



Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers with Less Than 0.6 m of Cover Subjected to Highway Loadings [Metric]¹

This standard is issued under the fixed designation C 850M; 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 0.6 m 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 This metric specification is equivalent to C 850 and is compatible in technical content.

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, controlled manufacture in the plant, and care that the installation conforms to the construction specifications. The owner of the precast reinforced concrete box sections specified herein is cautioned that he must properly correlate the loading conditions and the field requirements with the box section specified and provide inspection at the construction site.

NOTE 2—Specification C 789M is to be used for box sections subjected to highway loading with 0.6 m 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 Reinforcement²
- A 497 Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement²
- A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement²
- C 33 Specification for Concrete Aggregates³
- C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens³

C 150 Specification for Portland Cement⁴

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete³

C 497M Test Methods for Concrete Pipe, Manhole Sections, or Tile (Metric)⁵

C 595 Specification for Blended Hydraulic Cements⁴

C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete³

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

C 822 Terminology Relating to Concrete Pipe and Related Products⁵

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete³

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.

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.

Current edition approved Sept. 10, 1998. Published March 1999. Originally published as C 850M – 78. Last previous edition C 850M – 95b.

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 0.6 m of Cover Subjected to HS20 Loading^A

NOTE 1—Reinforcement areas are based on the mass of a column of earth over the width of the box section plus live loads as defined in Appendix X1.

NOTE 2—Concrete design strength 35 MPa.

Box Section, S × R, mm ^B	Thickness, mm			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}
900 × 600	175	150	100	360	720	420	280 ^E	360 ^E	300 ^E	360 ^E	360 ^E
900 × 900	175	150	100	280 ^E	760	470	280 ^E	360 ^E	300 ^E	380	360 ^E
1200 × 600	190	150	125	440	780	420	280 ^E	380 ^E	300 ^E	380 ^E	380 ^E
1200 × 900	190	150	125	380	870	490	280 ^E	380 ^E	300 ^E	420	380 ^E
1200 × 1200	190	150	125	340	910	510	280 ^E	380 ^E	300 ^E	440	380 ^E
1500 × 900	200	175	150	470	870	470	300 ^E	400 ^E	360 ^E	400 ^E	400 ^E
1500 × 1200	200	175	150	400	930	510	300 ^E	400 ^E	360 ^E	440	400 ^E
1500 × 1500	200	175	150	340	970	550	300 ^E	400 ^E	360 ^E	470	400 ^E
1800 × 900	200	175	175	640	890	440	360 ^E	400 ^E	360 ^E	400 ^E	400 ^E
1800 × 1200	200	175	175	550	970	510	360 ^E	400 ^E	360 ^E	420	400 ^E
1800 × 1500	200	175	175	490	1020	550	360 ^E	400 ^E	360 ^E	440	400 ^E
1800 × 1800	200	175	175	420	1080	610	360 ^E	400 ^E	360 ^E	470	400 ^E
2100 × 1200	200	200	200	680	950	510	400 ^E	400 ^E	400 ^E	400 ^E	400 ^E
2100 × 1500	200	200	200	610	1020	570	400 ^E	420	400 ^E	400 ^E	400 ^E
2100 × 1800	200	200	200	570	1080	610	400 ^E	420	400 ^E	420	400 ^E
2100 × 2100	200	200	200	530	1120	680	400 ^E	490	400 ^E	440	400 ^E
2400 × 1200	200	200	200	780	1080	570	400 ^E	400 ^E	400 ^E	400 ^E	400 ^E
2400 × 1500	200	200	200	720	1120	640	400 ^E	400 ^E	400 ^E	440	400 ^E
2400 × 1800	200	200	200	680	1190	700	400 ^E	530	400 ^E	440	400 ^E
2400 × 2100	200	200	200	640	1230	740	400 ^E	570	470	470	400 ^E
2400 × 2400	200	200	200	590	1270	800	490	610	550	470	400 ^E
2700 × 1500	225	225	225	720	1060	610	470 ^E	470 ^E	470 ^E	470 ^E	470 ^E
2700 × 1800	225	225	225	680	1120	680	470 ^E	470 ^E	470 ^E	470 ^E	470 ^E
2700 × 2100	225	225	225	640	1160	740	470 ^E	530	470 ^E	470 ^E	470 ^E
2700 × 2400	225	225	225	590	1210	800	470 ^E	570	510	470 ^E	470 ^E
2700 × 2700	225	225	225	570	1230	870	530	640	590	470 ^E	470 ^E
3000 × 1500	250	250	250	720	1020	610	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 1800	250	250	250	680	1060	680	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 2100	250	250	250	660	1100	740	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 2400	250	250	250	610	1140	800	510 ^E	550	510 ^E	510 ^E	510 ^E
3000 × 2700	250	250	250	570	1160	850	510 ^E	590	550	510 ^E	510 ^E
3000 × 3000	250	250	250	570	1210	910	570	680	660	510 ^E	510 ^E
3300 × 1200	275	275	275	800	930	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 1800	275	275	275	700	1020	680	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 2400	275	275	275	610	1080	800	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 3000	275	275	275	590	1140	910	550 ^E	610	610	550 ^E	550 ^E
3300 × 3300	275	275	275	590	1190	970	640	720	720	550 ^E	550 ^E
3600 × 1200	300	300	300	850	890	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 1800	300	300	300	740	970	680	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 2400	300	300	300	660	1040	800	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 3000	300	300	300	610 ^E	1120	910	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 3600	300	300	300	610 ^E	1210	1060	700	760	780	610 ^E	610 ^E

