Designation: C 850 – 95a

Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers with Less Than 2 ft of Cover Subjected to Highway Loadings[1]

This standard is issued under the fixed designation C 850; 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 with less than 2 ft of cover subjected to highway loadings and intended to be used for the construction of culverts and for the conveyance of storm water, industrial wastes, and sewage.

1.2 A complete metric companion to Specification C 850 has been developed—C 850M; therefore, no metric equivalents are presented in this specification.

NOTE 1—This specification is primarily a manufacturing and purchasing specification. However, standard designs 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 that the installation conforms to the construction specifications. The owner of the precast reinforced concrete box sections specified herein is cautioned that he must correlate the loading conditions and the field requirements with the box section specified and provide inspection at the construction site.

NOTE 2—Specification C 789 is to be used for box sections subjected to highway loading with 2 ft or more earth cover, or subjected to dead load only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 185 Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement[2]

A 497 Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement[2]

A 615/A615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement[2]

C 33 Specification for Concrete Aggregates[3]

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[3]

C 150 Specification for Portland Cement[4]

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete[3]

C 497 Test Methods for Concrete Pipe, Manhole Sections, or Tile[5]

C 595/C595M Specification for Blended Hydraulic Cements[4]

C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete[3]

C 789 Specification for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers[5]

C 822 Terminology Relating to Concrete Pipe and Related Products[5]

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete[3]

2.2 *AASHTO Standards:*[6]

Interim Specifications for Bridges, 1974 edition

Standard Specifications for Highway Bridges, Twelfth edition

3. Terminology

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

4. Types

4.1 Precast reinforced concrete box sections manufactured in accordance with this specification shall be of the types identified in Table 1 and Table 2 and shall be designated by type, span, and rise.

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.

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[1] This specification is under the jurisdiction of ASTM Committee C-13 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] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.01.

[5] *Annual Book of ASTM Standards*, Vol 04.05.

[6] Available from American Association for State Highway Transportation Officials, 444 N. Capitol, Washington, DC 20001.

TABLE 1 Design Requirement for Precast Reinforced Concrete Box Sections with Less Than 2 ft of Cover Subjected to HS20 Loading[A]

NOTE 1—Reinforcement areas are based on the weight of a column of earth over the width of the box section plus live loads as defined in Appendix X1. Concrete design strength 5000 psi.

