Designation: C 1577 – 08

Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD[1]

This standard is issued under the fixed designation C 1577; 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 single-cell precast reinforced concrete box sections cast monolithically and intended to be used for the construction of culverts and for the conveyance of storm water, industrial wastes and sewage.

NOTE 1—This specification is primarily a manufacturing and purchasing specification. However, standard designs per the AASHTO LRFD Bridge Design Specifications are included and the criteria used to develop these designs are given in Appendix X1. The successful performance of this product depends upon the proper selection of the box section, bedding, backfill, and care that the installation conforms to the construction specifications. The purchaser of the precast reinforced concrete box sections specified herein is cautioned that proper correlation of the loading conditions and the field requirements with the box section specified, and provision for inspection at the construction site, are required.

1.2 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 82/A 82M Specification for Steel Wire, Plain, for Concrete Reinforcement

A 185/A 185M Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

A 496/A 496M Specification for Steel Wire, Deformed, for Concrete Reinforcement

A 497/A 497M Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete

A 615/A 615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

C 33 Specification for Concrete Aggregates

C 150 Specification for Portland Cement

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C 497 Test Methods for Concrete Pipe, Manhole Sections, or Tile

C 595 Specification for Blended Hydraulic Cements

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 822 Terminology Relating to Concrete Pipe and Related Products

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete

2.2 *AASHTO Standards:*[3]

AASHTO LRFD Bridge Design Specifications

AASHTO LRFD Bridge Construction Specifications

2.3 *ASCE Standard:*[4]

ASCE 26–97 Standard Practice for Direct Design of Buried Precast Concrete Box Sections

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C 822.

4. Designation

4.1 Precast reinforced concrete box sections manufactured in accordance with this specification shall be legibly marked with the specification designation, span, rise, and design earth cover.

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[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.07 on Acceptance Specifications and Precast Concrete Box Sections.

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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, http://www.transportation.org.

[4] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

TABLE 1 Design Requirements for Precast Concrete Box Sections Under Earth, Dead and HL-93 Live Load Conditions

NOTE 1—Design earth loads and reinforcement areas are based on the weight of a column of earth over the width of the box section multiplied by a soil structure interaction factor as defined in Appendix X1.

NOTE 2—Concrete design strength 5000 psi.

NOTE 3—Steel areas are based on an HL-93 live load without the lane load as permitted by AASHTO, using either the design truck or the design tandem and taking the controlling case.

NOTE 4—The design earth cover indicated is the height of fill above the top of the box section. Design requirements are based on the material and soil properties, loading data, and typical section as included in Appendix X1. For alternative or special designs, see 7.2.

NOTE 5—Design steel area in square inches per linear foot of box section at those locations which are indicated on the typical section shown in Fig. 1.

NOTE 6—The top section designation, for example, 3 ft by 2 ft by 4 in. indicates (interior horizontal span in feet) by (interior vertical rise in feet) by (wall and slab thickness in inches).

NOTE 7—In accordance with the acceptance criteria in 7.2, the manufacturer is not prohibited from interpolating steel area requirements or submitting independent designs for fill heights between noted increments.

NOTE 8—The "M" dimension given in the tables is the required distance that A_{s1} shall be extended into the top and bottom slabs if it is used as reinforcement for the negative moment in these areas. This distance is based on the location where the negative moment in the slab becomes zero, plus an additional development length. Because the live load can be applied at any location along the top slab as the truck drives over it, it is possible for the "M" dimension to exceed one-half the length of the slab.

NOTE 9—(Advisory)—The reinforcing areas are based on 4 inch circumferential wire spacing. Under design conditions where crack control governs, an analysis following the design criteria in Table X1.1 with closer steel spacing may result in a reduction in steel area over those in the table.

3 ft by 2 ft by 4 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.17	0.25	0.16	0.10	0.17	0.17	0.17	0.14	
2<3	0.13	0.19	0.18	0.10					31
3-5	0.10	0.11	0.12	0.10					31
10	0.10	0.10	0.10	0.10					31
15	0.10	0.13	0.13	0.10					31
20	0.11	0.17	0.17	0.10					31
25	0.14	0.21	0.21	0.10					31
30	0.17	0.25	0.25	0.10					31
35	0.20	0.29	0.30	0.10					31

[A] Top slab 7 in., bottom slab 6 in.

3 ft by 3 ft by 4 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.17	0.27	0.17	0.10	0.17	0.17	0.17	0.14	
2<3	0.10	0.22	0.21	0.10					31
3-5	0.10	0.14	0.14	0.10					31
10	0.10	0.11	0.11	0.10					31
15	0.10	0.14	0.15	0.10					31
20	0.10	0.18	0.19	0.10					31
25	0.10	0.23	0.23	0.10					31
30	0.12	0.27	0.28	0.10					31
35	0.14	0.32	0.32	0.10					31

[A] Top slab 7 in., bottom slab 6 in.

4 ft by 2 ft by 5 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.18	0.27	0.15	0.12	0.18	0.18	0.18	0.14	
2<3	0.18	0.19	0.17	0.12					38
3-5	0.13	0.13	0.13	0.12					38
10	0.12	0.12	0.12	0.12					38
15	0.14	0.16	0.16	0.12					38
20	0.18	0.20	0.21	0.12					38
25	0.23	0.25	0.25	0.12					38
30	0.28	0.30	0.30	0.12					38

[A] Top slab 7.5 in., bottom slab 6 in.

4 ft by 3 ft by 5 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2^A	0.18	0.31	0.18	0.12	0.18	0.18	0.18	0.14	
2<3	0.15	0.23	0.20	0.12					38
3-5	0.12	0.16	0.16	0.12					38
10	0.12	0.14	0.14	0.12					38
15	0.12	0.18	0.18	0.12					38
20	0.14	0.23	0.24	0.12					38
25	0.17	0.29	0.29	0.12					38
30	0.21	0.35	0.35	0.12					38

^{A} Top slab 7.5 in., bottom slab 6 in.

4 ft by 4 ft by 5 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2^A	0.18	0.33	0.20	0.12	0.18	0.18	0.18	0.14	
2<3	0.12	0.26	0.23	0.12					38
3-5	0.12	0.18	0.18	0.12					38
10	0.12	0.15	0.15	0.12					38
15	0.12	0.19	0.20	0.12					38
20	0.12	0.25	0.25	0.12					38
25	0.14	0.31	0.31	0.12					38
30	0.17	0.37	0.37	0.12					38

^{A} Top slab 7.5 in., bottom slab 6 in.

5 ft by 3 ft by 6 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2^A	0.19	0.31	0.21	0.14	0.19	0.19	0.19	0.17	
2<3	0.18	0.24	0.19	0.14					45
3-5	0.14	0.17	0.16	0.14					36
10	0.14	0.16	0.17	0.14					36
15	0.16	0.21	0.22	0.14					35
20	0.21	0.27	0.28	0.14					35
25	0.26	0.34	0.34	0.14					35
30	0.31	0.41	0.41	0.14					35

^{A} Top slab 8 in., bottom slab 7 in.

5 ft by 4 ft by 6 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2^A	0.19	0.33	0.24	0.14	0.19	0.19	0.19	0.17	
2<3	0.16	0.27	0.22	0.14					45
3-5	0.14	0.19	0.18	0.14					45
10	0.14	0.18	0.18	0.14					36
15	0.14	0.23	0.24	0.14					35
20	0.17	0.30	0.31	0.14					35
25	0.21	0.37	0.38	0.14					35
30	0.25	0.44	0.45	0.14					35

^{A} Top slab 8 in., bottom slab 7 in.