^A Design requirements are based on maximum effects resulting from cover conditions ranging from 0 to 0.6 m 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, 900 by 600, indicates interior horizontal span, in millimetres, by interior vertical rise, in millimetres.

^C Design reinforcement areas in square millimetres per linear metre of box section length at those locations as shown in Fig. 2.

^D Design reinforcement areas in square millimetres per linear metre of box section width at those locations as shown in Fig. 2.

^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 con-

forming to the requirements of Specification C 595, 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

TABLE 2 Design Requirement for Precast Reinforced Concrete Box Sections with Less Than 0.6 m of Cover Subjected to Interstate Loading^A

NOTE 1—Reinforcement areas are based on the mass of a column of earth over the width of the box section plus live loads as defined in Appendix X1.

NOTE 2—Concrete design strength 35 MPa.

Box Section, S × R, mm ^B	Thickness, mm			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}
900 × 600	175	150	100	360	720	420	280 ^E	360 ^E	300 ^E	360 ^E	360 ^E
900 × 900	175	150	100	280 ^E	760	470	280 ^E	360 ^E	300 ^E	380	360 ^E
1200 × 600	190	150	125	440	800	420	280 ^E	380 ^E	300 ^E	380 ^E	380 ^E
1200 × 900	190	150	125	400	870	490	280 ^E	380 ^E	300 ^E	420	380 ^E
1200 × 1200	190	150	125	380	910	530	280 ^E	380 ^E	300 ^E	440	380 ^E
1500 × 900	200	175	150	550	870	590	300 ^E	400 ^E	360 ^E	400 ^E	400 ^E
1500 × 1200	200	175	150	490	930	660	300 ^E	400 ^E	360 ^E	440	400 ^E
1500 × 1500	200	175	150	440	970	720	300 ^E	400 ^E	360 ^E	470	400 ^E
1800 × 900	200	175	175	700	890	590	360 ^E	400 ^E	360 ^E	400 ^E	400 ^E
1800 × 1200	200	175	175	610	970	680	360 ^E	400 ^E	360 ^E	420	400 ^E
1800 × 1500	200	175	175	570	1020	720	360 ^E	400 ^E	360 ^E	440	400 ^E
1800 × 1800	200	175	175	530	1080	780	360 ^E	400 ^E	360 ^E	470	400 ^E
2100 × 1200	200	200	200	700	950	660	400 ^E	400 ^E	400 ^E	400 ^E	400 ^E
2100 × 1500	200	200	200	640	1020	720	400 ^E	420	400 ^E	400 ^E	400 ^E
2100 × 1800	200	200	200	590	1080	780	400 ^E	420	400 ^E	420	400 ^E
2100 × 2100	200	200	200	550	1120	830	400 ^E	490	400 ^E	440	400 ^E
2400 × 1200	200	200	200	910	1080	720	400 ^E	400 ^E	400 ^E	400 ^E	400 ^E
2400 × 1500	200	200	200	830	1120	800	400 ^E	400 ^E	400 ^E	440	400 ^E
2400 × 1800	200	200	200	760	1190	870	400 ^E	530	400 ^E	440	400 ^E