Box Section S × R, ft[B]	Thickness, in.			Circumferential Reinforcement Areas[C]					Distribution Reinforcement Areas[D]	
	Top Slab	Bottom Slab	Wall	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s7}	A_{s8}	A_{s5}	A_{s6}
3 × 2	7	6	4	0.17	0.34	0.20	0.13[E]	0.17[E]	0.14[E]	0.17[E]	0.17[E]
3 × 3	7	6	4	0.13[E]	0.36	0.22	0.13[E]	0.17[E]	0.14[E]	0.18	0.17[E]
4 × 2	7½	6	5	0.21	0.37	0.20	0.13[E]	0.18[E]	0.14[E]	0.18[E]	0.18[E]
4 × 3	7½	6	5	0.18	0.41	0.23	0.13[E]	0.18[E]	0.14[E]	0.20	0.18[E]
4 × 4	7½	6	5	0.16	0.43	0.24	0.13[E]	0.18[E]	0.14[E]	0.21	0.18[E]
5 × 3	8	7	6	0.22	0.41	0.22	0.14[E]	0.19[E]	0.17[E]	0.19[E]	0.19[E]
5 × 4	8	7	6	0.19	0.44	0.24	0.14[E]	0.19[E]	0.17[E]	0.21	0.19[E]
5 × 5	8	7	6	0.16	0.46	0.26	0.14[E]	0.19[E]	0.17[E]	0.22	0.19[E]
6 × 3	8	7	7	0.30	0.42	0.21	0.17[E]	0.19[E]	0.17[E]	0.19[E]	0.19[E]
6 × 4	8	7	7	0.26	0.46	0.24	0.17[E]	0.19[E]	0.17[E]	0.20	0.19[E]
6 × 5	8	7	7	0.23	0.48	0.26	0.17[E]	0.19[E]	0.17[E]	0.21	0.19[E]
6 × 6	8	7	7	0.20	0.51	0.29	0.17[E]	0.19[E]	0.17[E]	0.22	0.19[E]
7 × 4	8	8	8	0.32	0.45	0.24	0.19[E]	0.19[E]	0.19[E]	0.19[E]	0.19[E]
7 × 5	8	8	8	0.29	0.48	0.27	0.19[E]	0.20	0.19[E]	0.19[E]	0.19[E]
7 × 6	8	8	8	0.27	0.51	0.29	0.19[E]	0.20	0.19[E]	0.20	0.19[E]
7 × 7	8	8	8	0.25	0.53	0.32	0.19[E]	0.23	0.19[E]	0.21	0.19[E]
8 × 4	8	8	8	0.37	0.51	0.27	0.19[E]	0.19[E]	0.19[E]	0.19[E]	0.19[E]
8 × 5	8	8	8	0.34	0.53	0.30	0.19[E]	0.19[E]	0.19[E]	0.20	0.19[E]
8 × 6	8	8	8	0.32	0.56	0.33	0.19[E]	0.25	0.19[E]	0.21	0.19[E]
8 × 7	8	8	8	0.30	0.58	0.35	0.19[E]	0.27	0.22	0.22	0.19[E]
8 × 8	8	8	8	0.28	0.60	0.38	0.23	0.29	0.26	0.22	0.19[E]
9 × 5	9	9	9	0.34	0.50	0.29	0.22[E]	0.22[E]	0.22[E]	0.22[E]	0.22[E]
9 × 6	9	9	9	0.32	0.53	0.32	0.22[E]	0.22[E]	0.22[E]	0.22[E]	0.22[E]
9 × 7	9	9	9	0.30	0.55	0.35	0.22[E]	0.25	0.22[E]	0.22[E]	0.22[E]
9 × 8	9	9	9	0.28	0.57	0.38	0.22[E]	0.27	0.24	0.22[E]	0.22[E]
9 × 9	9	9	9	0.27	0.58	0.41	0.25	0.30	0.28	0.22[E]	0.22[E]
10 × 5	10	10	10	0.34	0.48	0.29	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 6	10	10	10	0.32	0.50	0.32	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 7	10	10	10	0.31	0.52	0.35	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 8	10	10	10	0.29	0.54	0.38	0.24[E]	0.26	0.24[E]	0.24[E]	0.24[E]
10 × 9	10	10	10	0.27	0.55	0.40	0.24[E]	0.28	0.26	0.24[E]	0.24[E]
10 × 10	10	10	10	0.27	0.57	0.43	0.27	0.32	0.31	0.24[E]	0.24[E]
11 × 4	11	11	11	0.38	0.44	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 6	11	11	11	0.33	0.48	0.32	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 8	11	11	11	0.29	0.51	0.38	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 10	11	11	11	0.28	0.54	0.43	0.26[E]	0.29	0.29	0.26[E]	0.26[E]
11 × 11	11	11	11	0.28	0.56	0.46	0.30	0.34	0.34	0.26[E]	0.26[E]
12 × 4	12	12	12	0.40	0.42	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 6	12	12	12	0.35	0.46	0.32	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 8	12	12	12	0.31	0.49	0.38	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 10	12	12	12	0.29[E]	0.53	0.43	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 12	12	12	12	0.29[E]	0.57	0.50	0.33	0.36	0.37	0.29[E]	0.29[E]

[A] Design requirements are based on maximum effects resulting from cover conditions ranging from 0 to 2 ft and the material and soil properties and loading data shown in Appendix X1. For modified or special designs see 7.2.
[B] The box section designation, for example, 3 × 2, indicates interior horizontal span, in feet, by interior vertical rise, in feet.
[C] Design reinforcement areas in square inches per linear foot of box section length at those locations as shown in Fig. 1.
[D] Design reinforcement areas in square inches per linear foot of box section width at those locations as shown in Fig. 1.
[E] Minimum reinforcement area is specified.

