Box Culvert Design (Basics)

- Josh Beakley
- Director of Technical Services
- American Concrete Pipe Association
Standards/Specifications for Box Culverts

- M 259 (C789 - Discontinued)
- M 273 (C 850 - Discontinued)
- C1433 (Standard)
- C1577 (LRFD)
Designation: C1577 – 13a

Standard Specification for
Precast Reinforced Concrete Monolithic Box Sections for
Culverts, Storm Drains, and Sewers Designed According to
AASHTO LRFD¹

This standard is issued under the fixed designation C1577; 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.
Additional Box Culvert Sizes in C1577 - 13a

- 5 x 2
- 6 x 2
- 7 x 2, 7 x 3
- 8 x 2, 8 x 3
- 9 x 2, 9 x 3, 9 x 4
- 10 x 2, 10 x 3, 10 x 4
- 11 x 2, 11 x 3
- 12 x 2, 12 x 3
## TABLE X1.1 Specific Criteria Used for Table 1

<table>
<thead>
<tr>
<th>Material Properties:</th>
<th>65 000 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel reinforcement, minimum specified yield stress</td>
<td>5000 psi</td>
</tr>
<tr>
<td>Concrete, minimum specified compressive strength</td>
<td></td>
</tr>
</tbody>
</table>

## Soil Data:

- Unit weight
- Ratio of lateral to vertical pressure from weight of earth
- External water table
- Soil structure interaction factor

### Capacity Reduction Factors
(from AASHTO LRFD Bridge Design Specifications):

- **Shear:** \( \eta = 1.0 \)
- **Axial compression combined with bending:** \( \eta = 1.0 \)

### Loading Data:

#### Load Modifiers:
- **Ductile Structures:** \( \eta = 1.0 \)
- **For earth fill: non-redundant member:** \( \eta = 1.0 \)
- **For the 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 X1.25)
- **Live Load:** LL = 1.75
- **Multiple Presence Factor (HL-93):** MPF = 1.2 (for one lane)

#### Live Load HL-93:
- Greater of:
  - Truck Axle Load
  - Tandem Axle Load

- **Area of box section resisting truck axle load:**
  - Direction Perpendicular to Span
  - Direction Parallel to Span

- **Area of box section resisting truck wheel load:**
  - Direction Perpendicular to Span
  - Direction Parallel to Span

### Dynamic Load Allowance (variable with depth):
- Uniform Internal Pressure
- Depth of water in box section
- External ground water pressure

### Lateral Live Load Pressure:
- From 0 to 5 ft
- 5 to 10 ft
- 10 to 20 ft
- 20 ft or greater

### Structural Arrangement:
- **Reinforcement Spacing:**
  - Concrete cover over steel
  - Top slab (outside face)

- **Side wall thickness:**
- **Slab thickness:**

### Haunch dimensions:
- Minimum reinforcing inside face slabs and side walls, outside face side walls and corners of slabs

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^ The structural arrangement and details are shown in Fig. 1.

^ Refer to Fig. X1.1 for wheel load arrangements.
AASHTO LRFD Bridge Design Specifications

- Section 3 – Loads and Load Factors
- Section 4 – Structural Analysis and Evaluation
- Section 5 – Concrete Structures
- Section 12 – Buried Structures and Tunnel Liners
LRFD Design
C12.11.2.1

Add the following to the beginning of this Article:

For the design of box culverts, three general load combinations envelope all controlling force effects for the Strength and Service limit states. These are:

- Maximum vertical, Maximum horizontal
- Maximum vertical, Minimum horizontal
- Minimum vertical, Maximum horizontal

Controlling force effects with maximum horizontal loads may occur with live load surcharge (LS) present or absent. Both situations should be investigated.

