Design Criteria for Large Box Culverts to MRTS24

Title: Design Criteria for Large Box Culverts
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1 PURPOSE

The purpose of these guidelines is to interpret the design criteria for Large Box Culverts to Main Roads Standard Specification MRTS 24 (06/09). The design criteria specifically exclude culverts that have the water under internal pressure.

2 REFERENCE DOCUMENTS

MRTS 24	Manufacture of Precast Concrete Culverts (06/09)
MRTS 70	Concrete (11/09)
MRTS 71	Reinforcing Steel (06/09)
AS 5100-2004	Bridge Design
AS1597.2-1996	Precast Reinforced Concrete Box Culverts

3 DEFINITION OF CULVERT

A culvert consists of inverted trough sections, spanning slabs (optional) and base slab, which may be installed as:

- Single cell culverts;
- Multi-cell with units side by side; and
- Culvert units joined by link/spanning slabs.

A culvert shall be designed for the following load cases:

- **Single cell** culverts designed for vertical loads and horizontal load effects on both legs;
- **Interior units** designed for vertical load effects only; and
- **Exterior units** designed for vertical load effects and horizontal load effects as applicable on one leg only.

All culverts shall be designed as portal frame structures pinned at the base. Movement is prevented at the interface of the base and culvert leg.

Sidesway shall be considered for the condition described below:

- Any unit placed on a **skewed alignment**, with less than 500 mm of support from an adjacent unit (based on a 1200mm long unit). Similarly, 2400mm and 3600mm long units with less than 1000mm and 1500mm of support respectively, are to be designed for sidesway.

For all other conditions, **sidesway may be considered prevented** by bearing against the soil, provided the unit is installed in accordance with AS1597.2 Section 6.

Spanning slabs shall be designed as **simply supported** structures only.

3.1 Standard Culverts

Standard culverts are rectangular in plan and have a length of 1.2, 2.4 and 3.6m.

A 2.4/3.6m unit is equal to two/three 1.2m placed side by side. 1.2m units are produced in accordance to the design criteria.

For design purposes, the equivalent 2.4/3.6m component is defined as:-

- having the same cross section as the 1.2m long unit
- double/triple the number of main bending reinforcement bars of the same diameter as a 1.2m unit. Bar spacing is similar in both lengths
- the same shrinkage and transverse reinforcement layout

4. DESIGN LOADS

4.1 Dead Loads

The density of concrete for dead load calculations shall be 2,500 kg/m^3. For ultimate load factor refer to Clause 4.7.

4.2 Live Loads

The culvert shall be designed for the worst live load effects of the following load cases:

1.2m wide culvert

a) A160
b) Single lane of M1600 moving traffic load
c) Two lanes of M1600 moving traffic load. Reduction for multiple lanes loading in accordance with AS5100 is permitted. (Applicable where culvert falls partially under two lanes).
d) Single lane of S1600 loading
e) Two lanes of S1600 traffic load. Reduction for multiple lanes loading in accordance with AS5100 is permitted.

f) HLP 400
g) Construction traffic loads consisting of A160, W80 and M1600 moving traffic load.

Note. The Contractor may specify special construction loads in accordance with Clause 12.4.1 of MRTS 03.

Culvert over 1.2m

(a) A160
(b) The number of M1600 moving traffic loads adjacent to each other to create the worst load effect on the component. Reduction factors for multiple lane loading in accordance of Table 6.6 AS 5100.2.
(c) HLP 400
(d) Construction traffic loads consisting of A160 and M1600 moving traffic load.

Note. The Contractor may specify special construction loads in accordance with Clause 12.4.1 of MRTS 03.

Each of the above load cases shall be applied over the complete range of fills applicable for the design.

4.3 Dynamic Load Allowance

The dynamic load allowance shall be in accordance with Clause 6.7 of AS5100.2

The dynamic load allowance for moving traffic loads for buried structures as per Clause 6.7.3 of AS5100.2.

4.4 Distribution of Live Load

The distribution of the wheel loads is in accordance with Clause 6.12 of AS 5100.2.

4.5 Earth Pressure

The earth pressure is to be determined for over consolidated condition (Clause 3.2.1.3 AS1597.2)

4.6 Live Load Surcharge Load

Live load surcharge is designed in accordance with Clause 13.2 AS 5100.2.