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

6. Materials

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/C 595M, except that the pozzolan constituent in the Type IP portland pozzolan cement shall be fly ash and shall not exceed 25 % by weight.

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

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

6.2.3.1 Portland cement only.

6.2.3.2 Portland blast furnace slag cement only.

6.2.3.3 Portland pozzolan cement only.

6.2.3.4 A combination of portland cement and fly ash wherein the proportion of fly ash is between 5 and 25 % by weight of total cementitious material (portland cement plus fly ash).

TABLE 2 Design Requirement for Precast Reinforced Concrete Box Sections with Less Than 2 ft of Cover Subjected to Interstate Loading[A]

NOTE 1—Reinforcement areas are based on the weight of a column of earth over the width of the box section plus live loads as defined in Appendix X1. Concrete design strength 5000 psi.

Box Section S × R, ft[B]	Thickness, in.			Circumferential Reinforcement Areas[C]					Distribution Reinforcement Areas[D]	
	Top Slab	Bottom Slab	Wall	A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s7}	A_{s8}	A_{s5}	A_{s6}
3 × 2	7	6	4	0.17	0.34	0.20	0.13[E]	0.17[E]	0.14[E]	0.17[E]	0.17[E]
3 × 3	7	6	4	0.13[E]	0.36	0.22	0.13[E]	0.17[E]	0.14[E]	0.18	0.17[E]
4 × 2	7½	6	5	0.21	0.38	0.20	0.13[E]	0.18[E]	0.14[E]	0.19	0.18[E]
4 × 3	7½	6	5	0.19	0.41	0.23	0.13[E]	0.18[E]	0.14[E]	0.21	0.18[E]
4 × 4	7½	6	5	0.18	0.43	0.25	0.13[E]	0.18[E]	0.14[E]	0.22	0.18[E]
5 × 3	8	7	6	0.26	0.41	0.28	0.14[E]	0.19[E]	0.17[E]	0.19[E]	0.19[E]
5 × 4	8	7	6	0.23	0.44	0.31	0.14[E]	0.19[E]	0.17[E]	0.21	0.19[E]
5 × 5	8	7	6	0.21	0.46	0.34	0.14[E]	0.19[E]	0.17[E]	0.22	0.19[E]
6 × 3	8	7	7	0.33	0.42	0.28	0.17[E]	0.19[E]	0.17[E]	0.19[E]	0.19[E]
6 × 4	8	7	7	0.29	0.46	0.32	0.17[E]	0.19[E]	0.17[E]	0.20	0.19[E]
6 × 5	8	7	7	0.27	0.48	0.34	0.17[E]	0.19[E]	0.17[E]	0.21	0.19[E]
6 × 6	8	7	7	0.25	0.51	0.37	0.17[E]	0.19[E]	0.17[E]	0.22	0.19[E]