5 ft by 5 ft by 6 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2^A	0.19	0.35	0.26	0.14	0.19	0.19	0.19	0.17	
2<3	0.14	0.29	0.24	0.14					45
3-5	0.14	0.21	0.20	0.14					45
10	0.14	0.19	0.20	0.14					45
15	0.14	0.24	0.25	0.14					36
20	0.15	0.31	0.32	0.14					35
25	0.18	0.38	0.39	0.14					35
30	0.21	0.46	0.47	0.14					35

^{A} Top slab 8 in., bottom slab 7 in.

6 ft by 3 ft by 7 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.20	0.31	0.22	0.17	0.19	0.19	0.19	0.17	
2<3	0.21	0.24	0.19	0.17					43
3-5	0.17	0.18	0.17	0.17					39
10	0.17	0.18	0.19	0.17					39
15	0.22	0.24	0.24	0.17					38
20	0.28	0.31	0.31	0.17					38
25	0.35	0.38	0.39	0.17					38
30	0.42	0.46	0.46	0.17					38

[A] Top slab 8 in.

6 ft by 4 ft by 7 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.19	0.34	0.25	0.17	0.19	0.19	0.19	0.17	
2<3	0.19	0.27	0.21	0.17					43
3-5	0.17	0.21	0.19	0.17					39
10	0.17	0.20	0.21	0.17					39
15	0.18	0.27	0.27	0.17					38
20	0.24	0.34	0.35	0.17					38
25	0.29	0.43	0.42	0.17					38
30	0.35	0.51	0.52	0.17					38

[A] Top slab 8 in.

6 ft by 5 ft by 7 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.19	0.37	0.28	0.17	0.19	0.19	0.19	0.17	
2<3	0.17	0.30	0.24	0.17					43
3-5	0.17	0.23	0.21	0.17					43
10	0.17	0.22	0.23	0.17					39
15	0.17	0.28	0.29	0.17					38
20	0.20	0.37	0.38	0.17					38
25	0.25	0.45	0.46	0.17					38
30	0.30	0.54	0.55	0.17					38

[A] Top slab 8 in.

6 ft by 6 ft by 7 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2[A]	0.19	0.38	0.30	0.17	0.19	0.19	0.19	0.17	
2<3	0.17	0.32	0.26	0.17					52
3-5	0.17	0.24	0.22	0.17					52
10	0.17	0.23	0.24	0.17					43
15	0.17	0.29	0.31	0.17					39
20	0.18	0.38	0.39	0.17					39
25	0.23	0.46	0.48	0.17					38
30	0.27	0.55	0.57	0.17					38

[A] Top slab 8 in.

7 ft by 4 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.21	0.34	0.25	0.19	0.19	0.19	0.19	0.19	
2<3	0.23	0.28	0.28	0.19					43
3-5	0.19	0.22	0.19	0.19					43
10	0.19	0.23	0.23	0.19					43
15	0.24	0.30	0.30	0.19					41
20	0.31	0.38	0.39	0.19					41
25	0.38	0.47	0.48	0.19					41
30	0.46	0.57	0.57	0.19					41

7 ft by 5 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.19	0.36	0.27	0.19	0.19	0.19	0.19	0.19	
2<3	0.21	0.31	0.31	0.19					47
3-5	0.19	0.24	0.21	0.19					43
10	0.19	0.25	0.26	0.19					43
15	0.21	0.32	0.33	0.19					41
20	0.27	0.41	0.42	0.19					41
25	0.33	0.51	0.52	0.19					41
30	0.40	0.61	0.62	0.19					41

7 ft by 6 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.19	0.38	0.30	0.19	0.19	0.19	0.19	0.19	
2<3	0.19	0.33	0.34	0.19					59
3-5	0.19	0.25	0.23	0.19					47
10	0.19	0.26	0.27	0.19					43
15	0.19	0.34	0.35	0.19					41
20	0.24	0.43	0.45	0.19					41
25	0.29	0.53	0.55	0.19					41
30	0.35	0.64	0.65	0.19					41

7 ft by 7 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.19	0.40	0.33	0.19	0.19	0.19	0.19	0.19	
2<3	0.19	0.36	0.37	0.19					59
3-5	0.19	0.27	0.25	0.19					59
10	0.19	0.27	0.29	0.19					47
15	0.19	0.35	0.37	0.19					43
20	0.22	0.44	0.46	0.19					43
25	0.27	0.54	0.57	0.19					43
30	0.32	0.65	0.67	0.19					41

8 ft by 4 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.27	0.38	0.29	0.19	0.19	0.19	0.19	0.19	
2<3	0.31	0.34	0.32	0.19					50
3-5	0.25	0.27	0.27	0.19					50
10	0.26	0.28	0.29	0.19					45
15	0.34	0.37	0.38	0.19					41
20	0.44	0.48	0.49	0.19					41

8 ft by 5 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.24	0.40	0.32	0.19	0.19	0.19	0.19	0.19	
2<3	0.28	0.37	0.35	0.19					50
3-5	0.23	0.29	0.30	0.19					45
10	0.23	0.31	0.32	0.19					45
15	0.30	0.41	0.42	0.19					41
20	0.39	0.52	0.54	0.19					41

8 ft by 6 ft by 8 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.22	0.42	0.35	0.19	0.19	0.19	0.19	0.19	
2<3	0.25	0.40	0.38	0.19					50
3-5	0.21	0.32	0.33	0.19					50
10	0.22	0.33	0.34	0.19					45
15	0.28	0.43	0.45	0.19					41
20	0.36	0.55	0.57	0.19					41

8 ft by 7 ft by 8 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.20	0.44	0.37	0.19	0.19	0.19	0.19	0.19	
2<3	0.23	0.43	0.41	0.19					55
3-5	0.19	0.34	0.35	0.19					55
10	0.20	0.34	0.36	0.19					50
15	0.26	0.45	0.47	0.19					41
20	0.33	0.57	0.60	0.19					41

8 ft by 8 ft by 8 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.20	0.45	0.40	0.19	0.19	0.19	0.19	0.19	
2<3	0.21	0.45	0.44	0.19					65
3-5	0.19	0.36	0.38	0.19					65
10	0.19	0.35	0.38	0.19					55
15	0.24	0.46	0.49	0.19					45
20	0.31	0.59	0.62	0.19					45

9 ft by 5 ft by 9 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.28	0.38	0.31	0.22	0.22	0.22	0.22	0.22	
2<3	0.32	0.38	0.34	0.22					54
3-5	0.25	0.30	0.30	0.22					49
10	0.28	0.33	0.34	0.22					49
15	0.36	0.43	0.45	0.22					44
20	0.47	0.56	0.57	0.22					44
25	0.58	0.69	0.71	0.22					44

9 ft by 6 ft by 9 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.25	0.40	0.34	0.22	0.22	0.22	0.22	0.22	
2<3	0.29	0.41	0.38	0.22					54
3-5	0.23	0.33	0.33	0.22					49
10	0.26	0.35	0.37	0.22					49
15	0.33	0.46	0.48	0.22					44
20	0.42	0.60	0.61	0.22					44
25	0.52	0.74	0.75	0.22					44

9 ft by 7 ft by 9 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.23	0.42	0.36	0.22	0.22	0.22	0.22	0.22	
2<3	0.26	0.44	0.41	0.22					59
3-5	0.22	0.35	0.35	0.22					54
10	0.24	0.37	0.39	0.22					49
15	0.31	0.48	0.51	0.22					44
20	0.39	0.62	0.65	0.22					44

9 ft by 8 ft by 9 in.

Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.22	0.43	0.39	0.22	0.22	0.22	0.22	0.22	
2<3	0.24	0.46	0.43	0.22					59
3-5	0.22	0.37	0.38	0.22					59
10	0.22	0.39	0.41	0.22					54
15	0.29	0.50	0.53	0.22					44
20	0.36	0.64	0.67	0.22					44

9 ft by 9 ft by 9 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.22	0.44	0.42	0.22	0.22	0.22	0.22	0.22	
2<3	0.23	0.49	0.46	0.22					72
3-5	0.22	0.39	0.40	0.22					72
10	0.22	0.40	0.43	0.22					59
15	0.27	0.51	0.55	0.22					49
20	0.34	0.66	0.69	0.22					49

10 ft by 5 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.30	0.36	0.30	0.24	0.24	0.24	0.24	0.24	
2<3	0.35	0.39	0.34	0.24					58
3-5	0.28	0.31	0.30	0.24					53
10	0.33	0.35	0.36	0.24					52
15	0.42	0.46	0.47	0.24					47
20	0.55	0.59	0.61	0.24					47
25	0.68	0.73	0.75	0.24					47

10 ft by 6 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.28	0.38	0.33	0.24	0.24	0.24	0.24	0.24	
2<3	0.32	0.42	0.37	0.24					58
3-5	0.26	0.34	0.33	0.24					52
10	0.30	0.38	0.39	0.24					52
15	0.39	0.49	0.51	0.24					47
20	0.50	0.63	0.65	0.24					47
25	0.61	0.78	0.80	0.24					47

10 ft by 7 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.25	0.40	0.36	0.24	0.24	0.24	0.24	0.24	
2<3	0.30	0.45	0.40	0.24					58
3-5	0.24	0.36	0.35	0.24					58
10	0.28	0.40	0.42	0.24					52
15	0.36	0.52	0.54	0.24					47
20	0.46	0.67	0.69	0.24					47
25	0.56	0.82	0.85	0.24					47

10 ft by 8 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.24	0.41	0.38	0.24	0.24	0.24	0.24	0.24	
2<3	0.27	0.47	0.43	0.24					64
3-5	0.24	0.38	0.38	0.24					58
10	0.26	0.42	0.44	0.24					52
15	0.34	0.54	0.57	0.24					47
20	0.43	0.69	0.72	0.24					47

10 ft by 9 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.24	0.42	0.41	0.24	0.24	0.24	0.24	0.24	
2<3	0.26	0.50	0.46	0.24					70
3-5	0.24	0.40	0.40	0.24					64
10	0.25	0.43	0.46	0.24					58
15	0.32	0.56	0.59	0.24					52
20	0.40	0.71	0.75	0.24					47

10 ft by 10 ft by 10 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.24	0.44	0.44	0.24	0.24	0.24	0.24	0.24	
2<3	0.25	0.52	0.48	0.24					79
3-5	0.24	0.42	0.43	0.24					70
10	0.24	0.44	0.48	0.24					64
15	0.30	0.57	0.61	0.24					52
20	0.38	0.73	0.77	0.24					52

11 ft by 4 ft by 11 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.36	0.33	0.27	0.26	0.26	0.26	0.26	0.26	
2<3	0.41	0.36	0.30	0.26					62
3-5	0.34	0.29	0.27	0.26					62
10	0.41	0.34	0.35	0.26					55
15	0.53	0.44	0.45	0.26					55
20	0.69	0.57	0.58	0.26					55
25	0.86	0.70	0.72	0.26					55

11 ft by 6 ft by 11 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.30	0.36	0.33	0.26	0.26	0.26	0.26	0.26	
2<3	0.35	0.43	0.37	0.26					62
3-5	0.29	0.35	0.33	0.26					55
10	0.35	0.40	0.42	0.26					55
15	0.45	0.52	0.54	0.26					50
20	0.57	0.67	0.69	0.26					50
25	0.71	0.83	0.85	0.26					50

11 ft by 8 ft by 11 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.26	0.40	0.38	0.26	0.26	0.26	0.26	0.26	
2<3	0.30	0.48	0.42	0.26					62
3-5	0.26	0.40	0.38	0.26					62
10	0.30	0.44	0.47	0.26					55
15	0.39	0.58	0.60	0.26					50
20	0.49	0.74	0.77	0.26					50
25	0.61	0.91	0.94	0.26					50

11 ft by 10 ft by 11 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.26	0.45	0.43	0.26	0.26	0.26	0.26	0.26	
2<3	0.27	0.53	0.48	0.26					75
3-5	0.26	0.44	0.43	0.26					69
10	0.28	0.48	0.52	0.26					62
15	0.35	0.61	0.65	0.26					55
20	0.44	0.78	0.83	0.26					50

11 ft by 11 ft by 11 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.26	0.47	0.46	0.26	0.26	0.26	0.26	0.26	
2<3	0.26	0.55	0.51	0.26					86
3-5	0.26	0.46	0.45	0.26					75
10	0.27	0.49	0.54	0.26					69
15	0.34	0.63	0.68	0.26					55
20	0.42	0.80	0.85	0.26					55

12 ft by 4 ft by 12 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.38	0.31	0.29	0.29	0.29	0.29	0.29	0.29	
2<3	0.44	0.37	0.30	0.29					73
3–5	0.37	0.30	0.29	0.29					66
10	0.44	0.34	0.35	0.29					66
15	0.60	0.46	0.48	0.29					59
20	0.78	0.60	0.61	0.29					59
25	0.97	0.74	0.75	0.29					59

12 ft by 6 ft by 12 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.32	0.36	0.32	0.29	0.29	0.29	0.29	0.29	
2<3	0.38	0.43	0.36	0.29					66
3-5	0.32	0.36	0.33	0.29					59
10	0.38	0.41	0.42	0.29					59
15	0.51	0.55	0.57	0.29					53
20	0.65	0.71	0.72	0.29					53
25	0.81	0.87	0.89	0.29					53

12 ft by 8 ft by 12 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.29	0.41	0.38	0.29	0.29	0.29	0.29	0.29	
2<3	0.33	0.49	0.42	0.29					66
3-5	0.29	0.41	0.38	0.29					59
10	0.34	0.46	0.48	0.29					59
15	0.44	0.61	0.64	0.29					53
20	0.57	0.78	0.81	0.29					53
25	0.69	0.96	0.99	0.29					53

12 ft by 10 ft by 12 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.29	0.45	0.43	0.29	0.29	0.29	0.29	0.29	
2<3	0.29	0.54	0.48	0.29					73
3-5	0.29	0.45	0.43	0.29					66
10	0.31	0.49	0.53	0.29					59
15	0.40	0.65	0.70	0.29					53
20	0.51	0.84	0.88	0.29					53
25	0.62	1.03	1.07	0.29					53

12 ft by 12 ft by 12 in.									
Design Earth Cover, ft	Circumferential Reinforcement Areas, in.^{2}/ft								
	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s5}	A_{s6}	A_{s7}	A_{s8}	"M," in.
0<2	0.29	0.49	0.48	0.33	0.29	0.29	0.29	0.29	
2<3	0.29	0.59	0.53	0.29					93
3-5	0.29	0.49	0.48	0.29					80
10	0.29	0.52	0.58	0.29					73
15	0.37	0.69	0.74	0.29					59
20	0.46	0.87	0.93	0.29					59

5. Basis of Acceptance

5.1 Acceptability of the box sections produced in accordance with Section 7 shall be determined by the results of the concrete compressive strength tests described in Section 10, by the material requirements described in Section 6, and by inspection of the finished box sections.