4.7 Ultimate Load Factors

Dead Load	1.2
Top Fill	1.4 and 0.9
W80, A160 & MS1600	1.8
HLP vehicle	1.5
Construction Vehicle	1.8

Earth Pressure Surcharge (from highway loads)	Clause 13.2 AS5100.2 A160, SM1600 HLP 400	1.8 1.8# 1.5#
Lateral Earth Pressure		1.4 and 0.7*

Boussinesq analysis required if adopted

* Single cell culverts are designed for
  1.4 both legs
  0.7 both legs
  1.4 on one leg and 0.7 other leg

4.8 Load Combinations

1. Concrete + Fill + Earth Pressure + Live Load
2. Concrete + Fill + Earth Pressure + Live Load Earth Surcharge
3. Concrete + Fill + Earth Pressure + Live Load + Live Load Earth Surcharge

The design load is the worst combination of load from zero fill to maximum height of fill.

4.9 Braking

No braking loads are required to be applied to a culvert

5. HANDLING LOADS

5.1 Transportation

All culvert units with a height up to and including 2100 mm are to be designed to be transported legs down. These units are to be designed to resist a horizontal force equal to half the unit mass multiplied by the acceleration due to gravity acting in the direction of the span acting through the location of the centre of gravity of the culvert unit.

All units with a height greater than 2100 mm shall be designed to be transported legs up and designed to resist a horizontal force equal to half the unit mass multiplied by the acceleration due to gravity acting in the direction of the span acting through the mid-height

5.2 Lifting

Spanning slabs are to be designed for a vertical uniformly distributed applied load equal to the unit mass multiplied by the gravitational acceleration acting on the slab self mass.

All units are to be designed for a vertical dynamic load of 50 percent of the weight at any stage of the lifting operation. (This is in addition to self weight.)

5.3 Steel Stress for Transportation and Lifting

Culvert units and spanning slabs are to resist handling loads without producing a stress in the reinforcing steel in excess of 0.6 F_{sy}.

5.4 Lifting Devices

All culvert units and spanning slabs are to be provided with cast-in lifting devices adjacent to each corner of the unit. Each lifting device is to have a minimum ultimate failure load equal to the self weight of the culvert unit or spanning slab.

6. DESIGN METHOD

6.1 General

All elements shall be designed with two layers of reinforcement.

6.2 Durability

The cover requirements in MRTS 24(06/09) are based on the assumption of *rigid formwork and intense vibration*. Rigid formwork and intense vibration is considered as steel form and adequate form vibrators. If this condition is not achieved, the covers shall be in accordance with Table 4.10.3(A) of AS 5100.5.

The cover requirements for culverts shall be classified by the exposure conditions specified in Clause 9.2 and 11.7 of MRTS 24(06/09). Cover shall be in accordance with Table 4.10.3(B) of AS5100.5.

6.3 Minimum Clear Bar Spacing

Minimum clear bar spacing shall conform to:

- Cl 8.1.7.2 (i) & (ii) of AS 5100.5 for rigid formwork and intense vibration.
- Cl 8.1.7.2 (i), (ii) & (iv) of AS 5100.5 for standard formwork and compaction.

6.4 Height of Fill

The culvert shall be designed for the worst load effect at all positions in the section.

Culverts shall be designed for every height of fill between zero to the maximum height of fill.

If a culvert has 5 m of fill for example, the design load is the worst combination of loads from zero to 5 m fill. The reason for this is that the construction load may be more severe than the final in service loads and the culvert may be used for a lesser height of fill.

Suggested heights of fill (mm) are: 0, 300, 900, 3000 and 5000 of fill.

6.5 Effective Span of Link Slabs

The effective span of a link slab is: *Clear Span + Thickness of link Slab*

6.6 Effective width for Moment (Culvert or link slab)

The footprint of the W80 load can be located at the edge of the culvert or link slab. The effective for bending shall be determined by Clause 9.6(b) of AS 5100.5.

6.7 Skew Link Slabs

Skew link slabs shall be designed to all load conditions including the position they are initially installed but the design shall also consider that the installation may be widened. Consequently the skew link slab must be designed for full live load for the full range of depths.