7 × 4	8	8	8	0.33	0.45	0.31	0.19[E]	0.19[E]	0.19[E]	0.19[E]	0.19[E]
7 × 5	8	8	8	0.30	0.48	0.34	0.19[E]	0.20	0.19[E]	0.19[E]	0.19[E]
7 × 6	8	8	8	0.28	0.51	0.37	0.19[E]	0.20	0.19[E]	0.20	0.19[E]
7 × 7	8	8	8	0.26	0.53	0.39	0.19[E]	0.23	0.19[E]	0.21	0.19[E]
8 × 4	8	8	8	0.43	0.51	0.34	0.19[E]	0.19[E]	0.19[E]	0.19[E]	0.19[E]
8 × 5	8	8	8	0.39	0.53	0.38	0.19[E]	0.19[E]	0.19[E]	0.20	0.19[E]
8 × 6	8	8	8	0.36	0.56	0.41	0.19[E]	0.25	0.19[E]	0.21	0.19[E]
8 × 7	8	8	8	0.34	0.58	0.45	0.19[E]	0.27	0.22	0.22	0.19[E]
8 × 8	8	8	8	0.31	0.60	0.48	0.23	0.29	0.26	0.22	0.19[E]
9 × 5	9	9	9	0.42	0.50	0.37	0.22[E]	0.22[E]	0.22[E]	0.22[E]	0.22[E]
9 × 6	9	9	9	0.39	0.53	0.40	0.22[E]	0.22[E]	0.22[E]	0.22[E]	0.22[E]
9 × 7	9	9	9	0.37	0.55	0.44	0.22[E]	0.25	0.22[E]	0.22[E]	0.22[E]
9 × 8	9	9	9	0.34	0.57	0.47	0.22[E]	0.27	0.24	0.22[E]	0.22[E]
9 × 9	9	9	9	0.32	0.58	0.50	0.25	0.30	0.28	0.22[E]	0.22[E]
10 × 5	10	10	10	0.44	0.48	0.36	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 6	10	10	10	0.41	0.50	0.40	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 7	10	10	10	0.39	0.52	0.43	0.24[E]	0.24[E]	0.24[E]	0.24[E]	0.24[E]
10 × 8	10	10	10	0.36	0.54	0.46	0.24[E]	0.26	0.24[E]	0.24[E]	0.24[E]
10 × 9	10	10	10	0.34	0.55	0.50	0.24[E]	0.28	0.26	0.24[E]	0.24[E]
10 × 10	10	10	10	0.33	0.57	0.53	0.27	0.32	0.31	0.24[E]	0.24[E]
11 × 4	11	11	11	0.49	0.44	0.32	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 6	11	11	11	0.43	0.48	0.40	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 8	11	11	11	0.38	0.51	0.46	0.26[E]	0.26[E]	0.26[E]	0.26[E]	0.26[E]
11 × 10	11	11	11	0.35	0.54	0.53	0.26[E]	0.29	0.29	0.26[E]	0.26[E]
11 × 11	11	11	11	0.34	0.57	0.56	0.30	0.34	0.34	0.26[E]	0.26[E]
12 × 4	12	12	12	0.50	0.42	0.32	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 6	12	12	12	0.44	0.46	0.39	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 8	12	12	12	0.40	0.50	0.46	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 10	12	12	12	0.36	0.56	0.53	0.29[E]	0.29[E]	0.29[E]	0.29[E]	0.29[E]
12 × 12	12	12	12	0.35	0.61	0.60	0.33	0.36	0.37	0.29[E]	0.29[E]

