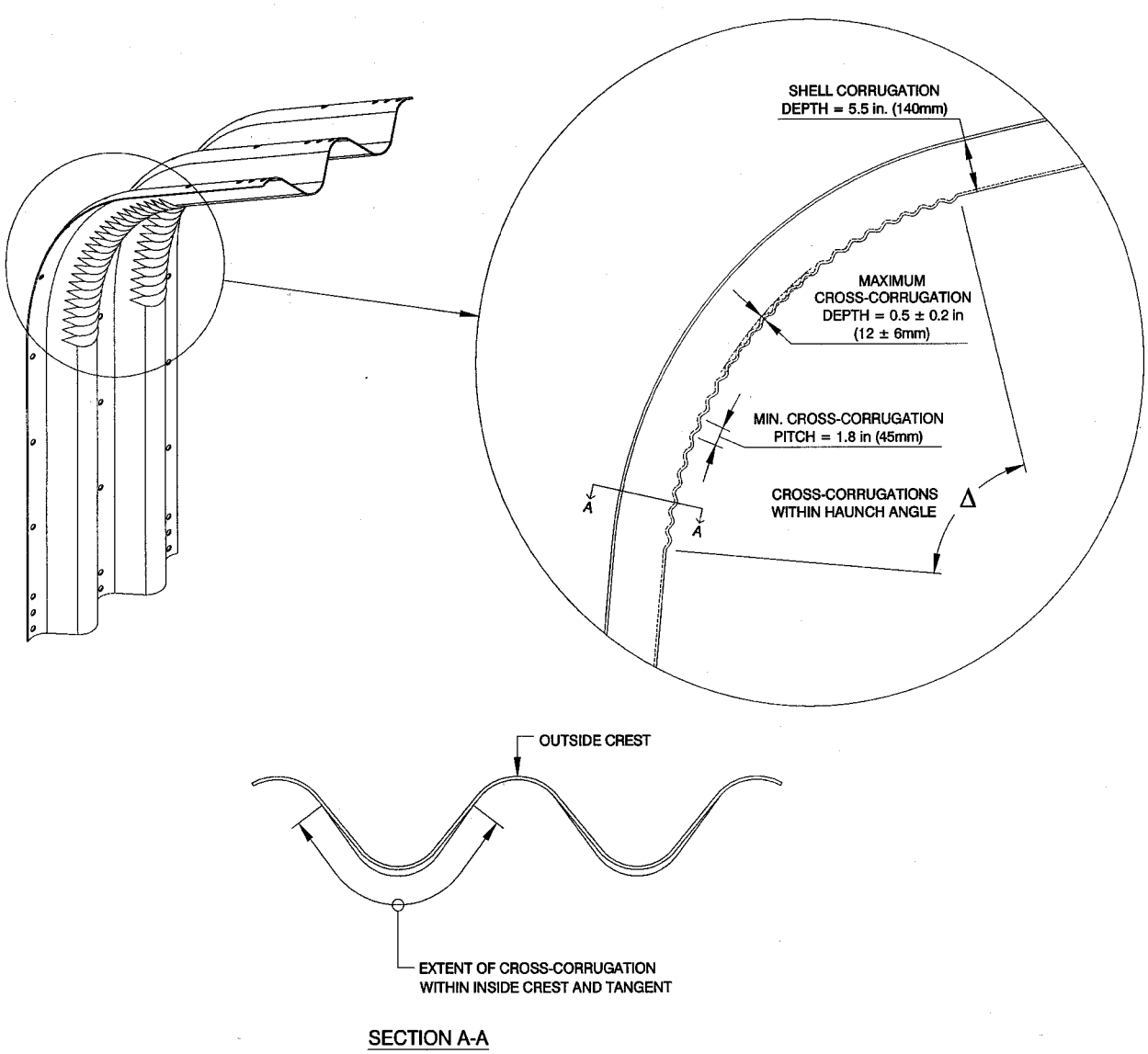

FIG. 8 Type V Cross-Corrugation Detail at Haunch

5.1.6 Dead load unit weight, if different than 120 lb/ft^3 [18.9 kN/m^3],

5.1.7 Structure live load vehicle configuration, if different than AASHTO HS 20-44 (see AASHTO LRFD Bridge Design Specifications, Customary U.S. Units [LRFD Bridge Design Specifications, SI Units),

5.1.8 Base channel, corrugated footing pads or full invert plates, if required. For box culverts not supported on concrete footings, allowable foundation bearing capacity, if different than 2 tons/ft^2 (192 kPa),

NOTE 3—Design procedures for corrugated footing pads or full invert plates are beyond the scope of this specification. However, general considerations for design of structural plate arch footings are given in A 796. Also, specific design criteria for similar applications are available in the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units).

5.1.9 End treatment (bevel, skew, grade or slope corrections, corrugated steel headwalls, cut-off walls, or other special provision), if required,

NOTE 4—End conditions involving beveled or skewed cut ends may require a support wall or collar. The design procedures for these end treatments as well as vertical headwalls are beyond the scope of this specification.

5.1.10 Optionally, structure type (if not included in the order, structure type shall be the option of the fabricator),

NOTE 5—Some of the structure types specified herein may be proprietary and available from only one fabricator. Also, some fabricators may furnish more than one type. The most competitive alternative will generally be obtained by leaving type selection to the option of the fabricator. Note the revised plate material used in Type V boxes as specified in 7.1 and 7.6.

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5.1.11 Other special requirements such as stubs, tap-ins, saddles, elbows, etc., if required, and

5.1.12 Material certification, if required (see 13.1).

NOTE 6—Typical ordering information may be described as: one corrugated steel box culvert, in accordance with ASTM A 964-, 7 ft, 3 in. rise by 20 ft, 8 in. span by 120 ft long, having a 1.4 ft minimum cover and a 3.0 ft maximum cover, with base channels for concrete footings; or two corrugated steel box culverts, in accordance with ASTM A 964M-, each being 1.88 m rise by 4.65 m span by 18.3 m long, each having 0.43 m minimum and maximum covers, assuming a dead load unit weight of 21.3 kN/m^3, having full invert plates and having ends slope adjusted for 2-percent grade, including certification.

6. Design Properties

6.1 The required design properties shall be determined for the crown and haunch segments of the box culvert in accordance with the ordering information and the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units) (see 1.6 and 2.2). The AASHTO specifications are applicable for the range of geometric limits given in Fig. 1 and Table 1.

7. Materials and Coatings

7.1 The corrugated plate material utilized for the shells of Type I, II, III and IV box culverts shall be fabricated from steel sheet or plate conforming to the chemical, mechanical, thickness, shape, and coating requirements of Specification A 761/A 761M. The corrugated plate material for Type V box culverts shall be fabricated from steel sheet or plate meeting the same requirements of A 761/A 761M except with a higher minimum flat plate yield strength of 40 ksi [275 MPa] and in accordance with the requirements of 7.11.

7.2 Stiffeners for Type I box culverts shall be 6 by 3 in. [152 by 76 mm] cold formed sections fabricated from steel sheet or plate conforming to the chemical, mechanical, thickness and coating requirements of Specification A 761/A 761M. They shall also meet the dimensions and tolerances of Fig. 2.

7.3 Stiffeners for Type II box culverts shall be 3 by 5 by 0.5 in. [76 by 127 by 13 mm] hot rolled steel angles conforming to the dimensional requirements of Specification A 6/A 6M and to the chemical and mechanical requirements of Specification A 36/A 36M. These members shall be hot dip galvanized after fabrication in accordance with the coating requirements of Specification A 123/A 123M.