Move the existing paragraph in this Article below the proposed added paragraph, since it relates to the first paragraph in Article 12.11.2.1.
HL-93 Live Load

3.6.1.2.1

“Vehicular live loading on the roadways of bridges or incidental structures, designated HL-93, shall consist of a combination of the:

- Design truck or design tandem, and
- Design lane load”
3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts

- Where the slab spans primarily in the transverse direction, only the axles of the design truck of Article 3.6.1.2.2 or design tandem of Article 3.6.1.2.3 shall be applied to the deck slab of the top of box culverts.
Applied Live loads

3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts

- Where the slab spans primarily in the longitudinal direction:

- For top slabs of box culverts of all spans and for all other cases, including slab-type bridges where the span does not exceed 15.0 ft, only the axle loads of the design truck or design tandem of Articles 3.6.1.2.2 and 3.6.1.2.3, respectively, shall be applied.
HS20 or HL 93 Single Axle
How Far Down?

3.6.1.2.6

“For single-span culverts, the effects of live load may be neglected where the depth of fill is more than 8.0 ft and exceeds the span length;”
Single Loaded Lane When Less Than 2 Feet

12.11.2.1 – “For traffic traveling parallel to the span, box culverts shall be designed for a single loaded lane with the single lane multiple presence factor.”
Axle Width
### Multiple Presence Factor

<table>
<thead>
<tr>
<th>Lanes</th>
<th>MPF</th>
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<tbody>
<tr>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>0.65</td>
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</tbody>
</table>
4.6.2.10.4 Precast Box Culverts

For precast box culverts with top slabs having span to thickness ratios (s/t) of 18 or less and segment lengths equal to or greater than 4 feet in length, shear transfer across the joint need not be provided.
For cast in place box culverts, and for precast box culverts with top slabs having span to thickness ratios (s/t) greater than 18 or segment lengths less than 4.0 ft., edge beams shall be provided as specified in Article 4.6.2.1.4
Fatigue

LRFD – 5.5.3.1

“Fatigue need not be investigated for concrete deck slabs in multigirder applications or reinforced-concrete box culverts.”
ETCulvert

Concrete Culvert Design in Accordance with AASHTO LRFD Specifications
ETCulvert Scope

- Handles both 3- and 4-sided culverts
- 1 to 4 cells
- Includes both US Customary and Metric (SI) Units
- Supports:
  - LRFD 5th Edition
  - STND 17th Edition
  - AREMA 2010 Edition
**Strength Limit State at Critical Sections: Flexure**

**Member 1: (Exterior Wall), Thickness = 6.00 in**

<table>
<thead>
<tr>
<th>Loc</th>
<th>Dist. (in)</th>
<th>Moment (k-ft)</th>
<th>A. F. (k)</th>
<th>Mu (k-ft)</th>
<th>Ma (k-ft)</th>
<th>phi (in2)</th>
<th>As (in2)</th>
<th>1.2Mcr (k-ft)</th>
<th>IR</th>
<th>OR</th>
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<tbody>
<tr>
<td>BOT</td>
<td>9.00</td>
<td>-2.32</td>
<td>11.89</td>
<td>3.61</td>
<td>5.20</td>
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<td>0.14</td>
<td>5.96</td>
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<td>0.06</td>
<td>5.96</td>
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<td>1.91</td>
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**Member 2: (Top Slab), Thickness = 8.00 in**

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<th>Loc</th>
<th>Dist. (in)</th>
<th>Moment (k-ft)</th>
<th>A. F. (k)</th>
<th>Mu (k-ft)</th>
<th>Ma (k-ft)</th>
<th>phi (in2)</th>
<th>As (in2)</th>
<th>1.2Mcr (k-ft)</th>
<th>IR</th>
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<tbody>
<tr>
<td>LT</td>
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**Member 3: (Interior Wall), Thickness = 6.00 in**

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<th>Moment (k-ft)</th>
<th>A. F. (k)</th>
<th>Mu (k-ft)</th>
<th>Ma (k-ft)</th>
<th>phi (in2)</th>
<th>As (in2)</th>
<th>1.2Mcr (k-ft)</th>
<th>IR</th>
<th>OR</th>
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**Member 4: (Bottom Slab), Thickness = 8.00 in**