[A] Design requirements are based on maximum effects resulting from cover conditions ranging from 0 to 2 ft and the material and soil properties and loading data shown in Appendix X1. For modified or special designs see 7.2.
[B] Design reinforcement areas in square inches per linear foot of box section length at those locations as shown in Fig. 1.
[C] The box section designation, for example, 3 × 2, indicates interior horizontal span, in feet, by interior vertical rise, in feet.
[D] Design reinforcement areas in square inches per linear foot of box section width at those locations as shown in Fig. 1.
[E] Minimum reinforcement area is specified.

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

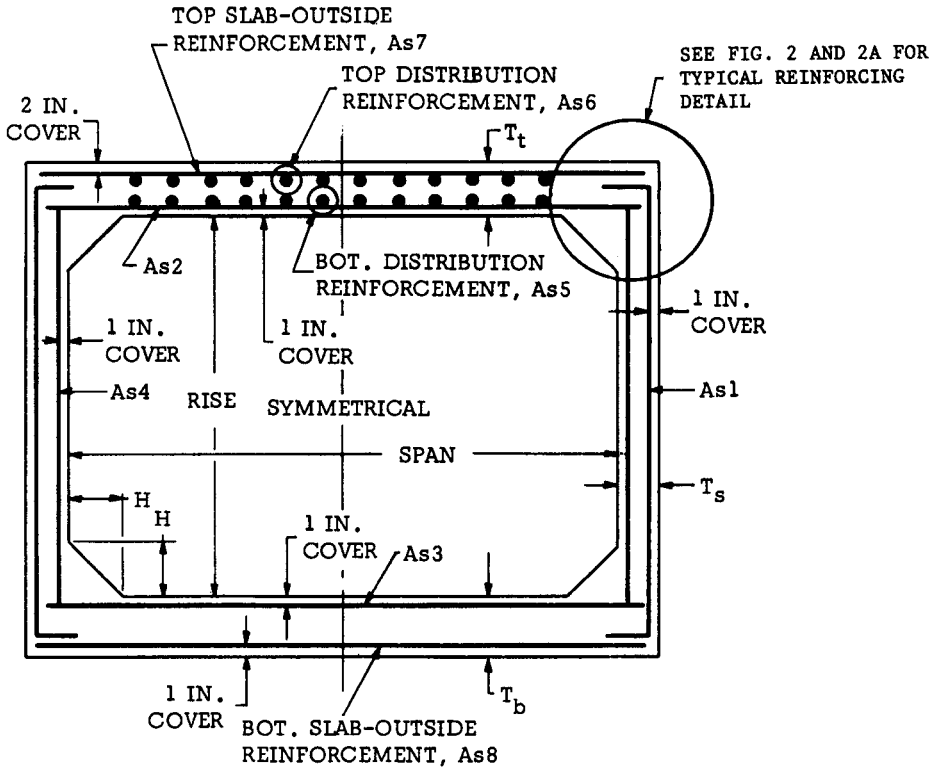
6.4 *Admixtures and Blends*—Admixtures and blends may be used with the approval of the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of welded wire fabric conforming to Specifications A 185 or A 497. Longitudinal distribution reinforcement may consist of welded wire fabric 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 pipe 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 or Table 2 and Fig. 1 and Fig. 2, subject to the provisions of Section 11. Table 1 sections are designed for a cover range from 0 to 2 ft plus AASHTO HS20 live load conditions. Table 2 sections are designed for a cover range from 0 to 2 ft plus Interstate live load conditions. Criteria used to develop Table 1 and Table 2 are given in Appendix X1.



NOTE 1—The haunch dimension, H, is equal to the thickness, T_s.

FIG. 1 Typical Box Section

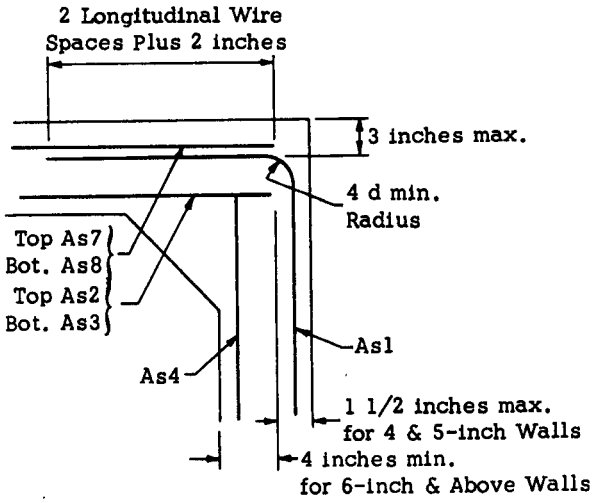


FIG. 2 Detail Reinforcement Arrangement

7.2 *Modified and Special Designs*—The manufacturer may request approval by the owner of modified designs which differ from the designs in 7.1; or special designs for sizes and loads other than those shown in Table 1 and Table 2.

7.3 *Placement of Reinforcement*—The cover of concrete over the circumferential reinforcement shall be 1 in. except on the outside top of the top slab where it shall be 2 in., subject to the provisions of Section 11. The inside circumferential and longitudinal reinforcement shall extend into the male portion of the joint, and the outside circumferential and longitudinal reinforcement shall extend into the female 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 fabric. Common reinforcement units may be utilized for both A_{s2}(or A_{s3}) and A_{s4}, and also for both A_{s7}(or A_{s8}) and A_{s1}, with the largest area requirement of each combination governing, bending the reinforcement 90° at the corners, and waiving the extension requirements of Fig. 2. See Fig. 3. The welded-wire fabric 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 may be welded-wire fabric or deformed billet-steel bars and shall meet the spacing