7.4 Stiffeners for Type IV box culverts shall be a 6 by 2 in. [152 by 51 mm] corrugated structural member fabricated from sheet or plate conforming to the chemical, mechanical, thickness, shapes and coating requirements of Specification A 761/A 761M.

7.5 Stiffeners for Type V box culverts shall be a 15 by 5.5 in. [381 by 140 mm] corrugated structural member fabricated from sheet or plate conforming to the chemical, mechanical, thickness, shapes and coating requirements of Specification A 761/A 761M except with a minimum flat plate yield strength of 40 ksi [275 MPa] and in accordance with the requirements of 7.11.

7.6 Base channels, when specified, shall be fabricated from flat steel plate conforming to the chemical, mechanical and coating requirements of Specification A 761/A 761M, having a nominal coated thickness of 0.188 in. [4.78 mm].

7.7 Corrugated steel footing and full invert members, when specified, shall conform to the same material and coating requirements as 7.1. Thickness shall be as required by the design (see Note 3).

7.8 Corrugated steel headwalls, when specified, shall conform to the same material and coating requirements as 7.1. Walers, tie-back rods, deadman anchors, and other members fabricated from steel shapes, plates and bars shall conform to the chemical and mechanical requirements of Specification A 36/A 36M, except that assembly fasteners shall meet the requirements of 7.10. These members shall be hot dip galvanized after fabrication in accordance with the coating requirements of Specification A 123/A 123M. Thickness, shape and dimensions of these members shall be as required by the design (see Note 4).

7.9 Steel cut-off walls, when specified, shall conform to the same material and coating requirements as 7.1 above, having a nominal coated thickness of not less than 0.111 in. [2.82 mm]. Cut-off walls are permitted to be either corrugated or flat.

7.10 Assembly fasteners. Bolts and nuts required to join corrugated members together, to join corrugated members to other structural shapes or to join structural shapes together shall conform to the requirements of Specification A 761/A 761M.

7.11 If agreed upon between the purchaser and the fabricator, steel sheet and plate having higher minimum yields are permitted to be substituted for Specification A 761/A 761M stock provided the elongation in 2 in. [50 mm] of the substituted steel is not less than 23 % before fabrication and the final fabricated product meets the required tolerances on shape and thickness specified in Specification A 761/A 761M.

TABLE 1 Geometric Limits of Box Culverts

Elements[A]	Minimum	Maximum
Span (*S*)	8.75 ft [2.67 m]	25.42 ft [7.75 m]
Rise (*R*)	2.50 ft [0.76 m]	10.50 ft [3.20 m]
Radius of crown (r_c)	. . .	24.79 ft [7.56 m]
Radius of haunch (r_h)	2.50 ft [0.76 m]	. . .
Haunch angle (Δ)	50°	70°
Length of leg (*D*)	0.50 ft [0.15 m]	5.2 ft [1.59 m]
Length of rib on leg (*t*)	[B]	. . .

[A] See Fig. 1 for illustration of geometric elements.

[B] Minimum 19 in. [483 mm] or length of leg (*D*) minus 3 in. [76 mm], whichever is less.

8. Fabrication

8.1 The corrugated steel shell of the box culvert shall conform to the geometric dimensional limits specified in Table 1 and shall be subject to the permissible variations of 10.1, 10.2, and 10.3.

8.2 Corrugated steel shell plates of all box culvert types shall be fabricated in accordance with Specification A 761/A 761M. The longitudinal plate lap of the steel shell shall be adequate to develop the bending and axial forces carried by the shell at the location of the lap.

8.3 Corrugated stiffeners for Type I box culverts shall be formed with smooth, continuous curves and tangents in the

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TABLE 2 Permissible Variations[A] in Box Culvert Dimensions

Rise[B]	Span[B]		Length		Area[C]
% Variation	Range-ft (m)	% Variation	Range-ft (m)	% Variation	% Variation
±2 % of span	8.75 to 12.24 [2.67 to 3.72]	±7 % of span	30 to 49 [9.1 to 15.0]	±5 % of length	−2 % of area
	12.25 to 20.41 [3.73 to 6.21]	±5 % of span	50 to 149 [15.1 to 45.5]	±3 % of length	
	20.42 to 25.42 [6.22 to 7.75]	±3 % of span	≥150 (≥45.6]	±1 % of length	

[A]The permissible variations listed provide for differences in shape between various manufacturers' standard products as well as normal manufacturing tolerances.
[B]In no case shall the permitted variations in rise and span result in a combination of cover height and loading requirements that fall outside the limits specified by the design (see 6.1].
[C]A limitation to the positive variation in area is not applicable.

cross section of the corrugation to the dimensional requirements shown in Fig. 2. Bolt hole spacing and edge distances shall be in accordance with Specification A 761/A 761M for the 6 by 2 in. [152 by 51 mm] corrugation. They shall be curved into annular rings conforming to the shape and dimensions of the structural plate shell. The bolt holes shall be punched so that all members having like dimensions and curvature are interchangeable. Sufficient bolt holes shall be provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the corrugated stiffeners. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.1 for the thickness and spacing class required by the design.

8.4 Hot rolled angle stiffeners for Type II box culverts shall be curved into annular rings conforming to the shape and dimensions of the structural plate shell. The bolt holes shall be punched so that all members having like dimensions and curvature are interchangeable. Sufficient bolt holes shall be provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the angle stiffeners. The layout of the angle stiffeners relative to the corrugated shell shall be in accordance with 4.1.2 for the thickness and spacing class required by the design.

8.5 Corrugated stiffeners for Type IV box culverts shall be a 6 by 2 in. [152 by 51 mm] corrugated structural member curved into annular rings conforming to the shape and dimensions of the structural plate shell. They shall be formed with smooth, continuous curves and tangents in the cross section of the corrugation. Bolt hole spacing and edge spacing shall be in accordance with Specification A 761/A 761M for the 6 by 2 in. [152 by 51 mm] corrugation. The bolt holes shall be punched so that all members having like dimensions and curvatures are interchangeable. Sufficient matching bolt holes shall be provided in the corrugated shell and stiffeners to meet the requirements of 8.8. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.4 for the thickness and spacing class required by the design.

8.6 Corrugated stiffeners for Type V box culverts shall be 15 by 5.5 in. [381 by 140 mm] corrugated structural members curved into annular rings conforming to the shape and dimensions of the structural plate shell. They shall be formed with smooth, continuous curves and tangents in the cross section of the corrugation. Bolt hole spacing shall be in accordance with Specification A 761/A 761M for the 15 by 5.5 in. [381 by 140 mm] corrugation except that edge bolt hole spacing shall be duplicated along the middle corrugation. The bolt holes shall be punched so that all members having like dimensions and curvatures are interchangeable. Sufficient bolt holes shall be provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the corrugated stiffeners. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.5 for the thickness and spacing class required by the design.

8.7 Stiffeners that are designed to be continuous around the periphery of the crown and haunch, but that are not fabricated in one piece, shall be either overlapped or provided with splice connections at the intermediate ends. The design of the overlap or splice shall be adequate to develop the bending and axial forces carried by the stiffener at the location of the overlap or splice.

8.8 Stiffeners shall be provided with adequate bolted connectors to resist the beam shear that develops between the stiffener and the shell due to the moment requirements described in 6.1.

