Technical Note 27

Guidelines for Design of Precast Concrete Box Culvert and Pipe Headwalls

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Queensland Government

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Contents

1 Purpose

The purpose of this Technical Note is to provide the design criteria for precast concrete headwalls for concrete box culvert[1] and concrete pipe culvert[2] applications.

Precast end structures shall be constructed in accordance with MRTS03 *Drainage, Retaining Structures and Protective Treatments*.

2 Referenced documents

2.1 Australian Standards

The table below lists Australian Standards referenced in this Technical Note.

Table 2.1 – Referenced Australian Standards

Reference	Title
AS 1597.1	*Precast reinforced concrete box culverts – Part 1: Small culverts (not exceeding 1200 mm span and 1200 mm height)*
AS 1597.2	*Precast reinforced concrete box culverts – Part 2: Large culverts (exceeding 1200 mm span or 1200 mm height and up to and including 4200 mm span and 4200 mm height)*
AS 3600	*Concrete structures*
AS/NZS 4671	*Steel reinforcing materials*
AS 5100	*Bridge Design (Set)*

2.2 Transport and Main Roads Technical Standards and Standard Drawings

The tables below list Transport and Main Roads Technical Specifications and Drawings referenced in this Technical Note.

Table 2.2(a) – Referenced Transport and Main Roads Technical Standards

Reference	Title
MRTS03	*Drainage, Retaining Structures and Protective Treatments*
MRTS24	*Manufacture of Precast Concrete Culverts*
MRTS25	*Manufacture of Precast Concrete Pipes*
MRTS26	*Manufacture of Fibre Reinforced Concrete Drainage Pipes*
MRTS70	*Concrete*
MRTS71	*Reinforcing steel*
MRTS72	*Manufacture of Precast Concrete Elements*
MRTS78	*Fabrication of structural steelwork*
MRTS78A	*Fabrication of structural stainless steelwork*

[1] Concrete box culverts may be precast in accordance with MRTS24 or cast in-situ reinforced concrete.
[2] Concrete pipes may be either machine manufactured steel reinforced concrete pipes to MRTS25 or wet cast steel reinforced concrete pipes to MRTS72 or fibre reinforced concrete pipes to MRTS26.

Table 2.2(b) - Referenced Transport and Main Roads Standard Drawings.

Drawing Numbers	Title
SD1243 Drawing 1 of 3	*Precast culvert headwalls: Headwall connections for pipe culverts – All sizes*
SD1243 Drawing 2 of 3	*Precast culvert headwalls: Headwall connections for box culverts – All sizes*
SD1243 Drawing 3 of 3	*Precast culvert headwalls: Headwall connections: Alternative for small culverts diameter or height ≤1200*

3 Size of precast concrete headwalls

Precast concrete headwalls are used for single cell and multi-cell culverts of pipe diameters from 375 mm to maximum 2550 mm and box culverts from 375 mm height to maximum 2400 mm height.

4 Precast concrete headwall to culvert connection

Precast concrete headwall to culvert connection shall be in accordance with this section and is summarised in Appendix A.

4.1 Cast in-situ headwall connection

A cast in-situ headwall connection as shown in Standard Drawing 1243 Drawings 1 and 2 shall be used for culverts with a diameter or height greater than 1200 mm. Cast in-situ headwall extension with minimum thickness as specified in the Standard Drawing 1243 Drawings 1 and 2 shall be used to connect the precast concrete headwall and the pipe or box culvert.

The actual headwall extension dimensions shall be determined to suit the project specific culvert dimensions. The precast concrete culvert surface within the contact area with the headwall extension shall be prepared as a construction joint as per MRTS70 *Concrete* to establish connection between the headwall extension and the precast concrete culvert by interface friction.

Galvanised cast-in threaded bar anchors (minimum 12 mm diameter) at a maximum spacing of 300 mm shall be provided in the cast in-situ headwall extension. These threaded bar anchors shall be used to connect the precast concrete headwall unit as per Standard Drawing 1243 Drawings 1 and 2. All cast-in threaded bar anchors shall maintain the minimum cover requirements. Alternatively, instead of cast-in threaded bar anchors, galvanised bolts may be installed on site by drilling through the headwall. A "cover meter" shall be used to locate the headwall reinforcing bars before drilling to avoid damaging the headwall reinforcement.

For higher Exposure Classifications of C1 or C2 to AS 5100, all anchor bolted assemblies shall be fabricated using stainless steel.

