Chapter 5

RC Box Culvert Design

Introduction

This chapter contains information regarding the design and layout of reinforced concrete box culverts (RCB's). The RCB's may be of precast or cast-in-place (CIP) construction. An existing culvert may be extended to meet current safety requirements or new roadway width if the existing structure is in good condition, is structurally adequate for any change in loading (grade change), and is providing acceptable hydraulic performance

Culvert Types

Non-rigid frame RC box culverts are designed when the clear span is 10'-0" or less. The slabs and walls of this type of culvert are considered to be simply supported beams for single barrel culverts, and the slabs for multi-barrel culverts are considered to be continuous.

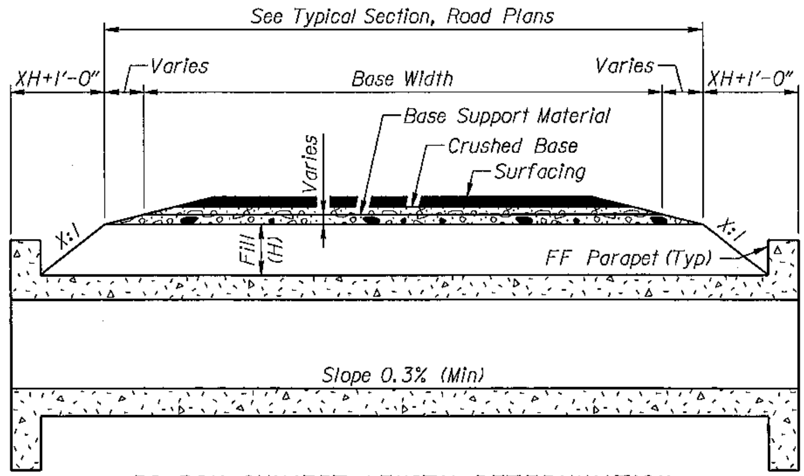
Rigid frame RC box culverts are designed when the clear span is greater than 10'-0". This type of culvert uses moment resisting steel at the wall-to-slab joints which reduce the bending moment in the slabs. Reinforcing steel is continuous between the slabs and walls. Most commonly, these are limited to single barrel culverts.

Precast concrete box culverts are comprised of reinforced box segments that are precast and shipped to the site for placement as a whole joined unit. This type of culvert is generally designed by the fabricator and is considered a rigid frame culvert. A precast culvert installation may include CIP components (culvert sections when skewed, wingwalls, parapets, cutoff walls and footings).

General Design Information

Apply Limit States and Resistance Factors in accordance with Article 12.5.5 Fatigue and Extreme Event limit states are not applicable to design of box culverts.

The length of a culvert under fill will be determined using the figure below. The front face of the parapets shall be outside the clear zone established by the Project Development Program or protected by guardrail if parapets lie within the clear zone. At- grade culvert lengths shall match the Project Development Program's typical section and any further requirements of AASHTO's A Policy on Geometric Design of Highways and Streets, inclusive of all revisions to date.



RC BOX CULVERT LENGTH DETERMINATION

For skewed culverts, the road grade should be considered in the length determinations.

The size of a culvert used as a hydraulic structure is based on the Hydraulic Report, which provides several alternates of opening sizes and depths of cutoff walls. The Design Squad Leader will select one of the sizes recommended and include it in a Structure Selection Report.

The call out for box culverts will be span x rise. For example, a box culvert with an opening of 8'-0" wide and 6'-0" tall would be called out as an 8 x 6 RCB. Standard precast box culverts range from 4'-0" x 4'-0" to 12'-0" x 12'-0" with the width and height varying in 1'-0" increments. Box culvert fabricators should be consulted for the availability of larger size sections. All new box culverts will have openings in 1'-0" increments. When extending an existing box, the existing opening shall be matched. For stock pass culverts that are not expected to carry significant drainage, standard plan stock pass structures shall be used.

Wall and slab thicknesses shall be determined by using the following guidelines.

For cast-in-place boxes:
- Minimum Wall Thickness: 8"
- Minimum Slab Thickness: 8"

For precast boxes:
Minimum Wall Thickness: 6"
Minimum Slab Thickness: 6"

For walls and slabs with two mats of reinforcing steel, the minimum thickness should be increased to provide proper clearance between reinforcing steel. The bottom slabs of box wingwalls shall have adequate thickness to provide development length of hook bars.

The dead loads applied to box culverts shall meet the following based on the culvert type.