8.9 Corrugated footing and invert plates shall be fabricated in accordance with Specification A 761/A 761M.

8.10 Special members for headwalls, cut-off walls, base channels, etc. and special plates forming skewed ends, beveled ends, or curved alignment, when required, shall be accurately cut to fit the requirements of the ordering information. Cut edges of members shall not contain excessive notches, gouges, or burrs, and shall present a workmanlike finish.

9. Repair of Damaged Coating

9.1 Plates, stiffeners, or accessories on which the metallic coating has been burned by welding, or has been otherwise damaged in fabricating or handling, shall be repaired in accordance with Specification A 761/A 761M.

10. Dimensions, Mass, and Permissible Variations

10.1 Furnished box culvert dimensions shall not vary from the ordered sizes by more than the permissible amounts given in Table 2, except as noted in 10.2 and 10.3.

10.2 When agreed upon between the purchaser and the fabricator, the span dimension furnished is permitted to exceed that allowed by the permissible variations given in Table 2. However, the variation in cross sectional area furnished shall meet the requirements of Table 2, compared to that ordered. Also, the actual span shall be used in lieu of the ordered span for structural design (see 1.2 and 6.1).

10.3 When agreed upon between the purchaser and the fabricator, the variation in the rise dimension furnished is permitted to exceed Table 2. However, the variation in cross sectional area furnished shall meet the requirements of Table 2, compared to that ordered. Also, the resulting shape and height

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of cover shall meet the structural and hydraulic design requirements for box culverts (see 1.2, 1.3, and 6.1).

11. Workmanship, Finish, and Appearance

11.1 Corrugated plate shells, stiffeners, accessories, and fasteners shall be of uniform quality consistent with good manufacturing, fabrication and inspection practices.

12. Sampling and Testing

12.1 Sampling and testing of corrugated plate material for chemical composition, mechanical properties, and coating weight shall be in accordance with Specification A 761/A 761M.

12.2 Sampling and testing of miscellaneous structural shapes and flat plates for chemical composition and mechanical properties shall be in accordance with Specification A 6/A 6M. Sampling and testing for coating weight of these members shall be in accordance with Specification A 123/A 123M.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. Rejection shall be reported to the fabricator promptly and in writing. In case of dissatisfaction with the results of the test, the fabricator shall make claim for a rehearing.

14. Material Certification

14.1 When specified in the purchase order or contract, the purchaser shall be furnished a material certification that samples representing each lot have been either tested or inspected as directed in this specification and that the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

15. Product Marking

15.1 Each corrugated plate, excluding corrugated stiffeners, shall be identified in accordance with the requirements of Specification A 761/A 761M.

16. Assembly Drawings

16.1 The purchaser shall be furnished with assembly drawings showing the layout and location of all structural members supplied in accordance with the ordering information. Legible identification shall be placed on each special member to designate its proper position in the finished structure and shall be referenced on the assembly drawings.

17. Keywords

17.1 bridge; box culvert; corrugated structural plate; culvert; galvanized steel; grade separation; low cover structure; low profile structure; storm sewer

APPENDIXES

(Nonmandatory Information)

X1. DIMENSIONS AND HYDRAULIC PROPERTIES OF BOX CULVERT SIZES COMMONLY AVAILABLE

X1.1 See Table X1.1 for nominal dimensions of box culvert sizes commonly available.

TABLE X1.1 Dimensions and Hydraulic Properties of Box Culvert Sizes Commonly Available

Number	Rise, ft [m]	Span, ft [m]	Area,[A] ft^2 [m^2]	R,[B] ft [m]	WP,[C] ft [m]	$AR^{2/3D}$	$AD^{1/2E}$
1	2 ft 6 in. [0.762]	9 ft 2 in. [2.79]	18.4 [1.71]	0.920 [0.280]	20.0 [6.10]	17.4 [0.732]	29.1 [1.49]
2	2 ft 7 in. [0.787]	9 ft 8 in. [2.95]	20.2 [1.88]	0.910 [0.277]	22.2 [6.77]	19.0 [0.798]	32.5 [1.67]
3	2 ft 8 in. [0.813]	10 ft 6 in. [3.19]	22.6 [2.10]	0.950 [0.290]	23.8 [7.25]	21.8 [0.919]	36.9 [1.89]
4	2 ft 9 in. [0.838]	11 ft 1 in. [3.37]	24.8 [2.30]	1.02 [0.311]	24.3 [7.41]	25.1 [1.06]	41.1 [2.11]
5	2 ft 10 in. [0.864]	11 ft 10 in. [3.60]	27.8 [2.58]	1.04 [0.317]	26.7 [8.15]	28.5 [1.20]	46.8 [2.40]
6	2 ft 11 in. [0.889]	12 ft 9 in. [3.89]	30.6 [2.84]	1.08 [0.329]	28.3 [8.64]	32.2 [1.36]	52.3 [2.68]
7	3 ft 1 in. [0.940]	13 ft 2 in. [4.02]	33.5 [3.11]	1.13 [0.344]	29.6 [9.04]	36.3 [1.53]	58.8 [3.02]
8	3 ft 2 in. [0.965]	14 ft 1 in. [4.29]	36.6 [3.40]	1.17 [0.357]	31.3 [9.53]	40.6 [1.71]	65.1 [3.34]
9	3 ft 3 in. [0.991]	14 ft 6 in. [4.43]	39.0 [3.62]	1.23 [0.375]	31.7 [9.66]	44.8 [1.88]	70.3 [3.61]
10	3 ft 4 in. [1.02]	9 ft [2.76]	24.2 [2.25]	1.13 [0.344]	21.4 [6.53]	26.3 [1.10]	44.2 [2.27]
11	3 ft 4 in. [1.02]	10 ft 1 in. [3.07]	27.7 [2.57]	1.18 [0.360]	23.5 [7.15]	30.9 [1.30]	50.6 [2.59]
12	3 ft 5 in. [1.04]	10 ft 10 in. [3.30]	30.8 [2.86]	1.20 [0.366]	25.7 [7.82]	34.8 [1.46]	56.9 [2.92]
13	3 ft 5 in. [1.04]	15 ft 4 in. [4.68]	43.3 [4.02]	1.27 [0.387]	34.1 [10.4]	50.8 [2.14]	80.0 [4.11]
14	3 ft 6 in. [1.07]	11 ft 6 in. [3.51]	33.2 [3.08]	1.25 [0.381]	26.6 [8.10]	38.5 [1.62]	62.1 [3.19]
15	3 ft 6 in. [1.07]	16 ft [4.89]	46.2 [4.29]	1.30 [0.396]	35.5 [10.8]	55.0 [2.32]	86.4 [4.43]
16	3 ft 8 in. [1.12]	12 ft 2 in. [3.70]	37.2 [3.46]	1.30 [0.396]	28.6 [8.72]	44.3 [1.86]	71.2 [3.65]
17	3 ft 8 in. [1.12]	16 ft 8 in. [5.09]	50.7 [4.71]	1.36 [0.415]	37.3 [11.4]	62.2 [2.62]	97.1 [4.98]
18	3 ft 9 in. [1.14]	12 ft 10 in. [3.91]	39.7 [3.69]	1.35 [0.411]	29.4 [8.96]	48.5 [2.04]	76.9 [3.94]
19	3 ft 10 in. [1.17]	13 ft 6 in. [4.10]	44.0 [4.09]	1.42 [0.433]	31.0 [9.44]	55.6 [2.34]	86.1 [4.42]
20	3 ft 10 in. [1.17]	17 ft 6 in. [5.33]	54.0 [5.02]	1.42 [0.433]	38.0 [11.6]	68.2 [2.87]	106 [5.42]
21	4 ft [1.22]	14 ft 4 in. [4.36]	47.8 [4.44]	1.44 [0.439]	33.2 [10.1]	61.0 [2.56]	95.6 [4.90]
22	4 ft [1.22]	18 ft 2 in. [5.54]	58.8 [5.46]	1.47 [0.448]	40.0 [12.2]	76.0 [3.20]	118 [6.03]
23	4 ft 1 in. [1.24]	9 ft 6 in. [2.90]	31.1 [2.89]	1.32 [0.402]	23.6 [7.18]	37.4 [1.57]	62.8 [3.22]