7. CONCRETE DESIGN

7.1 Shear in Slab

Shear in the slab shall conform to:

$$\phi V_{uc} = \phi \cdot 0.17 \cdot \sqrt{f_c'} bd \quad \text{(Cl. 9.2.1 AS 5100.5)}$$

[**Note** d **not** d_O]

For all loadings, b shall a maximum width of 1.2 m (or the width of the culvert at the critical section if less than 1.2m). d is the effective depth at the critical section for W80, SM1600 & HLP 400 loadings.

7.2 Shear Capacity of Recessed Roof Slab

For a recessed roof slab, the shear capacity of the roof slab shall be calculated a distance '*d*' from the support using '*d*' in calculating the shear capacity. '*d*' is the effective depth of the recessed section.

7.3 Maximum Shear Effects

The position of the load for maximum shear shall be located in such a way that the maximum shear is produced at the critical sections.

Where the culvert unit crown or link slab is to be investigated for shear the critical shear section shall be taken as shown in Figure 3.2 *Critical Shear Sections* in AS 1597.2.

7.4 Factor ϕ

The factor ϕ shall be in accordance with Table 2.2 of AS 5100.5.

7.5 Minimum Steel

The minimum reinforcing steel A_{st} in the link slab and roof of the culvert shall be 0.002bd.

7.6 Transverse Distribution in Roof or link Slab

Transverse (distribution) reinforcement shall be in accordance with Clause 8.3 Item (g) of MRTS 24 (06/09).

The minimum transverse distribution reinforcement in the bottom face shall be the greater of 25% of the main bending reinforcement or 333mm²/m. The bar spacing shall not exceed 300mm.

For skew units, transverse distribution reinforcement shall be based on the flexural steel at mid-width.

7.7 Shrinkage Reinforcement

Shrinkage reinforcement to be a minimum of 150 mm^2/m with a maximum spacing of 300 mm.

7.8 Anchorage of Positive Moment Reinforcement

Anchorage of positive moment reinforcement shall be in accordance with Clause 8.1.8.3(c) AS 5100.5.

7.9 Maximum Negative Moment Location

The location for maximum negative moment is in accordance with Clause 7.2.10(a) AS 5100.5.

7.10 Grade of Reinforcing Steel

Grade 500 deformed steel is permitted. Culvert manufacturers to state the grade.

7.11 Position of Reinforcement

Reinforcement shall be positioned on all faces at cover (i.e. haunches must be reinforced).

8. MANUFACTURE

8.1 Steel Spacers

Steel spacers in normal exposure are only permitted where rigid formwork, intense vibration are used.

9. ULTIMATE PROOF TESTING REQUIREMENTS OF MRTS 24

The loads in Clause 12.4 of MRTS 24 (06/09) only apply to 1.2m length SMALL culverts.

10. SEGMENTAL CULVERTS

Segmental culverts are subject to special additional criteria available upon request.

11. PRECAST CULVERT BASES

Precast culvert bases shall be designed to:

a) The ultimate capacity of the precast slab shall be at least equal to or greater than the capacity of the cast-in-situ slab in Main Roads standard drawings

b) The self-weight of the slab with a dynamic load allowance equivalent to 50 percent of self-weight is supported during handling of the slabs

c) The steel stress in the reinforcing shall be less than 0.6 f_y for handling loads (dead load and dynamic load allowance)

d) The installation method and design must be approved by TMR

12. DRAWINGS

The following information is required on the drawings in addition to Clause 8 of MRTS 24 (06/09):

a) Concrete strength/aggregate size
b) Exposure condition (B2 or C)
c) Cover to reinforcement
d) Fill height: Zero and maximum height of fill
e) Grade of reinforcing steel and steel schedule
f) Number and nominal spacing of reinforcing steel
g) Tolerances on dimensions, cover and steel bars
h) Standard design or designed for a particular location (e.g. non-skewed location)
i) Design standards (Culverts for Main Roads projects must conform to MRTS 24 (06/09), MRTS 70 (11/09) & MRTS 71 (06/09))
j) Design Loads (e.g. W80, A160, SM1600 & HLP400)
k) Formwork and compaction (e.g. rigid formwork and intense vibration)
l) Capacity and name of lifting device and lifting conditions (e.g., sling length or angle, minimum lifting strength of concrete)
m) Dimensions of haunch
n) Calculated mass of individual units
o) Traceability of drawing (e.g. plan number and revision number)
p) All drawings are to be certified by a RPEQ or NPER.

REFERENCES

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