For non-rigid culverts (No moment transfer between walls and slabs):

- Vertical earth pressure: 120 pcf
- Lateral earth pressure: 72 pcf

For rigid culverts (Moment transfer between slabs and walls):

- Vertical earth pressure: 120 pcf
- Load case 1 - Lateral earth pressure: 72 pcf
- Load case 2 - Lateral earth pressure: 36 pcf [Article 3.11.7]
- Load Case 2 need not be combined with the minimum load factor

Apply the multiplier for soil-structure interaction to the vertical soil loads in accordance with Article 12.11.2.2. Assume an embankment installation with compacted fill along the sides of the culvert. Box culverts will be designed for one fill height. The design fill height for new box culverts is based on the maximum fill height over the box. For box culvert extensions, the design fill height is based on the larger of the fill height over the extended portion or the fill height over the existing box culvert.

The application of live loads will be based on the design fill height over the box.

- For fill depths 2' and less [Articles 3.6.1.3.3 and 4.6.2.10]
    - Use only the axle loads from the HL93 design vehicle. This will include the design truck and the design tandem.
    - Apply a single vehicle on the culvert for the design live load including multiple presence factor.

- Fill depths greater than 2' [Article 3.6.1.2.6]
  - Determine the maximum live load effects from either the design truck or the design tandem.
  - Live load should be based on the maximum loading from either a single lane loaded or two trucks side by side (4' between trucks). The appropriate multiple presence factor should be applied for the number of lanes loaded.

Shear in top slabs of culverts shall be checked regardless of depth of fill. When determining the nominal concrete shear resistance, use the values of $\beta = 2$ and $\theta = 45°$ in the calculations.

The dynamic load allowance (IM) will be determined from the design fill over the top of the box (Art. 3.6.2.2) and will be applied to all components of the box culvert.

The horizontal live load surcharge should be based on 36 pcf times the depth of soil shown in the following table.

Wingwalls	
All heights	Depth of soil = 2'
Box Culverts	
Fill height ≤ 5'	Depth of soil = 4'
Fill height > 5’ > 10'	Depth of soil = 3'
Fill height > 10'	Depth of soil = 2'

The minimum reinforcement for walls and slabs less than 1'-0" thick shall be No.4 bars at 12". Reinforcement in interior walls of multi-barrel culverts may be placed in the center of the walls. Reinforcement in wingwalls shall be placed in the rear face only and shall be a minimum of No.4 bars at 12".

The requirements of Article 5.7.3.4 Control of Cracking by Distribution of Reinforcement in the LRFD Bridge Design Specifications shall only pertain to box culverts being used as a pedestrian underpass. In this case the exposure factor, γ_e, shall be taken as 1.00 (Class 1 exposure condition).

Wingwall Design Information

For box culverts with opening heights of 4'-0" to 12'-0" the wingwalls will be based on the standard LRFD design and details. No design will be required. The wingwall lengths are based on a 1:3 fill slope. The design squad leader may consider using a steeper slope when appropriate as approved by bridge staff. In this case, the standard wingwall design will still be applicable.

The design of culvert wingwalls will be based on the maximum height of the wall. For culvert wingwalls placed outside of the clear zone, the horizontal and vertical component of the live load surcharge shall be used concurrently for stability checks. This will cover the construction case where equipment is behind the wall during backfilling operations.

The minimum required area of reinforcement for temperature and shrinkage will not apply to culvert wingwalls.

Reinforced Concrete Box Culvert Design

The design span length should follow the placement of design reinforcement, skewed reinforcement would be designed for the length along the skew. For cast in place box culverts with skews 20 degrees or less, the design reinforcement should be placed parallel with centerline roadway. For cast in place box culverts with skews greater than 20 degrees, the design reinforcement should be placed perpendicular to the walls. For precast box culverts and cast in place end sections of precast box culverts, the design reinforcement will always be placed perpendicular to the walls. The dead load to the bottom slab includes the weight of soil above the culvert, top slab weight, and weight of all walls. Self weight of bottom slab is not included. Live load on the bottom slab is applied as a uniform load, distributed over the out-to-out width of the bottom slab.

Box culvert extensions should be designed to match the original culvert design (rigid or flexible). Cast-in-place (CIP) end sections for precast culverts should be designed as rigid or flexible based on the dimensions of the box opening.

For new multi-cell CIP boxes, the top and bottom slabs should be designed as continuous beams, with no moment transfer from slab to walls (flexible culvert).

For new CIP culverts that have skews less than or equal to 20 degrees, the transverse reinforcing steel in the top and bottom slabs shall be placed parallel with the skew.

For new CIP culverts that have skews greater than 20 degrees, the transverse reinforcing steel in the top and bottom slabs shall be placed normal to centerline culvert.

For culvert extensions, the placement of the transverse reinforcing steel in the top and bottom slabs shall match the existing culvert.

For CIP end sections used with precast box culvert sections the transverse reinforcing steel in the top and bottom slabs shall be placed normal to centerline culvert.

The use of BRASS-CULVERT as the design or design check for CIP boxes is recommended to decrease design time.