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TABLE X1.1 *Continued*

Number	Rise, ft [m]	Span, ft [m]	Area,[A] ft^2 [m^2]	R,[B] ft [m]	WP,[C] ft [m]	AR$^{2/3D}$	AD$^{1/2E}$
24	4 ft 1 in. [1.24]	14 ft 10 in. [4.52]	51.3 [4.77]	1.50 [0.457]	34.2 [10.4]	67.2 [2.83]	104 [5.32]
25	4 ft 2 in. [1.27]	10 ft 7 in. [3.22]	35.9 [3.34]	1.37 [0.418]	26.2 [7.99]	44.3 [1.86]	73.3 [3.76]
26	4 ft 2 in. [1.27]	15 ft 7 in. [4.74]	55.6 [5.17]	1.54 [0.469]	36.1 [11.0]	74.1 [3.12]	113 [5.82]
27	4 ft 2 in. [1.27]	18 ft 9 in. [5.72]	62.2 [5.78]	1.53 [0.466]	40.7 [12.4]	82.6 [3.47]	127 [6.51]
28	4 ft 3 in. [1.30]	11 ft 2 in. [3.42]	39.4 [3.66]	1.42 [0.433]	27.7 [8.46]	49.8 [2.09]	81.2 [4.17]
29	4 ft 3 in. [1.30]	19 ft 5 in. [5.92]	66.0 [6.13]	1.55 [0.472]	42.6 [13.0]	88.4 [3.72]	136 [6.98]
30	4 ft 4 in. [1.32]	11 ft 9 in. [3.59]	42.4 [3.94]	1.50 [0.457]	28.3 [8.62]	55.6 [2.34]	88.3 [4.53]
31	4 ft 4 in. [1.32]	16 ft 3 in. [4.96]	59.5 [5.53]	1.61 [0.491]	37.0 [11.3]	81.7 [3.44]	124 [6.35]
32	4 ft 5 in. [1.35]	12 ft 6 in. [3.80]	46.9 [4.36]	1.53 [0.466]	30.7 [9.34]	62.3 [2.62]	98.6 [5.06]
33	4 ft 6 in. [1.37]	13 ft 3 in. [4.03]	49.4 [4.59]	1.57 [0.479]	31.5 [9.59]	66.7 [2.81]	105 [5.37]
34	4 ft 6 in. [1.37]	16 ft 10 in. [5.13]	64.1 [5.95]	1.65 [0.503]	38.8 [11.8]	89.5 [3.77]	136 [6.97]
35	4 ft 6 in. [1.37]	20 ft [6.08]	70.8 [6.58]	1.64 [0.500]	43.2 [13.2]	98.5 [4.14]	150 [7.70]
36	4 ft 7 in. [1.40]	17 ft 9 in. [5.42]	67.2 [6.24]	1.68 [0.512]	40.0 [12.2]	95.0 [4.00]	144 [7.38]
37	4 ft 7 in. [1.40]	20 ft 8 in. [6.29]	74.7 [6.94]	1.66 [0.506]	45.0 [13.7]	105 [4.41]	160 [8.20]
38	4 ft 8 in. [1.42]	13 ft 9 in. [4.20]	54.8 [5.09]	1.66 [0.506]	33.0 [10.1]	76.8 [3.23]	118 [6.07]
39	4 ft 9 in. [1.45]	14 ft 7 in. [4.45]	59.1 [5.49]	1.69 [0.515]	35.0 [10.7]	83.9 [3.53]	129 [6.61]
40	4 ft 9 in. [1.45]	18 ft 4 in. [5.60]	73.1 [6.79]	1.74 [0.530]	42.0 [12.8]	106 [4.45]	159 [8.17]
41	4 ft 11 in. [1.50]	10 ft [3.04]	39.1 [3.63]	1.52 [0.463]	25.7 [7.84]	51.7 [2.17]	86.7 [4.45]
42	4 ft 11 in. [1.50]	11 ft [3.34]	44.2 [4.11]	1.57 [0.479]	28.2 [8.58]	59.7 [2.51]	98.0 [5.03]
43	4 ft 11 in. [1.50]	15 ft [4.57]	63.2 [5.87]	1.77 [0.539]	35.7 [10.9]	92.5 [3.89]	140 [7.19]
44	4 ft 11 in. [1.50]	19 ft 2 in. [5.83]	78.2 [7.26]	1.81 [0.552]	43.2 [13.2]	116 [4.89]	173 [8.89]
45	4 ft 11 in. [1.50]	21 ft 6 in. [6.57]	83.8 [7.79]	1.77 [0.539]	47.3 [14.4]	123 [5.16]	186 [9.53]
46	5 ft [1.52]	11 ft 8 in. [3.54]	48.2 [4.48]	1.66 [0.506]	29.0 [8.85]	67.6 [2.84]	108 [5.53]
47	5 ft [1.52]	15 ft 10 in. [4.82]	68.1 [6.33]	1.80 [0.549]	37.8 [11.5]	101 [4.24]	152 [7.81]
48	5 ft 1 in. [1.55]	12 ft 5 in. [3.79]	52.5 [4.88]	1.68 [0.512]	31.3 [9.52]	74.2 [3.12]	118 [6.07]
49	5 ft 1 in. [1.55]	19 ft 8 in. [5.98]	82.3 [7.65]	1.85 [0.564]	44.5 [13.6]	124 [5.22]	186 [9.52]
50	5 ft 2 in. [1.57]	12 ft 10 in. [3.91]	56.6 [5.26]	1.77 [0.539]	32.0 [9.75]	82.8 [3.48]	129 [6.60]
51	5 ft 2 in. [1.57]	16 ft 4 in. [4.98]	72.2 [6.71]	1.86 [0.567]	38.8 [11.8]	109 [4.59]	164 [8.42]
52	5 ft 3 in. [1.60]	17 ft 2 in. [5.22]	77.6 [7.21]	1.91 [0.582]	40.6 [12.4]	119 [5.03]	178 [9.12]
53	5 ft 3 in. [1.60]	20 ft 8 in. [6.30]	88.4 [8.21]	1.90 [0.579]	46.5 [14.2]	136 [5.71]	203 [10.4]
54	5 ft 4 in. [1.63]	13 ft 8 in. [4.17]	60.8 [5.65]	1.79 [0.546]	34.0 [10.4]	89.6 [3.77]	140 [7.20]
55	5 ft 4 in. [1.63]	22 ft 8 in. [6.90]	95.0 [8.83]	1.91 [0.582]	49.7 [15.2]	146 [6.15]	219 [11.25]
56	5 ft 5 in. [1.65]	14 ft [4.27]	65.6 [6.09]	1.89 [0.576]	34.7 [10.6]	100 [4.22]	153 [7.83]
57	5 ft 5 in. [1.65]	18 ft [5.49]	82.2 [7.64]	1.95 [0.594]	42.2 [12.8]	128 [5.40]	191 [9.81]
58	5 ft 5 in. [1.65]	21 ft 2 in. [6.44]	94.1 [8.74]	1.98 [0.604]	47.5 [14.5]	148 [6.24]	219 [11.2]
59	5 ft 7 in. [1.70]	11 ft [3.34]	47.9 [4.45]	1.65 [0.503]	29.0 [8.85]	66.9 [2.81]	113 [5.81]