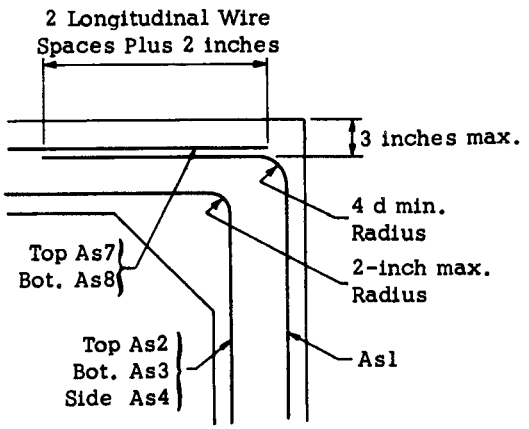


FIG. 3 Detail Option

requirements of 7.4. The ends of the longitudinal distribution reinforcement shall be not 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 fabric sheet shall be not less than the spacing of the longitudinal wires plus 2 in. A_{s1} shall be lapped with A_{s7} and A_{s8} as shown in Fig. 2 or Fig. 3 and may be connected by welding. A_{s4} may be lapped and welded at any location or connected by welding at the corners to A_{s2} and A_{s3}. The spacing center to center of the circumferential wires shall be not 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. The spacing center to center of the longitudinal distribution wires or bars for either line of reinforcing in the top slab shall be not more than 8 in.

8. Joints

8.1 The precast reinforced concrete box sections shall be produced with male and female 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.

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 pipe 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 pipe 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 in 28 days or less. Any one of the following methods of curing or combinations thereof may be used:

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

9.2.2 *Water Curing*—The box sections may 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 may be applied and shall be left intact until the required concrete compressive strength is attained. The concrete temperature at the time of the 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 shall be permitted in each box section for the purpose of handling and laying.

10. Physical Requirements

Concrete Testing

10.1 *Type of Specimen*—Compression tests for determining concrete compressive strength may be made on either concrete cylinders or on cores drilled from the box section. (See Specification C 39.)

10.2 *Compression Testing of Cylinders*:

10.2.1 *Cylinder Production*—Cylinders shall be prepared in accordance with the Cylinder Strength Test Method of Test Methods C 497.

10.2.2 *Number of Cylinders*—Prepare not fewer than five test cylinders from 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 compressive strengths of all cylinders tested for a group are equal to or greater than the design concrete strength, the compressive strength in the group of box sections shall be accepted.

10.2.3.2 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, then the compressive strength of the concrete in the group of box sections shall be accepted.

10.2.3.3 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 10.2.3.1 or 10.2.3.2, the acceptability of the group shall be determined in accordance with the provisions of 10.2.

10.3 *Compression Testing of Cores*:

10.3.1 *Obtaining Cores*—Cores shall be obtained and prepared in accordance with the Core Strength Test Method of Test Methods C 497.

10.3.2 *Number of Cores*—One core shall be taken from a box section selected at random from each group of 15 box sections of a single size or fraction of such a group from each continuous production run.

10.4 *Acceptability on the Basis of Core Test Results*:

10.4.1 When the compressive strengths of cores tested for a group of box sections are equal to or greater than the design concrete strength, the compressive strength of the concrete for the group is acceptable.

10.4.2 If the compressive strength of the core tested is less than the design concrete strength, the box section from which that core was taken may be recored. If the compressive strength of the recore is equal to or greater than the design concrete compressive strength, the compressive strength of the concrete for the group is acceptable.

10.4.3 If the compressive strength of the recore is less than the design concrete strength, the box section from which the core was 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 box section. If the compressive strength of both cores is equal to or greater than the design concrete compressive strength, the concrete compressive strength of the remainder of the group shall be acceptable. If the compressive strength of either of the two cores tested is less than the design concrete compressive strength, then the remainder of the group shall be either 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 the box sections that have a core with less than the design concrete compressive strength shall be rejected.