5.2 Box sections shall be considered ready for acceptance when they conform to the requirements of this specification.

6. Material

6.1 *Reinforced Concrete*—The reinforced concrete shall consist of cementitious materials, mineral aggregates and water, in which steel has been embedded in such a manner that the steel and concrete act together.

6.2 *Cementitious Materials*:

6.2.1 *Cement*—Cement shall conform to the requirements for portland cement of Specification C 150 or shall be portland blast-furnace slag cement or portland-pozzolan cement conforming to the requirements of Specification C 595, except that the pozzolan constituent in the Type IP portland-pozzolan cement shall be fly ash.

6.2.2 *Fly Ash*—Fly ash shall conform to the requirements of Specification C 618, Class F or Class C.

6.2.3 *Ground Granulated Blast-Furnace Slag*—GGBFS shall conform to the requirements of Grade 100 or 120 of Specification C 989.

6.2.4 *Allowable Combinations of Cementitious Materials*—The combination of cementitious materials used in concrete shall be one of the following:

6.2.4.1 Portland cement only,

6.2.4.2 Portland blast furnace slag cement only,

6.2.4.3 Portland pozzolan cement only,

6.2.4.4 A combination of portland cement and fly ash,

6.2.4.5 A combination of portland cement and ground granulated blast-furnace slag, or

6.2.4.6 A combination of portland cement, ground granulated blast-furnace slag (not to exceed 25 % of the total cementitious weight) and fly ash (not to exceed 25 % of the total cementitious weight).

6.3 *Aggregates*—Aggregates shall conform to Specification C 33, except that the requirements for gradation shall not apply.

6.4 *Admixtures and Blends*—Admixtures and blends shall only be used with the approval of the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of welded wire reinforcement conforming to Specifications A 185/A 185M or A 497/A 497M. Circumferential reinforcement areas in Table 1 are based solely on the use of welded wire reinforcement with 4 in. spacing of the circumferential wires. Refer to 11.6 if alternate steel designs utilizing steel bars, Grade 60, in conjunction with or in lieu of welded wire reinforcement are to be submitted for the owner's approval. Longitudinal distribution reinforcement shall consist of welded wire reinforcement or deformed billet-steel bars conforming to Specification A 615/A 615M, Grade 60.

6.6 *Synthetic Fibers*—Collated fibrillated virgin polypropylene fibers may be used at the manufacturer's option, in concrete boxes as a nonstructural manufacturing material. Only Type III synthetic fibers designed and manufactured specifically for use in concrete and conforming to the requirements of specification C 1116 shall be accepted.

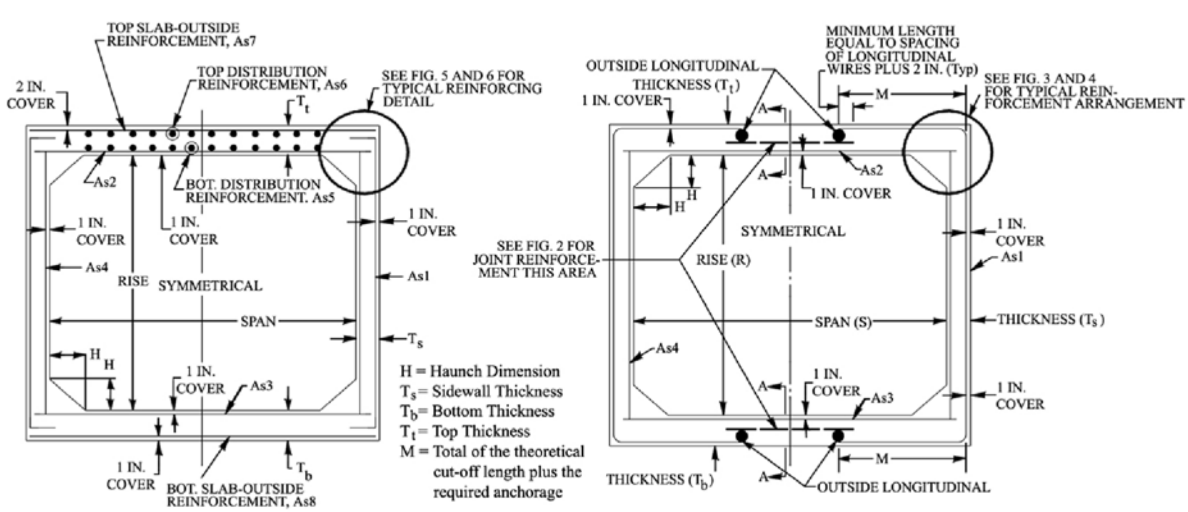
7. Design

7.1 *Design Tables*—The box section dimensions, compressive strength of the concrete, and reinforcement details shall be as prescribed in Table 1 and Figs. 1-9, subject to the provisions of Section 11. Table 1 sections are designed for combined earth dead load and AASHTO HL-93 live load without the lane load, as permitted by AASHTO. Criteria used to develop Table 1 is given in Appendix X1.

NOTE 2—The tabular designs in this specification were prepared according to the AASHTO LRFD Bridge Design Specifications.

7.2 *Modified and Special Designs*—The manufacturer shall request approval by the purchaser for modified designs which differ from the designs in Section 7; or special designs for sizes and loads other than those shown in Table 1. When spans are required that exceed those prescribed in Table 1, the design shall be based on the criteria given in Appendix X1. In addition, the span shall be designed to have adequate stiffness to limit deflection as given in Commentary C9.7.1.1 of AASHTO LRFD Bridge Design Specifications.

NOTE 3—(Advisory)—Construction procedures, such as heavy equipment movement or stockpiling of material over or adjacent to a box structure can induce higher loads than those used for the structure's final design. These construction and surcharge loads are allowable as long as the final steel areas in the box are larger than those required for the construction phase. The design engineer shall take into consideration the potential for higher loads induced by construction procedures in determining the final design of the box structure.