60	5 ft 7 in. [1.70]	14 ft 10 in. [4.53]	70.7 [6.57]	1.92 [0.585]	36.8 [11.2]	109 [4.60]	167 [8.57]
61	5 ft 7 in. [1.70]	18 ft 4 in. [5.58]	87.9 [8.17]	2.02 [0.616]	43.5 [13.3]	140 [5.91]	208 [10.7]
62	5 ft 8 in. [1.73]	11 ft 5 in. [3.47]	52.6 [4.89]	1.77 [0.539]	29.7 [9.06]	77.0 [3.24]	125 [6.42]
63	5 ft 8 in. [1.73]	15 ft 5 in. [4.71]	75.1 [6.98]	2.00 [0.610]	37.6 [11.4]	119 [5.02]	179 [9.17]
64	5 ft 8 in. [1.73]	19 ft 3 in. [5.87]	93.3 [8.67]	2.07 [0.631]	45.1 [13.7]	152 [6.38]	222 [11.4]
65	5 ft 8 in. [1.73]	22 ft 2 in. [6.77]	101 [9.38]	2.05 [0.625]	49.3 [15.0]	163 [6.86]	240 [12.3]
66	5 ft 9 in. [1.75]	12 ft [3.66]	57.2 [5.31]	1.84 [0.561]	31.1 [9.47]	85.9 [3.61]	137 [7.03]
67	5 ft 10 in. [1.78]	16 ft [4.89]	80.7 [7.50]	2.03 [0.619]	39.8 [12.1]	129 [5.44]	195 [10.0]
68	5 ft 10 in. [1.78]	19 ft 10 in. [6.05]	97.2 [9.03]	2.10 [0.640]	46.3 [14.1]	159 [6.71]	235 [12.0]
69	5 ft 10 in. [1.78]	23 ft 9 in. [7.24]	108 [10.1]	2.05 [0.625]	52.8 [16.1]	175 [7.35]	261 [13.4]
70	5 ft 11 in. [1.80]	12 ft 10 in. [3.92]	62.3 [5.79]	1.88 [0.573]	33.1 [10.1]	94.9 [3.99]	152 [7.77]
71	5 ft 11 in. [1.80]	16 ft 8 in. [5.07]	84.7 [7.87]	2.08 [0.634]	40.7 [12.4]	138 [5.81]	206 [10.6]
72	6 ft [1.83]	13 ft 2 in. [4.02]	66.6 [6.19]	1.97 [0.600]	33.8 [10.3]	105 [4.40]	163 [8.37]
73	6 ft 1 in. [1.85]	14 ft [4.27]	72.1 [6.70]	2.01 [0.613]	35.9 [10.9]	115 [4.83]	178 [9.12]
74	6 ft 1 in. [1.85]	17 ft 2 in. [5.23]	91.3 [8.48]	2.15 [0.655]	42.5 [12.9]	152 [6.40]	225 [11.5]
75	6 ft 1 in. [1.85]	19 ft 2 in. [5.85]	97.1 [9.02]	2.17 [0.661]	44.7 [13.6]	163 [6.85]	239 [12.3]
76	6 ft 1 in. [1.85]	23 ft 4 in. [7.10]	114 [10.6]	2.19 [0.668]	51.9 [15.8]	192 [8.07]	280 [14.4]
77	6 ft 2 in. [1.88]	20 ft 11 in. [6.37]	106 [9.80]	2.19 [0.668]	48.2 [14.7]	178 [7.49]	262 [13.4]
78	6 ft 2 in. [1.88]	24 ft 10 in. [7.56]	119 [11.1]	2.19 [0.668]	54.3 [16.6]	201 [8.44]	296 [15.2]
79	6 ft 3 in. [1.91]	14 ft 4 in. [4.37]	76.6 [7.12]	2.09 [0.637]	36.7 [11.2]	125 [5.27]	192 [9.82]
80	6 ft 3 in. [1.91]	18 ft [5.48]	96.9 [9.00]	2.21 [0.674]	43.8 [13.4]	164 [6.92]	242 [12.4]
81	6 ft 4 in. [1.93]	10 ft 10 in. [3.30]	53.8 [5.00]	1.82 [0.555]	29.6 [9.01]	80.2 [3.37]	135 [6.94]
82	6 ft 4 in. [1.93]	15 ft 1 in. [4.61]	82.5 [7.66]	2.13 [0.649]	38.7 [11.8]	137 [5.75]	208 [10.6]
83	6 ft 4 in. [1.93]	18 ft 4 in. [5.60]	102 [9.47]	2.27 [0.692]	44.9 [13.7]	176 [7.41]	256 [13.2]
84	6 ft 5 in. [1.96]	11 ft 9 in. [3.59]	61.2 [5.69]	1.93 [0.588]	31.7 [9.66]	94.9 [3.99]	155 [7.95]
85	6 ft 6 in. [1.98]	15 ft 6 in. [4.72]	87.1 [8.09]	2.22 [0.677]	39.2 [12.0]	148 [6.24]	222 [11.4]
86	6 ft 6 in. [1.98]	19 ft 2 in. [5.85]	107 [9.90]	2.29 [0.698]	46.6 [14.2]	185 [7.79]	272 [13.9]
87	6 ft 6 in. [1.98]	20 ft 2 in. [6.16]	109 [10.1]	2.30 [0.701]	47.5 [14.5]	190 [8.01]	278 [14.3]
88	6 ft 6 in. [1.98]	22 ft 5 in. [6.83]	118 [11.0]	2.32 [0.707]	51.0 [15.6]	207 [8.73]	302 [15.5]
89	6 ft 6 in. [1.98]	24 ft 4 in. [7.40]	127 [11.8]	2.31 [0.704]	55.1 [16.8]	222 [9.35]	324 [16.6]
90	6 ft 7 in. [2.01]	12 ft 5 in. [3.78]	66.4 [6.17]	2.01 [0.613]	33.0 [10.1]	106 [4.45]	170 [8.74]
91	6 ft 7 in. [2.01]	16 ft 3 in. [4.94]	93.5 [8.69]	2.25 [0.686]	41.6 [12.7]	161 [6.75]	240 [12.3]
92	6 ft 8 in. [2.03]	13 ft 1 in. [3.99]	72.3 [6.72]	2.06 [0.628]	35.1 [10.7]	117 [4.93]	187 [9.57]
93	6 ft 8 in. [2.03]	19 ft 8 in. [6.01]	113 [10.5]	2.38 [0.725]	47.6 [14.5]	202 [8.50]	293 [15.0]
94	6 ft 9 in. [2.06]	13 ft 6 in. [4.12]	76.9 [7.14]	2.15 [0.655]	35.8 [10.9]	128 [5.39]	200 [10.2]
95	6 ft 9 in. [2.06]	16 ft 10 in. [5.12]	98.3 [9.13]	2.33 [0.710]	42.2 [12.9]	173 [7.27]	255 [13.1]
96	6 ft 10 in. [2.08]	17 ft 5 in. [5.31]	105 [9.76]	2.37 [0.722]	44.3 [13.5]	187 [7.86]	275 [14.1]
97	6 ft 10 in. [2.08]	2 ft 3 in. [6.48]	122 [11.3]	2.42 [0.738]	50.3 [15.3]	219 [9.23]	318 [16.3]