4.2 Bolted headwall connection for culvert diameters or heights up to 1200 mm

When pre mix on site concrete supply is limited, the precast concrete headwall unit may be connected to the box / pipe culvert using steel bolts and brackets for pipe culverts up to diameter 1200 mm and box culverts height up to 1200 mm as per Standard Drawing 1243 Drawing 3. Gaps between the precast concrete headwall unit penetration and box / pipe culvert shall be filled with 1:3 cement mortar.

For higher Exposure Classifications of C1 or C2 to AS 5100, all anchor bolt assemblies and brackets shall be fabricated using stainless steel.

4.3 Headwall connection for small culverts diameter or height up to 450 mm

For small culverts diameter or height up to 450 mm, the use of headwall connection details specified in Section 4.1 and 4.2 can be omitted dependent upon the site conditions and the risk of separation of headwalls, as assessed by the project engineer. Factors such as low flow in small culverts, and ease of maintenance in the event of separation can be considered in the assessment.

The gap between the precast concrete culvert and headwall penetration shall be filled with 1:3 cement mortar.

4.4 Sloping headwall

Where permitted by the project specification and where an appropriate risk assessment has been completed by the project design engineer (refer Section 4.3), sloping headwalls may be considered for pipe diameters less than 450 mm diameter or box culverts less than 450 mm high. Note that typically sloping headwalls are only suitable for single cell culvert installations and for culverts with a low fill height.

4.4.1 Headwall Types Not Permitted

Driveable Culvert Endwalls / Headwalls are not permitted for use on Transport and Main Roads projects.

4.5 Cut off wall

A cast in-situ cut off wall with minimum thickness and depth as specified in Standard Drawing 1243 Drawings 1 and 2 shall be constructed in front of the precast concrete headwall unit and connected to the apron for scour protection. The depth of the cut off wall shall be modified to suit the project specific requirements.

The cut off wall shall be connected to the precast concrete headwall unit using threaded bar anchors as per the Standard Drawing 1243. Galvanised cast-in ferrules (minimum 12 mm diameter) at a maximum spacing of 400 mm shall be provided in the precast concrete apron during casting of the precast concrete headwall unit to connect the threaded bar anchors to the cut-off wall. All cast-in ferrules shall maintain the minimum cover to reinforcement.

A precast concrete cut off wall may also be used. It shall be connected to the precast concrete headwall using anchor bolts as per Standard Drawing 1243 Drawing 3 for culverts diameter or height up to 1200 mm. For larger size culverts, the precast concrete cut off wall shall be designed to suit project specific requirements.

4.6 Drainage behind wingwalls

Weepholes of 50 mm diameter shall be provided at maximum centres of 1200 mm (both vertically and horizontally) in wingwalls of the precast concrete headwall unit. A 300 x 300 x 150 mm no-fines concrete block or approved equivalent shall be provided at each weephole for drainage filtration.

5 Design life and durability

The design life of precast concrete box and pipe culvert headwalls, headwall extensions and cut off walls shall be 100 years.

The minimum exposure classification, minimum concrete strength and cover to reinforcement shall be as shown in Table 5.

Table 5 – Concrete durability for culvert headwall units, headwall extensions and cut off walls

Minimum exposure classification[1]	B2 to AS 5100
Minimum concrete strength	S40/20 – Cast in-situ S50/20 – Precast Concrete
Cover to reinforcement	to AS 5100.5

Note 1: Minimum concrete grade and cover to reinforcement for higher Exposure Classification of C1 and C2 shall be in accordance with AS 5100.5.

6 Design loads

The design loads, load factors and load combinations shall comply with the following requirements.

6.1 Horizontal earth pressure

Horizontal earth pressure due to compacted fill shall be calculated for the “at rest” condition with coefficient of earth pressure “at rest” (Ko) equal to 0.5. ULS load factor for horizontal earth pressure shall be 1.5.

6.2 Live load surcharge load

Live load surcharge shall be determined in accordance with Clause 14.2 of AS 5100.2. Horizontal earth pressure coefficients shall be the same as Section 6.1 of this Technical Note.

6.3 Load factors and load combinations

Load factors and load combinations shall be in accordance with AS 5100.2.

7 Materials

7.1 Precast concrete

Precast concrete shall be in accordance with MRTS72 *Manufacture of Precast Concrete Elements*.