Fill Height Less than 2 ft

Fill Height 2 ft and Greater

FIG. 1 Typical Box Sections

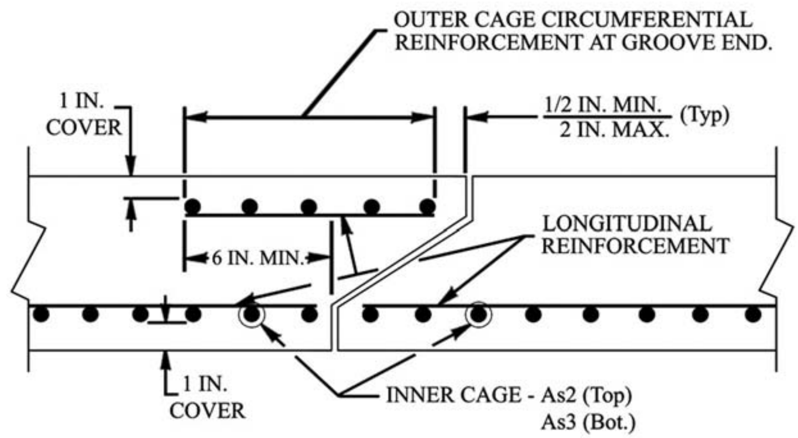


FIG. 2 Section A-A Top and Bottom Slab Joint Reinforcement

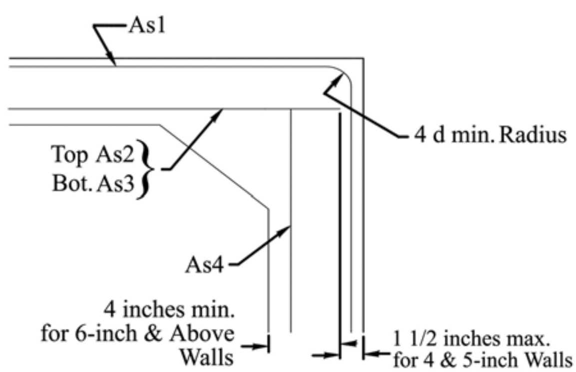


FIG. 3 Detail Inner Reinforcement

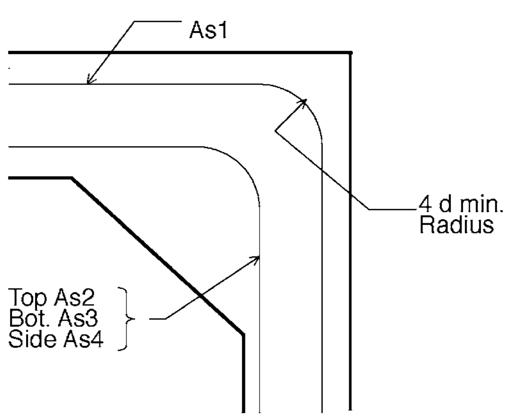


FIG. 4 Detail Option (see Fig. 3)

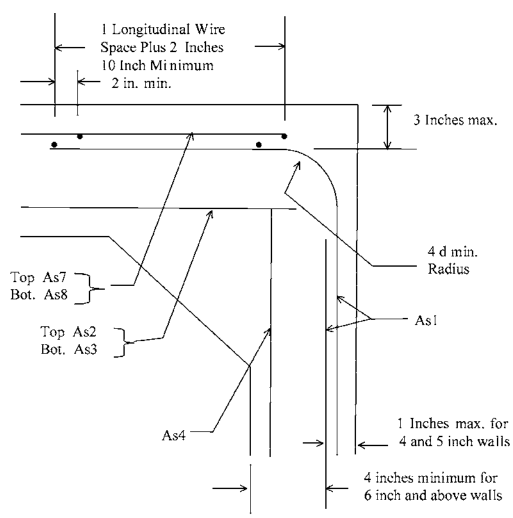


FIG. 5 Detailed Reinforcement Arrangement

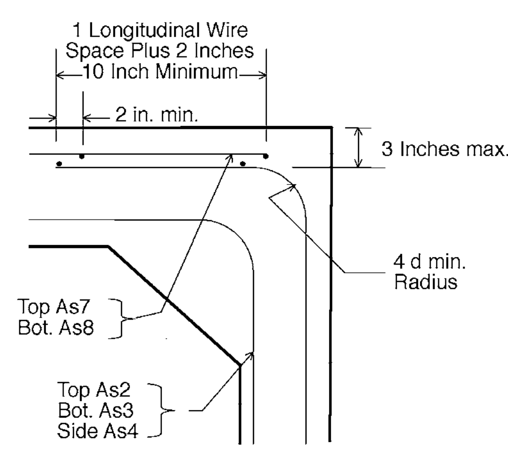


FIG. 6 Detail Option

7.3 *Placement of Reinforcement*—The cover of concrete over the circumferential reinforcement shall be 1 in., subject to the provisions of Section 11. The inside circumferential reinforcement shall extend into the tongue portion of the joint and the outside circumferential reinforcement shall extend into the groove portion of the joint. The clear distance of the end circumferential wires shall be not less than ½ in. nor more than 2 in. from the ends of the box section. Reinforcement shall be assembled utilizing any combination of single or multiple layers of welded-wire reinforcement. Multiple layers shall not be separated by more than the thickness of one longitudinal wire plus ¼ in. The multiple layers shall be fastened together to form a single cage. All other specification requirements such as laps, welds, and tolerances of placement in the wall of the box section shall apply to this method of fabricating a reinforcement cage. It is not prohibited for a common reinforcement unit to be utilized for both A_{s2} (or A_{s3}) and A_{s4}, and

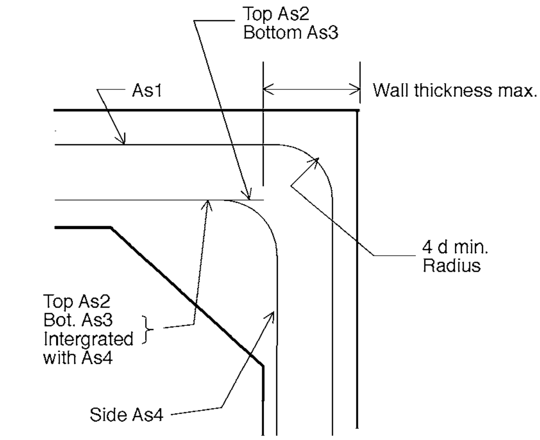


FIG. 7 Alternate Detail (see Fig. 3)

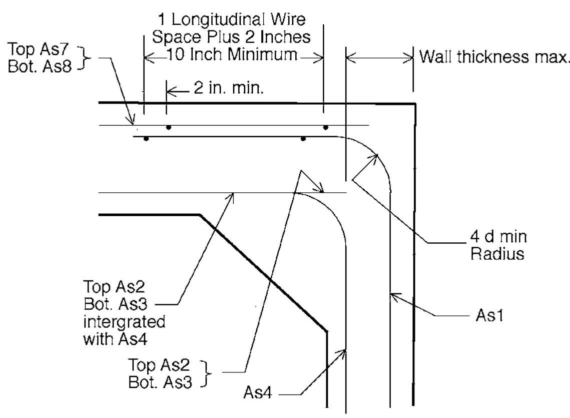


FIG. 8 Alternate Detail (see Fig. 5)

also for both A_{s7} (or A_{s8}) and A_{s1}, with the largest area requirement governing, bending the reinforcement at the corners and waiving the extension requirements of Fig. 3 and Fig. 5 (see Fig. 4). When a single cage of multiple circumferential steel areas is used for A_{s2} (or A_{s3}) and A_{s4} reinforcement, the slab or wall requiring the larger steel area shall have this additional circumferential steel extending for the full span of the slab or rise of the wall. The welded wire reinforcement shall be composed of circumferential and longitudinal wires meeting the spacing requirements of 7.4 and shall contain sufficient longitudinal wires extending through the box section to maintain the shape and position of reinforcement. Longitudinal distribution reinforcement shall be welded-wire reinforcement or deformed billet-steel bars and shall meet the spacing requirements of 7.4. The ends of the longitudinal distribution reinforcement shall not be more than 2 in. from the ends of the box section. The exposure of the ends of longitudinals, stirrups, and spacers used to position the reinforcement shall not be a cause for rejection.