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TABLE X1.1 *Continued*

Number	Rise, ft [m]	Span, ft [m]	Area,[A] ft^2 [m^2]	R,[B] ft [m]	WP,[C] ft [m]	AR$^{2/3}$[D]	AD$^{1/2}$[E]
98	6 ft 11 in. [2.11]	14 ft 2 in. [4.32]	83.1 [7.72]	2.20 [0.671]	37.8 [11.5]	141 [5.91]	219 [11.2]
99	6 ft 11 in. [2.11]	19 ft 7 in. [5.97]	112 [10.4]	2.39 [0.728]	46.8 [14.3]	200 [8.42]	294 [15.1]
100	6 ft 11 in. [2.11]	23 ft 5 in. [7.14]	132 [12.3]	2.46 [0.750]	53.7 [16.4]	241 [10.1]	347 [17.8]
101	7 ft [2.13]	14 ft 8 in. [4.48]	88.4 [8.21]	2.28 [0.695]	38.8 [11.8]	153 [6.44]	234 [12.0]
102	7 ft [2.13]	18 ft 1 in. [5.51]	111 [10.3]	2.46 [0.750]	45.2 [13.8]	202 [8.52]	294 [15.1]
103	7 ft [2.13]	21 ft 2 in. [6.44]	127 [11.8]	2.51 [0.765]	50.8 [15.5]	235 [9.90]	337 [17.3]
104	7 ft [2.13]	25 ft 4 in. [7.71]	142 [13.2]	2.47 [0.753]	57.6 [17.5]	260 [10.9]	376 [19.3]
105	7 ft 11 in. [2.16]	15 ft 5 in. [4.69]	94.5 [8.78]	2.33 [0.710]	40.6 [12.4]	166 [6.99]	252 [12.9]
106	7 ft 2 in. [2.18]	11 ft 4 in. [3.44]	63.0 [5.85]	1.98 [0.604]	31.8 [9.70]	99.3 [4.18]	169 [8.65]
107	7 ft 2 in. [2.18]	18 ft 9 in. [5.71]	117 [10.9]	2.52 [0.768]	46.5 [14.2]	217 [9.14]	314 [16.1]
108	7 ft 3 in. [2.21]	12 ft 3 in. [3.73]	71.2 [6.61]	2.07 [0.631]	34.4 [10.5]	116 [4.87]	192 [9.83]
109	7 ft 3 in. [2.21]	15 ft 8 in. [4.79]	98.7 [9.17]	2.40 [0.732]	41.1 [12.5]	177 [7.44]	266 [13.6]
110	7 ft 3 in. [2.21]	20 ft 7 in. [6.27]	125 [11.6]	2.53 [0.771]	49.4 [15.1]	232 [9.77]	337 [17.3]
111	7 ft 3 in. [2.21]	22 ft 7 in. [6.88]	136 [12.6]	2.57 [0.783]	52.9 [16.1]	255 [10.7]	366 [18.8]
112	7 ft 4 in. [2.24]	12 ft 10 in. [3.90]	76.0 [7.06]	2.17 [0.661]	35.0 [10.7]	127 [5.36]	206 [10.6]
113	7 ft 4 in. [2.24]	19 ft 1 in. [5.83]	122 [11.3]	2.55 [0.777]	47.6 [14.5]	227 [9.54]	329 [16.9]
114	7 ft 4 in. [2.24]	24 ft 5 in. [7.44]	147 [13.6]	2.60 [0.792]	56.5 [17.2]	278 [11.7]	398 [20.4]
115	7 ft 5 in. [2.26]	13 ft 4 in. [4.06]	80.4 [7.47]	2.23 [0.680]	36.1 [11.0]	137 [5.77]	219 [11.2]
116	7 ft 5 in. [2.26]	16 ft 6 in. [5.02]	107 [9.89]	2.46 [0.750]	43.3 [13.2]	194 [8.17]	290 [14.9]
117	7 ft 6 in. [2.29]	16 ft 10 in. [5.13]	112 [10.4]	2.53 [0.771]	44.1 [13.4]	207 [8.71]	305 [16.7]
118	7 ft 6 in. [2.29]	19 ft 10 in. [6.03]	130 [12.1]	2.62 [0.799]	49.5 [15.1]	247 [10.4]	355 [18.2]
119	7 ft 7 in. [2.31]	14 ft [4.26]	88.4 [8.21]	2.30 [0.701]	38.4 [11.7]	154 [6.48]	243 [12.5]
120	7 ft 8 in. [2.34]	14 ft 4 in. [4.38]	91.0 [8.45]	2.36 [0.719]	38.6 [11.8]	161 [6.79]	252 [12.9]
121	7 ft 8 in. [2.34]	17 ft 6 in. [5.34]	119 [11.1]	2.61 [0.796]	45.6 [13.9]	226 [9.49]	329 [16.9]
122	7 ft 8 in. [2.34]	20 ft [6.10]	127 [11.8]	2.61 [0.796]	48.7 [14.8]	241 [10.1]	352 [18.0]
123	7 ft 8 in. [2.34]	21 ft 2 in. [6.45]	135 [12.5]	2.65 [0.808]	50.9 [15.5]	258 [10.9]	373 [19.1]
124	7 ft 8 in. [2.34]	23 ft 6 in. [7.18]	151 [14.0]	2.71 [0.826]	55.6 [16.9]	293 [12.3]	417 [21.4]
125	7 ft 9 in. [2.36]	15 ft [4.57]	99.4 [9.23]	2.45 [0.747]	40.6 [12.4]	181 [7.60]	277 [14.2]
126	7 ft 9 in. [2.36]	25 ft 4 in. [7.72]	161 [15.0]	2.73 [0.832]	59.1 [18.0]	315 [13.26]	449 [23.0]
127	7 ft 10 in. [2.39]	18 ft 3 in. [5.56]	126 [11.7]	2.66 [0.811]	47.2 [14.4]	241 [10.1]	351 [18.0]
128	7 ft 11 in. [2.41]	15 ft 8 in. [4.78]	107 [9.92]	2.51 [0.765]	42.5 [13.0]	197 [8.30]	300 [15.4]
129	7 ft 11 in. [2.41]	18 ft 10 in. [5.74]	132 [12.3]	2.71 [0.826]	48.7 [14.9]	257 [10.8]	372 [19.1]
130	7 ft 11 in. [2.41]	20 ft 10 in. [6.34]	143 [13.3]	2.77 [0.844]	51.7 [15.8]	283 [11.9]	403 [20.7]
131	8 ft 1 in. [2.46]	16 ft [4.88]	112 [10.4]	2.59 [0.789]	43.2 [13.2]	211 [8.87]	318 [16.3]
132	8 ft 1 in. [2.46]	19 ft 3 in. [5.86]	136 [12.6]	2.76 [0.841]	49.2 [15.0]	267 [11.3]	386 [19.8]
133	8 ft 1 in. [2.46]	20 ft 11 in. [6.38]	141 [13.1]	2.75 [0.838]	51.3 [15.6]	277 [11.7]	401 [20.6]
134	8 ft 1 in. [2.46]	22 ft 10 in. [6.95]	154 [14.3]	2.81 [0.856]	54.7 [16.7]	306 [12.9]	437 [22.4]
135	8 ft 2 in. [2.49]	16 ft 8 in. [5.08]	120 [11.1]	2.67 [0.814]	44.8 [13.7]	230 [9.68]	342 [17.5]
136	8 ft 2 in. [2.49]	24 ft 6 in. [7.45]	166 [15.4]	2.86 [0.872]	58.1 [17.7]	335 [14.1]	475 [24.4]
137	8 ft 3 in. [2.51]	16 ft 10 in. [5.13]	124 [11.6]	2.73 [0.832]	45.6 [13.9]	243 [10.2]	357 [18.3]
138	8 ft 3 in. [2.51]	20 ft 2 in. [6.15]	146 [13.6]	2.84 [0.866]	51.5 [15.7]	293 [12.3]	420 [21.5]
139	8 ft 3 in. [2.54]	17 ft 1 in. [5.21]	126 [11.7]	2.75 [0.838]	45.7 [13.9]	247 [10.4]	363 [18.6]
140	8 ft 5 in. [2.57]	20 ft 4 in. [6.21]	143 [13.2]	2.81 [0.856]	50.7 [15.5]	284 [11.9]	414 [21.2]
141	8 ft 5 in. [2.57]	21 ft 10 in. [6.65]	156 [14.5]	2.89 [0.881]	53.9 [16.4]	316 [13.3]	452 [23.2]
142	8 ft 6 in. [2.59]	17 ft 8 in. [5.38]	133 [12.4]	2.80 [0.853]	47.5 [14.5]	264 [11.1]	388 [19.9]
143	8 ft 6 in. [2.59]	23 ft 8 in. [7.23]	169 [15.7]	2.96 [0.902]	57.2 [17.4]	349 [14.7]	494 [25.3]
144	8 ft 7 in. [2.62]	18 ft 4 in. [5.58]	140 [13.0]	2.87 [0.875]	48.7 [14.9]	283 [11.9]	410 [21.0]
145	8 ft 7 in. [2.62]	21 ft 2 in. [6.46]	161 [14.9]	2.97 [0.905]	54.1 [16.5]	332 [14.0]	471 [24.1]
146	8 ft 7 in. [2.62]	25 ft 4 in. [7.73]	182 [16.9]	3.00 [0.914]	60.8 [18.5]	379 [16.0]	534 [27.4]
147	8 ft 9 in. [2.67]	18 ft 11 in. [5.77]	147 [13.7]	2.94 [0.896]	50.0 [15.2]	302 [12.7]	435 [22.3]
148	8 ft 10 in. [2.69]	21 ft 3 in. [6.48]	158 [14.6]	2.95 [0.899]	53.4 [16.3]	324 [13.6]	468 [24.0]
149	8 ft 10 in. [2.69]	23 ft [7.01]	172 [15.9]	3.04 [0.927]	56.4 [17.2]	360 [15.2]	510 [26.2]
150	8 ft 11 in. [2.72]	19 ft 4 in. [5.90]	152 [14.1]	2.97 [0.905]	51.2 [15.6]	314 [13.2]	454 [23.3]
151	8 ft 11 in. [2.72]	24 ft 6 in. [7.48]	186 [17.3]	3.10 [0.945]	59.0 [18.3]	395 [16.6]	555 [28.4]
152	9 ft 1 in. [2.77]	20 ft [6.10]	162 [15.0]	3.05 [0.930]	53.0 [10.1]	340 [14.3]	487 [25.0]
153	9 ft 3 in. [2.82]	21 ft 10 in. [6.67]	173 [16.1]	3.10 [0.945]	55.9 [17.0]	368 [15.5]	527 [27.0]
154	9 ft 3 in. [2.82]	23 ft 10 in. [7.26]	188 [17.5]	3.10 [0.969]	59.2 [18.0]	407 [17.1]	572 [29.3]
155	9 ft 5 in. [2.87]	21 ft 3 in. [6.48]	177 [16.5]	3.19 [0.972]	55.6 [16.9]	384 [16.2]	544 [27.9]
156	9 ft 5 in. [2.87]	25 ft 4 in. [7.73]	203 [18.8]	3.26 [0.994]	62.2 [19.0]	446 [18.8]	623 [31.9]
157	9 ft 8 in. [2.95]	23 ft 2 in. [7.07]	190 [17.6]	3.25 [0.991]	58.4 [17.8]	416 [17.5]	590 [30.3]
158	9 ft 9 in. [2.97]	24 ft 8 in. [7.52]	205 [19.1]	3.34 [1.02]	61.5 [18.7]	459 [19.3]	641 [32.9]
159	10 ft 1 in. [3.07]	24 ft [7.32]	207 [19.2]	3.40 [1.04]	60.9 [18.6]	468 [19.7]	657 [33.7]
160	10 ft 2 in. [3.10]	25 ft 5 in. [7.75]	223 [20.7]	3.48 [1.06]	64.0 [19.5]	511 [21.5]	710 [36.4]
161	10 ft 6 in. [3.20]	24 ft 9 in. [7.54]	225 [20.9]	3.56 [1.09]	63.2 [19.3]	525 [22.1]	729 [37.4]