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<th>Dist. (in)</th>
<th>Moment (k-ft)</th>
<th>A. F. (k)</th>
<th>Mu (k-ft)</th>
<th>Ma (k-ft)</th>
<th>phi (in2)</th>
<th>As (in2)</th>
<th>1.2Mcr (k-ft)</th>
<th>IR</th>
<th>OR</th>
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<tbody>
<tr>
<td>LT</td>
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<td>1.41</td>
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<td>0.32</td>
<td>10.59</td>
<td>1.56</td>
<td>2.02</td>
</tr>
</tbody>
</table>
Windows Standard Toolbar

Spec.: LRFD 5th ed. 2010
Type of Culvert: Precast

Physical Dimensions
- Clear Span: 7'-0"
- Clear Height: 5'-0"
- Top Slab: 8"
- Bottom Slab: 8"
- Ext. Wall: 6"
- Int. Wall: 6"
- Fill Depth: 1.99 ft
- Length: 5'-0"
- Skew Angle: 0.00 deg
- Bottom Slab Support: Full Slab
- Top Haunch: 8"
- Bottom Haunch: 8"

Material Properties
- Concrete
  - Strength, f': 5,000 ksi
  - Density: 0.150 kcf
  - Elasticity, Ec: 4287 ksi
  - Type: Normal wt
- Steel
  - Yield, fy: 65 ksi
  - Allow Stress: 24 ksi
Defining Trucks

- **Variable axle spacing and magnitude**
- **Also define lane and tandem loads**

![Vehicle Properties Window](Image)

- **Axles**: 
  - No. of Axles: 3
  - Axle Weights, k:
    - Axle # | Weight, k
    - 1 | 8
    - 2 | 32
    - 3 | 32

- **Axle Spacings, ft**:
  - 1-2: 14
  - 2-3: 14 to 28

- **Tandem**:
  - Include Tandem: Yes
  - Axle 1 Weight, k: 25.00
  - Axle 2 Weight, k: 25.00
  - Axle Spacing, ft: 4.00

- **Lane Load**:
  - Uniform Load, klf: 0.64
  - P-Moment, k: 0.00
  - P-Shear, k: 0.00

- **Combine**:
  - Truck + Lane or Tandem + Lane
  - Truck or Tandem or Lane

- **Profile View**
- **Plan View**
Results Graphs

Top slabs - Unfactored Live Load (+Moment)

Left vs. Length (ft)

+Moment (k-ft/ft)
3D Rendering

Controls
- Reset View
- Zoom
- Elevation (Front)
- Zoom In
- Plan (Top)
- Zoom Out
- Side (Right)

View
- Normal
- Wireframe

Reinforcement
- Level: interior, exterior
- Type: transverse, longitudinal, corner
- Location: top, bottom, left, right

To Rotate: Hold down Shift + Left Mouse Button and move the mouse
To Translate: Hold down Ctrl + Left Mouse Button and move the mouse
To Zoom: Use the mouse wheel
Future Plans for ETCulvert

- Include support for more sophisticated structural analysis options
- Add soil-structure interaction
- Add support for Canadian Highway Bridge Code
- Allow access to reinforcement size/spacing pair library
- Add wingwalls, footings, appurtenances
- Additional user requests and agencies
- Support for AASHTOWare
BOX CULVERT INSTALLATIONS & APPLICATIONS

- Steven R. Smart
- Director of HY-SPAN® Bridges and Structures
- Independent Concrete Pipe Company
Pre cast Box Cul vert Production

DRY CAST METHOD
Precast Box Culvert Production

WETCAST METHOD
19’ x 3’ Oversize Box Culverts
Pre Site Inspection

The site should be evaluated prior to starting the work

Check which way is the best way to access the culvert to be installed

Check for overhead utilities contact utility companies about covering or relocating lines if needed well in advance

Locate any buried utilities to check for conflicts

Run routes for trucking to make sure you can get trucks to the site
Shop Drawings

Shop drawings and plan details will determine the dimensions and elevations of the structure.

Shop drawings for spans 12’ and smaller are not required unless the rise or design cover height is outside or not listed in the tables established by ASTM-1577 for Precast Box Culvert Sections designed for LRFD. (714.04c)
Wingwalls and headwalls require shop drawings showing elevations and design calculations.