7.4 *Laps, Welds, and Spacing*—Splices in the circumferential reinforcement shall be made by lapping. The overlap measured between the outermost longitudinal wires of each reinforcement sheet shall not be less than the space containing two longitudinal wires of each mesh plus 2 in., but not less than 10 in. If A_{s1} is extended to the middle of either slab and connected, welded splices or lapped splices shall be used in the connection. When used, A_{s7} and A_{s8} shall be lapped with A_{s1} as shown in Fig. 5, Fig. 6, or Fig. 8 and are not prohibited from being connected by welding. If welds are made to circumferential reinforcement, they shall be made only to selected circumferential wires that are not less than 18 in. apart along the longitudinal axis of the box section as shown in Fig. 9. Also, when spacers are welded to circumferential wires, they shall be welded only to these selected circumferential wires. There shall be no welding to other circumferential wires, except A_{s4} is not prohibited from being lapped and welded at any location or connected by welding at the corners to A_{s2} and A_{s3}. No welds shall be made to A_{s2} or A_{s3} circumferential wires in the middle third of the span as shown in Fig. 9. When distribution reinforcement is to be fastened to a cage by welding, it shall be welded only to longitudinal wires and only within 18 in. of the end of the box section. The spacing center to center of the circumferential wires shall not be less than 2 in. nor more than 4 in. The spacing center to center of the longitudinal wires shall not be more than 8 in.

NOTE 4—(Advisory)–The AASHTO LRFD Bridge Design Specifications should be consulted for weld requirements not directly addressed in this standard.

8. Joints

8.1 The precast reinforced concrete box sections shall be produced with tongue and groove ends. The ends shall be of such design and the ends of the box sections so formed that the sections can be laid together to make a continuous line of box sections compatible with the permissible variations given in Section 11.

8.2 Outer cage circumferential reinforcement as shown in Figs. 1 and 2 shall be placed in the top and bottom slabs at the groove portion of the joint when A_{s1} is not continuous over the span. The minimum area of such reinforcement in square inches per linear foot of box section length shall be the same as the areas specified for A_{s4} in Table 1.

9. Manufacture

9.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials and water as will produce a homogeneous concrete mixture of such quality that the box section will conform to the test and design requirements of this specification. All concrete shall have a water-cementitious materials ratio not exceeding 0.53 by weight. Cementitious materials shall be as specified in 6.2 and shall be added to the mix in a proportion not less than 470 lb/yd^3 unless mix designs with a lower cementitious materials content demonstrate that the quality and performance of the box section meet the requirements of this specification.

9.2 *Curing*—The box sections shall be cured for a sufficient length of time so that the concrete will develop the specified compressive strength by the time of delivery. Any one of the following methods of curing or combinations thereof shall be used:

9.2.1 *Steam Curing*—The box sections shall be low pressure, steam-cured by a system that will maintain a moist atmosphere.

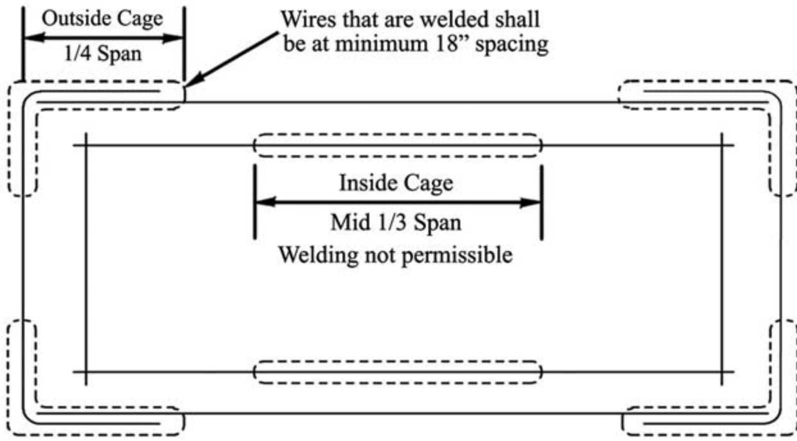


FIG. 9 Critical Zones of High Stress Where Welding is Restricted

9.2.2 *Water Curing*—The box sections shall be water-cured by any method that will keep the sections moist.

9.2.3 *Membrane Curing*—A sealing membrane conforming to the requirements of Specification C 309 shall be applied and shall be left intact until the required concrete compressive strength is attained. The concrete temperature at the time of application shall be within 10°F of the atmospheric temperature. All surfaces shall be kept moist prior to the application of the compounds and shall be damp when the compound is applied.

9.3 *Forms*—The forms used in manufacture shall be sufficiently rigid and accurate to maintain the box section dimensions within the permissible variations given in Section 11. All casting surfaces shall be of smooth nonporous material.

9.4 *Handling*—Handling devices or holes are not prohibited in each box section for the purpose of handling and laying.

10. Physical Requirements

10.1 *Type of Test Specimen*—Compression tests for determining concrete compressive strength shall be allowed to be made on either standard rodded concrete cylinders or concrete cylinders compacted and cured in like manner as the box sections, or on cores drilled from the box section.

10.2 *Compression Testing of Cylinders*:

10.2.1 Cylinders shall be prepared, cured, and tested in accordance with Section 11 of Test Methods C 497. Cylinders shall be exposed to the same curing conditions as the manufactured box sections and shall remain with the sections until tested.

10.2.2 Prepare not less than three test cylinders from each concrete mix used within a group (one day's production) of box sections.

10.2.3 *Acceptability on the Basis of Cylinder Test Results*:

10.2.3.1 When the average compressive strength of all cylinders tested is equal to or greater than the design concrete strength, not more than 10 % of the cylinders tested have a compressive strength less than the design concrete strength, and no cylinder tested has a compressive strength less than 80 % of the design concrete strength, the lot shall be accepted.

10.2.3.2 Box sections that fail to meet the strength requirements under 10.2 shall not be retested under 10.3 without the approval of the purchaser.

10.2.3.3 When the compressive strength of the cylinders is unavailable, the acceptability of the lot shall be determined in accordance with the provisions of 10.3.

10.3 *Compression Testing of Cores*:

10.3.1 Cores shall be obtained, prepared, and tested for compressive strength in accordance with the provisions of Test Methods C 497.

10.3.2 Three cores shall be taken from three sections (one core from each) selected at random from each group of 15 box sections or fraction thereof, of a single size from each continuous production run.

10.3.3 *Acceptability by Core Tests*:

10.3.3.1 Concrete represented by these three core tests shall be considered acceptable if the average of the three core strengths is equal to or greater than 85 % of the required compressive strength of the concrete with no one core less than 75 % of the required compressive strength.

10.3.3.2 If the compressive strength of the three cores does not meet the requirements of 10.3.3.1, the sections from which the cores were taken shall be rejected. Two box sections from the remainder of the group shall be selected at random and one core shall be taken from each and tested. If both cores have a strength equal to or greater than 85 % of the required strength, the remainder of the group is acceptable. If the compressive strength of either of the two cores tested is less than 85 % of the required strength of the concrete, the remainder of the group of box sections shall be rejected, or, at the option of the manufacturer, each box section of the remainder of the group shall be cored and accepted individually, and any of these box sections that have core strengths less than 85 % of the required strength of the concrete shall be rejected.