2400 × 2100	200	200	200	720	1230	950	400 ^E	570	470	470	400 ^E
2400 × 2400	200	200	200	660	1270	1020	490	610	550	470	400 ^E
2700 × 1500	225	225	225	890	1060	780	470 ^E	470 ^E	470 ^E	470 ^E	470 ^E
2700 × 1800	225	225	225	830	1120	850	470 ^E	470 ^E	470 ^E	470 ^E	470 ^E
2700 × 2100	225	225	225	780	1160	930	470 ^E	530	470 ^E	470 ^E	470 ^E
2700 × 2400	225	225	225	720	1210	990	470 ^E	570	510	470 ^E	470 ^E
2700 × 2700	225	225	225	680	1230	1060	530	640	590	470 ^E	470 ^E
3000 × 1500	250	250	250	930	1020	760	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 1800	250	250	250	870	1060	850	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 2100	250	250	250	830	1100	910	510 ^E	510 ^E	510 ^E	510 ^E	510 ^E
3000 × 2400	250	250	250	760	1140	970	510 ^E	550	510 ^E	510 ^E	510 ^E
3000 × 2700	250	250	250	720	1160	1060	510 ^E	590	550	510 ^E	510 ^E
3000 × 3000	250	250	250	700	1210	1120	570	680	660	510 ^E	510 ^E
3300 × 1200	275	275	275	1040	930	680	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 1800	275	275	275	910	1020	850	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 2400	275	275	275	800	1080	970	550 ^E	550 ^E	550 ^E	550 ^E	550 ^E
3300 × 3000	275	275	275	740	1140	1120	550 ^E	610	610	550 ^E	550 ^E
3300 × 3300	275	275	275	720	1210	1190	640	720	720	550 ^E	550 ^E
3600 × 1200	300	300	300	1060	890	680	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 1800	300	300	300	930	970	830	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 2400	300	300	300	850	1060	970	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 3000	300	300	300	760	1190	1120	610 ^E	610 ^E	610 ^E	610 ^E	610 ^E
3600 × 3600	300	300	300	740	1290	1270	700	760	780	610 ^E	610 ^E

^A Design requirements are based on maximum effects resulting from cover conditions ranging from 0 to 0.6 m 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, 900 by 600, indicates interior horizontal span, in millimetres, by interior vertical rise, in millimetres.

^C Design reinforcement areas in square millimetres per linear metre of box section length at those locations as shown in Fig. 2.

^D Design reinforcement areas in square millimetres per linear metre of box section width at those locations as shown in Fig. 2.

^E Minimum reinforcement area is specified.

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

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

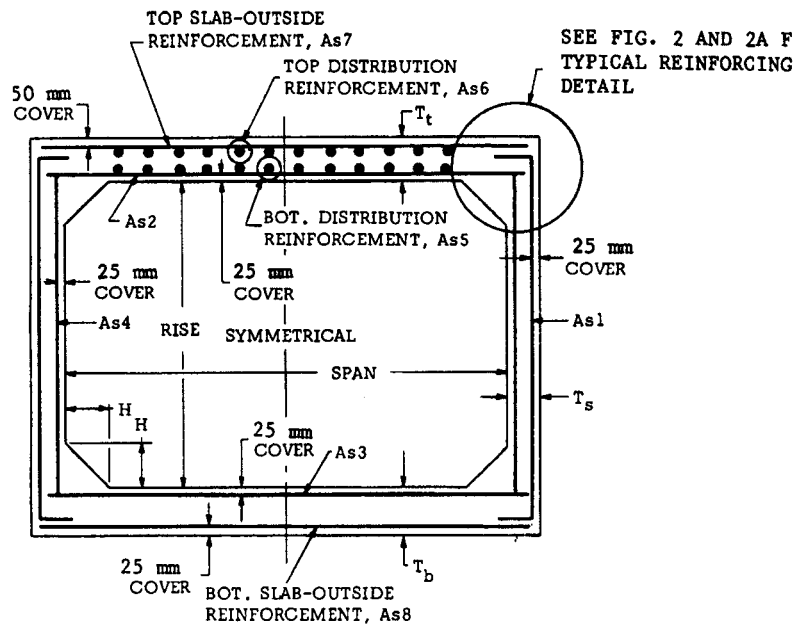
6.4 Admixtures and Blends—Admixtures and blends may be used with the approval of the owner.