Per section 105.02 shop drawings shall be signed and sealed by an Indiana Professional Engineer and submitted to INDOT for approval.
INDEPENDENT CONCRETE PIPE CORPORATION
INDIANAPOLIS, INDIANA  317-262-4920

23 PIECES AT 5'-2" + 14" FOR JOINTS = 120'-0"

LOW STR.
ELEV. = 532.25

FLOW

TOP OF FOOTING
ELEV. = 525.25

WINGWALL "A"
11.1 TONS

BOTTOM OF WING
ELEV. = 525.33

HEADWALL = 535.25

TOP OF 24"x12"
HEADWALL = 535.1

S.R. 256

NOTE: TOP OF WING FOOTINGS AT BOTTOM OF BOX CULVERT.

WINGWALL "B1"
10.6 TONS

WINGWALL "B2"
12.1 TONS

TOP OF FOOTING
ELEV. = 525.1

GENERAL NOTES
THE DESIGN CONFORMS TO LOADING IN ACCORDANCE WITH
THE 2010 AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS,
5TH EDITION.

MINIMUM 28-DAY CONCRETE COMpressive STRENGTH SHALL
BE 5000 PSI.

REINFORCEMENT SHALL BE WELDED WIRE FABRIC CONFORMING
TO AASHTO M66 (ASTM A 496) SMOOTH OR (ASTM A 496)
DEFORMED WIRE.

HEADWALL DESIGN LOADING:
ACTIVE EARTH PRESSURE = 40 PSF
LIVE LOAD SUBSURFACE = 2 FEET EQUIVALENT SOIL
HEIGHT, WHERE REQUIRED

TOP OF WING SET AT TOP OF HEADWALL.
BOTTOM OF WING FOOTING 3'-0" BELOW BOX CULVERT.

S.R. 256 OVER STINK DITCH
PROJECT/DES. 0710867  COUNTY
CONTRACT B-30235  STATION

ABNA

GENERAL LAYOUT
SPAN 20' x RISE 6'-0" x WALL 12'

DATE: 7/11/2012

SHEET
Installation

► Subgrade line and grade verified and established.

► The grade and alignment should be established prior to setting the boxes. The alignment of the first piece should be carefully laid out so the section can be set as close as possible. The outside corners at the end of the box with a line down one side is the best way to insure the alignment stays consistent. Be sure to check the plans and shop drawings for grade to determine if the structure is sumped and the flow line elevation is proper.
Unloading Product

20' x 8' x 5'
Installing process

Once the line and grade has been verified then the first section can be set in place. A string line or paint line running on the outside edge of the box is the best way to maintain alignment. It is necessary to spend as much time needed to insure the first piece is on the proper line. This will make all the other pieces easier. After the first piece is set a small trench at the bell end should be dug so as not to roll up stone or sand into the joint of the next section.
Methods used to home joints

- Pullers made especially for this type of work
- Come-a-longs used on both sides of the box
- Equipment pushing from the front or side
20' x 12' x 4' Oversize Box Culvert
Laying backward
Importance of staying on line and grade

► Every box should be checked for alignment and grade
► Once it gets off it’s nearly impossible to get back
Completion of joints

► Bituminous mastic sealant applied prior to jointing of box culverts (907.11 b)

► Joint membrane system in rolls a minimum of 12” width (907.07) example: Polyguard 175 or material meeting ASTM 877 for External Wrap

► The surface should be clean and dry in order for the wrap to stick properly

► In cold conditions it may be necessary to heat the wrap to make it stick
Headwall and Wing Wall Installation

► Establishing grade for wings
► Rigging of wings
► Bolting of wings to box sections
► Installing detached headwall
19' x 3' x 6' with sidemount guardrail
Skewed ends
Backfill and Compaction

Uniform Lifts with approved material not to exceed 24” on either side (714.05).

Check minimum cover for equipment traversing structure, normally 2 lifts.
Special applications
8’ x 6’ x 6’ with 30” hole
18' x 6' x 6'

36” RCP- actual 50” dia.
Thank goodness it was precast!
Even producers have problems with boxes at times
Alcohol...

Because no great story starts with a salad.
THANK YOU!

?’s