[A] Inside area of box culvert cross section.
[B] Hydraulic radius of box culvert cross section.
[C] Wetted perimeter of box culvert cross section.
[D] Uniform flow section factor.
[E] Inlet control section factor.

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X2. MANUFACTURERS' SUGGESTED DESIGN PROPERTIES

X2.1 The plastic moment capacities tabulated in Tables X2.1-X2.4 are based on fully effective composite action. For corrugated steel shells, with or without auxiliary stiffeners, the actual plastic moment capacity at ultimate load is a function of several factors and may be less than theoretical values. The plastic moment capacities tabulated in Table X2.5 for the Type V box are based on cumulative (non-composite) action.

TABLE X2.1 Type I Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]

Stiffener Thickness, in. [mm]	Stiffener Spacing Class	Shell Thickness in in. [mm]				
		0.111 [2.82]	0.140 [3.56]	0.170 [4.32]	0.188 [4.78]	0.218 [5.54]
	A	6.46 [12.7]	7.29 [32.4]	8.02 [35.7]	. . .	. . .
0.111 [2.82]	B	9.43 [41.9]	10.7 [47.6]	11.9 [52.9]	. . .	. . .
	C	12.0 [53.5]	12.9 [57.5]	13.8 [61.5]	. . .	. . .
	A	7.43 [33.0]	8.42 [37.4]	9.21 [41.0]	9.87 [43.9]	. . .
0.140 [3.56]	B	11.1 [49.4]	12.5 [55.6]	13.7 [60.8]	14.5 [64.5]	. . .
	C	14.6 [65.1]	15.6 [69.2]	16.6 [73.7]	17.2 [76.3]	. . .
	A	8.36 [37.3]	9.52 [42.4]	10.4 [46.5]	11.0 [48.8]	11.8 [52.7]
0.170 [4.32]	B	12.0 [53.5]	14.4 [64.0]	15.2 [67.6]	16.2 [71.9]	17.5 [77.8]
	C	17.5 [78.0]	18.3 [81.4]	19.0 [84.5]	19.5 [86.7]	20.3 [90.2]
	A	. . .	10.1 [45.0]	11.1 [49.3]	11.7 [52.1]	12.6 [56.3]
0.188 [4.78]	B	. . .	14.7 [65.4]	16.2 [72.2]	17.2 [76.3]	18.6 [82.7]
	C	. . .	20.0 [89.2]	20.8 [92.4]	21.3 [94.6]	22.0 [98.0]
	A	. . .	. . .	12.1 [54.0]	12.8 [57.0]	14.2 [63.1]
0.218 [5.54]	B	. . .	. . .	17.7 [78.6]	18.8 [83.5]	20.2 [89.8]
	C	. . .	. . .	23.6 [105]	24.0 [107]	24.8 [110]
	A	. . .	. . .	. . .	13.9 [61.7]	15.1 [67.2]
0.249 [6.33]	B	. . .	. . .	. . .	20.0 [89.1]	21.9 [97.2]
	C	. . .	. . .	. . .	26.8 [119]	27.6 [123]