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 400.

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 0.6 m plus ASSHTO HS20 live load



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

FIG. 1 Typical Box Section

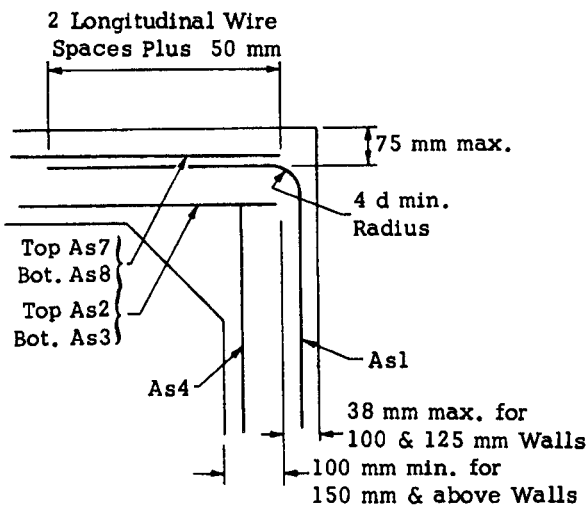


FIG. 2 Detail Reinforcement Arrangement

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 requirements of 7.4. The ends of the longitudinal distribution reinforcement shall be not more than 50 mm 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.

conditions. Table 2 sections are designed for a cover range from 0 to 0.6 m plus Interstate live load conditions. Criteria used to develop Table 1 and Table 2 are given in Appendix X1.

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 25 mm except in the outside top of the top slab where it shall be 50 mm, 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 13 mm nor more than 50 mm from the

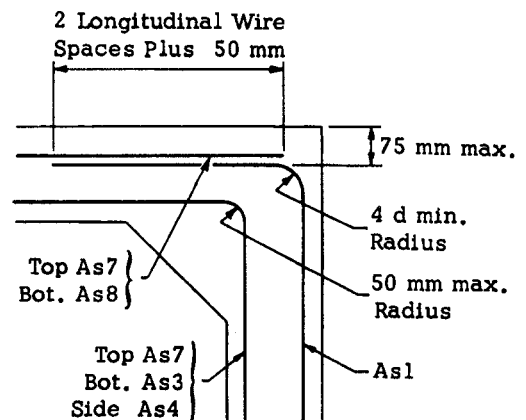


FIG. 3 Detail Option

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 50 mm. 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 50 mm nor more than 100 mm. The spacing center to center of the longitudinal wires shall not be more than 200 mm. 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 200 mm.

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 280 kg/m³, 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 $\pm 6^\circ\text{C}$ 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 Method 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 is 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 box culvert manufacturer shall establish the rise and span of the existing equipment to the nearest millimetre and verify that it is within the limits given in Table 3. The internal dimensions shall not vary more than 1 % from the manufacturer's established metric size.

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 5 mm, 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 10 mm/m of internal span, with a maximum of 16 mm for all sizes through 2100 mm internal span, and a maximum of 19 mm for internal spans greater than 2100 mm, 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 10 mm/m of length with a maximum of 13 mm in any box section.

11.5 Position of Reinforcement—The maximum variation in the position of the reinforcement for 130-mm or less wall thicknesses shall be ± 10 mm, and for greater than 130-mm slab and wall thicknesses shall be ± 13 mm. In no case, however, shall the cover over the reinforcement be less than 16 mm, 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 42

mm. 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

TABLE 3 Permissible Variation in Internal Size (Span or Rise)

Span or Rise Designated Size, mm	Permissible Variation, Internal Size, mm	
	min	max
600	600	620
900	900	920
1200	1200	1230
1500	1500	1540
1800	1810	1850
2100	2110	2160
2400	2410	2460
2700	2710	2770
3000	3020	3080
3300	3320	3390
3600	3620	3690

APPENDIX

(Nonmandatory Information)

X1. DESIGN CRITERIA USED TO DEVELOP TABLES 1 AND 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 0.6 m.