The minimum concrete strength shall be in accordance with Table 5 for the relevant minimum exposure classification. The minimum concrete strength for higher exposure classifications shall be in accordance with AS 5100.5.

7.2 Cast in-situ concrete

Concrete shall be in accordance with MRTS70 *Concrete*.

The minimum concrete strength shall be in accordance with Table 5 for the relevant minimum exposure classification. The minimum concrete strength for higher exposure classifications shall be in accordance with AS 5100.5.

7.3 Steel reinforcement

Steel reinforcement shall be in accordance with MRTS71 *Reinforcing Steel*.

8 Handling

8.1 Steel stress for transportation and lifting

Precast concrete headwall units shall be designed to resist handling loads without producing a stress in the reinforcing steel in excess of the allowable maximum steel stress in accordance with AS 5100 but not greater than 0.6fsy.

8.2 Lifting anchors

All precast concrete headwall and cut off wall units shall be provided with cast-in lifting devices. Dynamic lifting factors, factor of safety for lifting devices and concrete pull out capacity shall be in accordance with MRTS72 *Manufacture of Precast Concrete Elements*. Proprietary lifting devices shall be of Transport and Main Roads approved products. Lifting points and lifting anchors shall be designed and certified in accordance with MRTS72 *Manufacture of Precast Concrete Elements*.

9 Structural analysis

Due to the shape of the precast concrete element, it is considered appropriate that the magnitude and location of the critical forces acting on the structure are determined by a Finite Element Analysis or any other appropriate structural analysis method.

10 Structural design

Structural design for strength shall be in accordance with AS 5100.

10.1 Crack control for shrinkage and temperature effects

To control the cracking due to shrinkage and temperature effects of precast concrete headwalls, the minimum area of reinforcement required in primary and secondary direction shall be in accordance with Clause 9.5.3 of AS 3600.

10.2 Position of reinforcement

Position of reinforcement shall be such that all haunches are reinforced.

11 Manufacturing requirements

11.1 Precast concrete elements

Manufacture of precast concrete elements shall be in accordance with MRTS72 *Manufacture of Precast Concrete Elements*. The lifting points designed in accordance with Section 8.2 of this Technical Note shall be shown in the drawings.

12 Staple joints

Where the precast concrete headwall is supplied in more than one section, staple joints or alternative joints acceptable to Transport and Main Roads shall be used to connect the segments. The staple joints shall be designed to transmit shear only. The joint shall consist of galvanized bars placed within aligned preformed recesses and grouted into position with a departmental approved cementitious grout with a 28 day strength of not less than 50 MPa.

This type of joint shall be designed and RPEQ certified by the precast concrete supplier. Joint details shall be shown in the supplier’s precast concrete headwall drawings.

13 Structural steel fabrication

Structural steel works and structural stainless-steel works shall be fabricated in accordance with MRTS78 *Fabrication of structural steelwork* and MRTS78A *Fabrication of structural stainless steelwork* respectively.

14 Drawings

The following minimum information shall be shown on the project drawings:

a) Concrete class, concrete strength, and aggregate size.

b) Design Life, Exposure Classification, and cover to reinforcement.

c) Number and nominal spacing of reinforcing steel.

d) Connection details between precast concrete elements in accordance with the Standard Drawing referred in Table 2.2(b).

e) Lifting point locations, rigging diagram, and lifting anchor specifications.

f) Project location.

g) Design loads and design standards including this Technical Note, TN27.

h) Strength of concrete when stripped from form in accordance with MRTS72.

i) Formwork type and concrete compaction method.

j) Traceability of drawing (e.g. Plan number and revision number).

k) Staple joint (if required), and

l) RPEQ certification of drawings.

Appendix A – Selection of connection Types between precast concrete headwall unit and culvert

Culvert size	Connection Types between precast concrete headwall unit and culvert			Use of sloping headwall[2] (Section 4.4)
	Cast in-situ headwall connection (Section 4.1)	Bolted headwall connection (Section 4.2)	No connection[1] (Section 4.3)	
Diameter or height up to 450 mm	✓	✓	✓	✓
Diameter or height from 450 mm up to 1200 mm	✓	✓	×	×
Diameter from 1200 mm up to 2550 mm or height from 1200 mm up to 2400 mm	✓	×	×	×

Note 1: Dependent upon the site conditions and the risk of separation of headwall (refer Section 4.3). To be assessed by the designer.

Note 2: Refer Section 4.4 for requirements.