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TABLE X2.2 Type II Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]

Shell Thickness, in. [mm]	Stiffener Spacing Class		
	Class A	Class B	Class C
0.111 [2.82]	12.4 [54.9]	14.2 [63.3]	17.2 [76.4]
0.140 [3.56]	13.7 [60.7]	15.7 [69.8]	18.8 [83.7]
0.170 [4.32]	14.9 [66.1]	17.0 [75.8]	20.4 [90.5]
0.188 [4.78]	15.6 [69.4]	17.8 [79.4]	21.4 [95.0]
0.218 [5.54]	16.7 [74.2]	19.0 [84.7]	22.7 [101]
0.249 [6.33]	17.7 [78.8]	20.2 [89.9]	24.0 [107]
0.280 [7.11]	18.7 [83.3]	21.3 [94.7]	25.3 [112]

TABLE X2.3 Type III Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m][A]

Shell Thickness, in. [mm]	Plastic Moment, k-ft/ft [kN-m/m]
0.140 [3.56]	10.8 [48.2]
0.170 [4.32]	13.2 [58.9]
0.188 [4.78]	14.8 [65.9]
0.218 [5.54]	17.3 [77.0]
0.249 [6.33]	19.8 [88.0]
0.280 [7.11]	22.3 [99.2]
0.318 [8.08]	25.3 [112]
0.377 [9.58]	30.4 [135]

[A]Plastic moment capacities listed are not applicable to cross-corrugated plates (plates transversely corrugated to facilitate curving).

TABLE X2.4 Type IV Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]

Stiffener Thickness, in. [mm]	Shell Thickness, in. [mm]						
	0.111 [2.82]	0.140 [3.56]	0.170 [4.32]	0.188 [4.78]	0.218 [5.54]	0.249 [6.33]	0.280 [7.11]
0.111 [2.82]	9.01 [40.08]	10.29 [45.79]	11.46 [50.99]	12.16 [54.10]	13.12 [58.37]	14.15 [62.95]	15.28 [67.98]
0.140 [3.56]	10.29 [45.79]	11.76 [52.29]	13.08 [58.18]	13.90 [61.84]	15.12 [67.27]	16.26 [72.33]	17.20 [76.53]
0.170 [4.32]	11.46 [50.99]	13.08 [58.18]	14.58 [64.84]	15.47 [68.83]	16.83 [74.85]	18.12 [80.60]	19.35 [86.06]
0.188 [4.78]	12.16 [54.10]	13.90 [61.84]	15.47 [68.83]	16.45 [73.18]	17.88 [79.53]	19.23 [85.56]	20.55 [91.41]
0.218 [5.54]	13.12 [58.37]	15.12 [67.27]	16.83 [74.85]	17.88 [79.53]	19.48 [86.67]	20.95 [93.17]	22.35 [99.42]
0.249 [6.33]	14.15 [62.95]	16.26 [72.33]	18.12 [80.60]	19.23 [85.56]	20.95 [93.17]	22.58 [100.47]	24.09 [107.18]
0.280 [7.11]	15.28 [67.98]	17.20 [76.53]	19.35 [86.06]	20.55 [91.41]	22.35 [99.42]	24.09 [107.18]	25.78 [114.68]

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TABLE X2.5 Type V Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m][A]

Stiffener Thickness, in. [mm]		Stiffener Spacing Class	Shell Thickness, in. [mm]				
			0.140[3.56]	0.170[4.32]	0.218[5.54]	0.249[6.33]	0.280[7.11]
No Stiffeners							
Full Section Crown/Leg			14.5[63.8]	17.7[78.0]	23.1[101.9]	26.5[116.6]	29.8[131.3]
Cross-corrugated Haunch			6.9[30.3]	9.8[43.2]	15.8[69.7]	20.2[89.2]	25.1[111.0]
0.140 [3.56]	Crown	Continuous	29.0[127.6]	32.2[141.8]	37.6[165.7]	41.0[180.4]	44.3[195.1]
	Haunch	A	11.4[50.4]	14.4[63.3]	20.6[90.9]	24.8[109.3]	29.8[131.1]
	Haunch	B	10.3[45.3]	13.2[58.2]	19.5[85.8]	23.7[104.3]	28.6[126.1]
0.170 [4.32]	Crown	Continuous	32.2[141.8]	35.4[156.0]	40.9[180.0]	44.2[194.6]	47.6[209.4]
	Haunch	A	13.4[59.0]	16.3[71.9]	22.6[99.5]	26.8[118.0]	31.7[139.7]
	Haunch	B	11.7[51.8]	14.7[64.7]	21.0[92.3]	25.1[110.8]	30.1[132.5]
0.218 [5.54]	Crown	Continuous	37.6[165.7]	40.9[180.0]	46.3[203.9]	49.7[218.6]	53.0[233.3]
	Haunch	A	17.6[77.4]	20.5[90.3]	26.8[117.9]	31.0[136.4]	35.9[158.1]
	Haunch	B	14.9[65.6]	17.8[78.5]	24.1[106.1]	28.3[124.6]	33.2[146.3]
0.249 [6.33]	Crown	Continuous	41.0[180.4]	44.2[194.6]	49.7[218.6]	53.0[233.2]	56.3[247.9]
	Haunch	A	20.4[89.7]	23.3[102.6]	29.6[130.2]	33.8[148.7]	38.7[170.4]
	Haunch	B	17.0[74.8]	19.9[87.7]	26.2[115.3]	30.4[133.8]	35.3[155.6]
0.280 [7.11]	Crown	Continuous	44.3[195.1]	47.5[209.4]	53.0[233.3]	56.3[248.0]	59.6[262.7]
	Haunch	A	23.7[104.2]	26.6[117.1]	32.9[144.7]	37.1[163.2]	42.0[185.0]
	Haunch	B	19.4[85.7]	22.4[98.6]	28.7[126.2]	32.9[144.7]	37.8[166.4]

[A]Plastic moment capacities for Type V box based on minimum design yield strength of 44.0 ksi [300 MPa] for the formed plate, manufactured from flat plate with a minimum yield strength of 40.0 ksi [275 MPa]. Moment capacities with stiffeners based on cumulative (non-composite) properties. Moment capacities for plain and stiffened haunch sections have been adjusted by applying a haunch reduction factor to account for cross-corrugated plates (see Fig. 8). See proceedings of CSCE 2nd Engineering Materials Symposium, Ottawa, Ontario, Canada, June 1995, for further information.

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