NOTE 5—(Advisory)—The percentage shown for acceptance of core tests are in accordance with ACI 318 which states that, "To expect core tests to be equal to f'_c is not realistic, since differences in the size of specimens, conditions of obtaining samples, and procedures for curing do not permit equal values to be obtained". The variations of the specimens such as length to diameter ratio, drilling direction and process, aggregate size and sample preparation may all have an effect on the test results. Embedded steel reinforcement affects the test results because of the loss of concrete continuity.

10.4 *Plugging Core Holes*—The core holes shall be plugged and sealed by the manufacturer in a manner such that the box section will meet all of the test requirements of this specification. Box sections so sealed shall be considered as satisfactory for use.

10.5 *Test Equipment*—Every manufacturer furnishing box sections under this specification shall furnish all facilities and personnel necessary to carry out the tests required.

11. Permissible Variations

11.1 *Internal Dimensions*—The internal dimensions shall not vary more than 1 % from the design dimensions. The haunch dimensions shall not vary more than ¼ in. from the design dimensions.

11.2 *Slab and Wall Thickness*—The slab and wall thickness shall not be less than that shown in the design by more than 5 % or 3⁄16 in., whichever is greater. A thickness more than that required in the design shall not be a cause for rejection.

11.3 *Length of Opposite Surfaces*—Variations in laying lengths of two opposite surfaces of the box section shall not be more than ⅛ in./ft of internal span, with a maximum of ⅝ in. for all sizes through 7 ft internal span, and a maximum of ¾ in. for internal spans greater than 7 ft, except where beveled ends for laying of curves are specified by the purchaser.

11.4 *Length of Section*—The underrun in length of a section shall not be more than ⅛ in./ft of length with a maximum of ½ in. in any box section.

11.5 *Position of Reinforcement*—The maximum variation in the position of the reinforcement of 5-in. or less slab and wall thickness shall be ± ⅜ in., and for greater than 5-in. slab and wall thickness shall be ± ½ in. In no case, however, shall the cover over the reinforcement be less than ⅝ in., as measured to the internal surface or the external surface except the cover over the reinforcement for the external surface of the top slab for boxes with under 2 ft of cover shall not be less than 1⅝ in. The preceding minimum cover limitation does not apply at the mating surfaces of the joint.

11.6 *Area of Reinforcement*—The areas of steel reinforcement shall be the design steel areas as shown in Table 1. Steel areas greater than those required shall not be cause for rejection. The permissible variation in diameter of any wire in finished reinforcement shall conform to the tolerances prescribed for the wire before fabrication by either Specification A 82/A 82M or A 496/A 496M as applicable. If steel bars (Grade 60) are used in lieu of welded wire reinforcement, the steel areas presented in Table 1 shall be increased to account for the difference in steel yield strength, steel spacing, concrete cover, and crack control between the welded wire reinforcement. and steel bars.

11.7 *Haunch Dimensions*—The vertical and horizontal dimensions shall be equal to the side wall thickness. If haunches with other dimensions are used, a special reinforcement design for the actual dimensions shall be completed. In lieu of performing a special design, for the specific case where the actual haunch dimensions are larger than the standard dimensions and vertical and horizontal haunch dimensions are equal, the A_{s1} steel area shall be increased 1 % for every 5 % increase in the haunch dimension over that specified in Table 1 and A_{s2} and A_{s3} shall be reduced by an equal percentage.

12. Repairs

12.1 Box sections shall be repaired, if necessary, because of imperfections in manufacture or handling damage and will be acceptable if, in the opinion of the purchaser, the repaired box section conforms to the requirements of this specification.

13. Inspection

13.1 The quality of materials, the process of manufacture, and the finished box sections shall be subject to inspection by the purchaser.

14. Rejection

14.1 Box sections are subject to rejection on account of failure to conform to any of the specification requirements. Individual box sections are subject to rejection because of any of the following:

14.1.1 Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint,

14.1.2 Defects that indicate mixing and molding not in compliance with 9.1, or honeycombed or open texture that would adversely affect the function of the box sections,

14.1.3 Abnormalities in the ends of the box sections to the walls and center line of the box section, within the limits of variations given in Section 11, except where beveled ends are specified, and

14.1.4 Damaged ends, where such damage would prevent making a satisfactory joint.

15. Marking

15.1 The following information shall be legibly marked on each box section by indentation, waterproof paint, or other approved means:

15.1.1 Box section span, rise, maximum and minimum design earth cover, and specification designation.

15.1.2 Date of manufacture, and

15.1.3 Name or trademark of the manufacturer.

15.2 Each section shall be clearly marked on either the inner or outer surface during the process of manufacture so that the location of the top will be evident immediately after the forms are stripped. In addition, the word "top" shall be lettered with waterproof paint on the inside top surface.

APPENDIX

(Nonmandatory Information)

X1. DESIGN CRITERIA USED TO DEVELOP TABLE 1

X1.1 Bedding and Backfill Assumptions

X1.1.1 The bedding is assumed to provide a slightly yielding, uniformly distributed support over the bottom width of the box section. Reference Section 27 of the AASHTO LRFD Bridge Construction Specifications for standard installation practices. For additional information on the construction of precast concrete box section systems, ASCE 26–97 may be consulted.

X1.1.2 The design earth covers and reinforcement areas are based on the weight of a column of earth over the width of the box section multiplied by a soil-structure interaction factor (see Table X1.1). Select granular backfill is assumed above the box culvert.

X1.2 Criteria for Loads

X1.2.1 Design loads are based on the American Association of State Highway and Transportation Officials (AASHTO LRFD Bridge Design Specifications).

X1.2.2 Live loads for designs given in Table 1 are HL-93 loadings without the lane load as defined in the AASHTO LRFD specifications. Dynamic load allowances are in accordance with the AASHTO specification. The HL-93 live load consists of the design truck (32 000 lb axle, identical to the HS 20 truck of the Standard Specifications) or a design tandem (two 25 000 lb axles spaced 4 feet apart).

X1.2.3 For box sections with less than 2 ft of cover, wheel loads are distributed perpendicular to the span by the use of longitudinal distribution reinforcement in the top and bottom of the top slab. The width of the live load distribution for an entire axle at these depths is E = 96 (in.) + 1.44Span (ft) where E = distribution width in inches. The length of the applied load is L = 10 (in.) + 1.15H (in.). For box sections with 2 ft or more of cover, the wheel load is applied as a tire footprint of w = 20 (in.) by l = 10 inches on the surface and distributed through the soil to the top of the box with dimensions equal to the tire footprint plus 1.15H in each direction assuming use of a select granular backfill above the culvert. Live loads are applied from a truck traveling parallel to the span of the box. If live load travel is at an angle greater than 15° from parallel to the span, a separate analysis must be performed. Live loads are applied for all depths and are not cut off at any preset depth.

X1.2.4 Cover loads for designs given in Table 1 are the weight of a column of earth of a width equal to the outside width dimension of the box section and a height equal to the depth of cover over the top of the section multiplied by the appropriate AASHTO soil structure interaction factor.

X1.2.5 Lateral earth pressure from weight of earth above and adjacent to a box section is taken as 0.50 times the vertical pressure. This value is increased by the load factor of 1.35 for the maximum lateral earth pressure used in design. The box culverts are also evaluated for a minimum lateral earth pressure, which may result in increased steel areas in certain locations of the box culvert. AASHTO allows for a 50 % reduction in the lateral earth pressure in lieu of applying a minimum earth load factor of 0.90. This results in a minimum lateral earth pressure design value of 0.25 times the maximum vertical earth pressure This minimum value is 50 % of the maximum value. For Table 1, additional lateral pressure in lbf/ft^2 from approaching truck wheel loads is added when determining steel areas only at sections where area is increased by increased lateral pressure (see Table X1.1).