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 $[1200 + 0.06 \times (\text{span minus one haunch})]$, in millimetres, 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 $(200 + 1.75 H \text{ cover})$ in millimetres. Cover loads for designs given in Table 1 and Table 2 are the mass 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 mass 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 kilopascals from approaching wheel loads is taken as 33.5 divided by depth to surface in metres, or 38.3 where depth to surface is less than 0.6 m, 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. Fig. X1.1

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 789M. Reinforcement areas are governed by either service live load fatigue stress limitation of 145 MPa, or service total load stress limitation of 248 MPa, or ultimate total load yield stress limitation of 414 MPa. Crack width is controlled by limiting maximum spacing of circumferential reinforcement (welded wire fabric) to 100 mm and longitudinal distribution reinforcement (welded wire fabric or deformed grade 60 bars) to 200 mm. 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, $0.002 A_g$ or $265 \text{ mm}^2/\text{m}$, 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 789M 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.

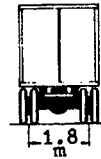
X1.4.5 Haunch dimensions are the values used in Specification C 789M and are the same as the sidewall thickness, T_s , shown in Table 1 and Table 2.

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.

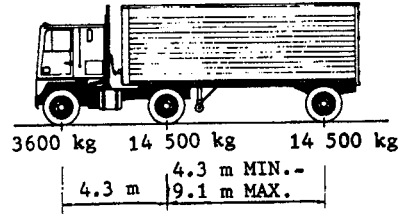
WHEEL SPACING

HS-20 Truck
and
Interstate Alternate Load



AXLE LOADS

HS-20 Load



AXLE LOADS

Interstate Alternate Load

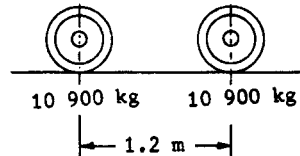


FIG. X1.1 Axle Loads for Box Section Standard Designs

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

Material Properties:		Interstate (Table 2)	2 @ 10 900 kg each (see Fig. X1.1)
Welded wire fabric (circumferential or longitudinal distribution reinforcement), specified yield stress	414 MPa	Lateral earth pressure from approaching wheel	38.3 kPa to 0.6 m earth cover 33.5/H kPa where H is depth of earth cover, m, when depth exceeds 0.6 m
Deformed bars (longitudinal distribution reinforcement), specified yield stress	414 MPa		
Length of box section resisting truck wheel load	1200 + 0.06 (span minus haunches) mm	Impact (variable with depth), see AASHTO Bridge Specifications, 1973	30 % to 20 %
Length of wheel bearing area parallel to slab span	(200 + 1.75H) mm	Uniform internal pressure	0.0
Concrete, minimum specified compressive strength	35 MPa	Depth of water in box section	equal to inside height
		External ground water pressure	0.0
Soil Data:		Structural Arrangements:	
Unit weight	1920 kg/m ³	Concrete cover over steel:	
Ratio of lateral to vertical pressure from weight of earth	0.25 min to 0.50 max	Top of top slab	50 mm
External water table	below box section invert	All other surfaces	25 mm
Effective weight coefficient for soil load	1.0	Slab thickness	see Tables 1 and 2
		Side wall thickness	see Tables 1 and 2
		Haunch dimensions	vertical and horizontal dimensions both equal to side wall thickness
Capacity Reduction Factors:		Minimum reinforcement	0.002 Ag or 265 mm ² /m, whichever is greater
Shear	0.85		
Axial compression combined with bending	0.70 to 0.90		
Loading Data:		The structural arrangement and details are shown in Figs. 1 and 2.	
Load factor—dead load	1.5		
Load factor—live load	2.2		
Truck axle load:			
HS20 (Table 1)	14 500 kg (see Fig. X1.1)		