10.5 *Plugging Core Holes*—Core holes shall be plugged and sealed by the manufacturer in a manner such that the pipe section will meet all of the requirements of this specification. Pipe sections so plugged and sealed shall be considered satisfactory for use.

10.6 *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 vary not more than 1 % from the design dimensions. The haunch dimensions shall vary not 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 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 for 5-in. or less wall thicknesses shall be ±⅜ in., and for greater than 5-in. slab and wall thicknesses 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 of the box section, except the cover over the reinforcement for the external surface of the top slab 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 and Table 2. Steel areas greater than those required shall not be cause for rejection. The permissible variation in diameter of any reinforcement shall conform to the tolerances prescribed in the ASTM specification for that type of reinforcement.

12. Repairs

12.1 Box sections may be repaired, if necessary, because of imperfections in manufacture or handling damage and will be acceptable if, in the opinion of the owner, 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 owner.

14. Rejection

14.1 Box sections shall be subject to rejection on account of failure to conform to any of the specification requirements. Individual box sections may be rejected 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,

14.1.3 The ends of the box sections are not normal 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. Product 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, table number, and specification designation,

15.1.2 Date of manufacture,

15.1.3 Name or trademark of the manufacturer,

15.1.4 Identification of the plant, and

15.1.5 Each section shall be clearly marked by indentation 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.

16. Keywords

16.1 concrete box—precast; culvert; sewer pipe; storm drain

APPENDIX

(Nonmandatory Information)

X1. DESIGN CRITERIA USED TO DEVELOP TABLE 1 AND TABLE 2

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.

X1.1.2 The cover over the top of the box section may vary from 0 to 2 ft.

X1.2 Criteria for Loads

X1.2.1 Design loads are based on the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges,* Twelfth ed., 1977.

X1.2.2 Live loads for designs given in Table 1 are HS20 loadings as defined in the AASHTO specifications. Live loads for designs given in Table 2 are interstate loadings as defined in U.S. Dept of Commerce, Bureau of Public Roads Circular Memorandum 22-40, 22 April 1957. Impact allowances are in accordance with AASHTO specifications. Wheel loads are distributed over a width of [48 + 0.06 × (span minus one haunch)], in inches, perpendicular to the span by use of longitudinal distribution reinforcement in top and bottom of top slab. Loads are spread parallel to span over a length equal to (8 + 1.75 H cover) in inches. Cover loads for designs given in Table 1 and Table 2 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.

X1.2.3 Lateral earth pressure from weight of earth above and adjacent to a box section is taken as a minimum of 0.25 times vertical pressure, and an additional 0.25 times vertical pressure is added in determining reinforcement areas only when areas are increased by such increased lateral pressure. Additional lateral pressure in pounds force per square foot from approaching wheel loads is taken as 700 divided by depth to surface in feet, or 800 where depth to surface is less than 1 ft, and is added when determining reinforcement areas only at sections where areas are increased by increased lateral pressure..

X1.3 Method 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 factor design provisions given in AASHTO Interim Specifications for Bridges 1974. The load factor for dead load is increased from 1.3 to 1.5 for consistency with Specification C 789. Reinforcement areas are governed by either service live load fatigue stress limitation of 21 000 lbf/in.^{2}, or service total load stress limitation of 36 000 lbf/in.^{2}, or ultimate total load yield stress limitation of 60 000 lbf/in.^{2} Crack width is controlled by limiting maximum spacing of circumferential reinforcement (welded wire fabric) to 4 in. and longitudinal distribution reinforcement (welded wire fabric or deformed grade 60 bars) to 8 in. Longitudinal distribution reinforcement called for in Table 1 and Table 2 for top slab inside face is in accordance with distribution reinforcement formulas given in AASHTO specification for bridge decks. Longitudinal distribution reinforcement is also required in the top 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.

X1.4.2 Some box section designs shown in Table 1 and Table 2 have reinforcement area requirements designated by "*E*" as minimum reinforcement area. For such cases, the reinforcement areas calculated for support of design loads are less than the minimum area which is specified in AASHTO specifications, 0.002 Ag or 0.125 in.^{2}/ft, whichever is greater.