X1.3 Methods of Analysis

X1.3.1 The structural effects of the loads described in X1.2 are evaluated based on the elastic method of structural analysis. Design moments, shears, and thrusts are determined by computer analysis using the stiffness matrix method, and design is based on maximum stress resultants at critical sections caused by the most severe combination of design loads.

X1.4 Method of Design

X1.4.1 Box section design is based on load and resistance factor design provisions given in AASHTO LRFD Bridge Design Specifications. Reinforcement areas are governed by either ultimate total load yield stress limitation of 65 000 lbf/in.^{2}, service total load stress limitation (cracking), or maximum shear capacity using flexural reinforcement. Capacity reduction factors of 1.0 for flexure and axial compression, and 0.90 for shear were used. All designs in the tables are based on welded wire fabric with a maximum of 4 in. spacing unless noted otherwise. Longitudinal distribution reinforcement called for in Table 1 for top slab inside face is in accordance with distribution reinforcement formulas given in the AASHTO specification for bridge decks. Longitudinal distribution reinforcement is also required in the outside face of the top slab, when wheel loads are adjacent to joints which provide only shear connections between box section units. These requirements were determined by evaluating analyses with loads in various positions on and near the edge of slabs having various length to width ratios and various conditions of edge restraint. Distribution reinforcement shall either be welded wire reinforcement or deformed Grade 60 bars, subject to the provisions of section 11.6. A slab thickness of 1⁄12 the span (or greater) as required by this specification encompasses the recommended minimum section depth and deflection requirements in the AASHTO LRFD Bridge Design Specifications.

X1.4.2 Some box section designs shown in Table 1 have minimum practical steel area requirements. For such designs, the steel areas calculated for support of design loads are less than the minimum steel area which is specified for slabs in the AASHTO specification, (0.002 bt), and thus, the minimum reinforcement areas are shown in Table 1.

X1.4.3 For specific criteria used in Table 1, refer to Table X1.1.

TABLE X1.1 Specific Criteria Used for Table 1[A]

Material Properties:	
Steel reinforcement, minimum specified yield stress	65 000 psi
Concrete, minimum specified compressive strength	5000 psi
Soil Data:	
Unit weight	120 lbf/ft^3
Ratio of lateral to vertical pressure from weight of earth	0.50 max to 0.25 min
External water table	below box section invert
Soil structure interaction factor	$F_e = 1 + 0.20(H/B_c)$
	B_c = outside width of culvert
	$F_e max = 1.15$
Capacity Reduction Factors	
(from AASHTO LRFD Bridge Design Specifications):	
Shear	0.90
Axial compression combined with bending	1.0
Loading Data:	
Load Modifiers:	
Ductile Structures	$\eta = 1.0$
For earth fill: non-redundant member	$\eta = 1.05$
For live load: redundant member	$\eta = 1.0$
Typical Bridge	$\eta = 1.0$
Load Factors:	
Dead Load	Max DL = 1.25, Min DL = 0.90
Earth Load (Vertical)	Max ELV = 1.30, Min ELV = 0.90
Earth Load (Horizontal)	Max ELH = 1.35 (see X1.2.5)
Live Load	LL = 1.75
Multiple Presence Factor	MPF = 1.2 (for one lane)
Live Load HL-93:[B]	
Greater of:	
Truck Axle Load	32 000 lbf
Tandem Axle Load	2 at 25 000 lbf each
H < 2 ft	
Area of box section resisting truck axle load	
Direction Perpendicular to Span	E = 96 (in.) + 1.44Span (ft)
Direction Parallel to Span	L = 10 (in.) + 1.15H (in.)
H ≥ 2 ft	
Area of box section resisting truck wheel load	
Direction Perpendicular to Span	W = 20 (in.) + 1.15H (in.)
Direction Parallel to Span	L = 10 (in.) + 1.15H (in.)
Dynamic Load Allowance (variable with depth)	= 0.33(1 – 0.125H)
Uniform internal pressure	0.0
Depth of water in box section	equal to inside height
External ground water pressure	0.0
Lateral Live Load Pressure:	
From 0 to 5 ft	160 psf
5 ≥ 10 ft	160 – [(H-5)/(10-5)](160-120) psf
10 ≥ 20 ft	120 – [(H-10)/(20-10)](120-80) psf
20 ft or greater	80 psf
Structural Arrangement:	
Reinforcement Spacing	4.0 in.
Concrete cover over steel	1.0 in.
Top slab (outside face)	1.0 in. for fill heights 2 ft and greater, 2.0 in. for fill heights under 2 ft
Side wall thickness	1⁄12 times inside span plus 1.0 in. up to 7-ft span, 1⁄12 inside span above 7-ft span
Slab thickness	equal to sidewall thickness unless otherwise noted
Haunch dimensions	vertical and horizontal dimensions both equal to side wall thickness
Minimum reinforcing inside face slabs and side walls, outside face side walls and corners of slabs	0.002 bt

[A] The structural arrangement and details are shown in Fig. 1.
[B] Refer to Fig. X1.1 for wheel load arrangements.

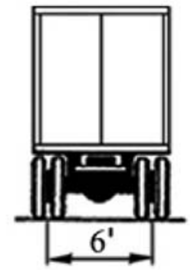
X1.4.4 The maximum height of earth cover shown in Table 1 is determined by the shear strength of the box section without the use of special shear reinforcement and by the standard weight of the column of earth directly above the box section multiplied by the soil structure interaction factor.

X1.5 Multiple Cell Installations

X1.5.1 The designs given herein are for single-cell precast reinforced concrete box sections. The units shall be allowed to be used in parallel for multicell installations if means of positive lateral bearing by continuous contact between the sides of adjacent boxes are provided. Compacted earth fill, granular backfill, flowable fill, or grouting between the units are considered means of providing such positive bearing.

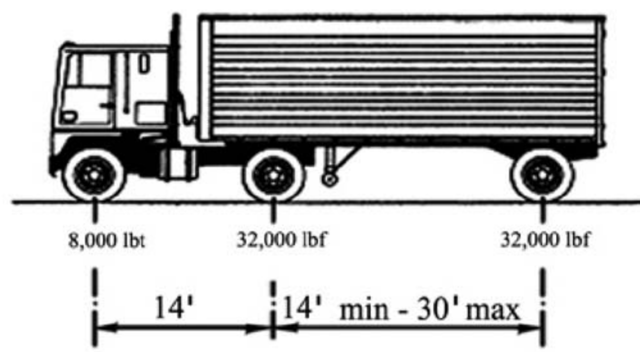
WHEEL SPACING

Design Truck
and
Design Tandem



AXLE LOADS

Design Truck



AXLE LOADS

Design Tandem

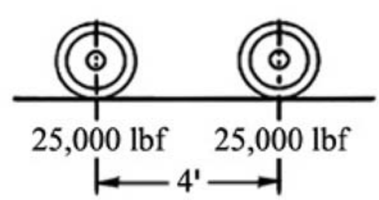


FIG. X1.1 Axle Loads for Box Section Standard Designs