X1.4.3 For specific criteria used to develop Table 1 and Table 2, refer to Table X1.1.

X1.4.4 The top and bottom slab and sidewall thicknesses given in Table 1 and Table 2 either conform to the dimensions used in Specification C 789 or provide the minimum thickness required because of shear requirements given the AASHTO specification. The effective width of top or bottom slab for distribution of shear stress resulting from wheel loads is the same width used for determining maximum bending moments per unit of box section length.

X1.4.5 Haunch dimensions are the values used in Specification C 789 and are the same as the sidewall thickness, T_s, shown in Table 1 and Table 2.

X1.5 Multiple-Cell Installations

X1.5.1 The designs given herein are for single cell precast reinforced concrete box sections. The units may 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, or grouting between the units are considered means of providing such positive bearing.

TABLE X1.1 Specific Criteria Used to Develop Table 1 and Table 2

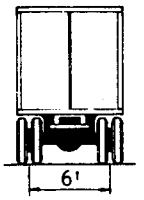
Material Properties:	
Welded wire fabric (circumferential or longitudinal distribution reinforcement), specified yield stress	60 000 psi
Deformed bars (longitudinal distribution reinforcement), specified yield stress	60 000 psi
Length of box section resisting truck wheel load	48 + 0.06 (span minus haunches) in.
Length of wheel bearing area parallel to slab span	(8 + 1.75H) in.
Concrete, minimum specified compressive strength	5 000 psi
Soil Data:	
Unit weight	120 lbf/ft^3
Ratio of lateral to vertical pressure from weight of earth	0.25 min to 0.50 max
External water table	below box section invert
Effective weight coefficient for soil load	1.0
Capacity Reduction Factors:	
Shear	0.85
Axial compression combined with bending	0.70 to 0.90
Loading Data:	
Load factor—dead load	1.5
Load factor—live load	2.2
Truck axle load:	
HS20 (Table 1)	32 000 lbf (see Fig. X1.1)
Interstate (Table 2)	2 @ 24 000 lbf each (see Fig. X1.1)
Lateral earth pressure from approaching wheel	800 lbf/ft^2 to 1 ft earth cover 700/*H* lbf/ft^2 where *H* is depth of earth cover, ft, when depth exceeds 1 ft
Impact (variable with depth), see AASHTO Bridge Specifications, 1977	30 % to 20 %
Uniform internal pressure	0.0
Depth of water in box section	equal to inside height
External ground water pressure	0.0
Structural Arrangements:	
Concrete cover over steel:	
Top of top slab	2 in.
All other surfaces	1 in.
Slab thickness	see Table 1 and Table 2
Side wall thickness	see Table 1 and Table 2
Haunch dimensions	vertical and horizontal dimensions both equal to side wall thickness
Minimum reinforcement	0.002 Ag or 0.125 in.^{2}/ft, whichever is greater
The structural arrangement and details are shown in Fig. 1 and Fig. 2.	

WHEEL SPACING

HS-20 Truck

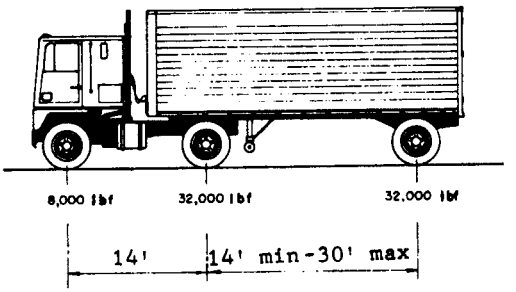
and

Interstate Alternate Load



AXLE LOADS

HS-20 Load



AXLE LOADS

Interstate Alternate Load

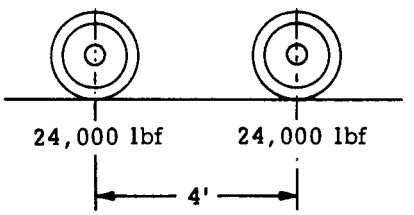


FIG. X1.1 Axle Loads for Box Section Standard Designs