Technical Note 27

Guidelines for Design of Precast Culvert and Pipe Headwalls

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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. This technical note also provides guidelines for the design of the connection between the culvert and precast headwall unit using cast in-situ headwall extensions behind the precast headwall or bolted connection and cast in-situ or precast cutoff wall in front of the apron.

2 Referenced documents

2.1 Australian Standards

The table below lists Australian Standards referenced in this technical document.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS 1597.2 (2013)</td>
<td>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)</td>
</tr>
<tr>
<td>AS 3600 (2018)</td>
<td>Concrete structures</td>
</tr>
<tr>
<td>AS/NZS 4671 (2001)</td>
<td>Steel reinforcing materials</td>
</tr>
<tr>
<td>AS 5100 (2017)</td>
<td>Bridge Design (set)</td>
</tr>
</tbody>
</table>

2.2 Transport and Main Roads Technical Standards and Standard Drawings

The tables below lists Transport and Main Roads Technical Specifications and Drawings referenced in this technical document.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
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<tbody>
<tr>
<td>MRTS03</td>
<td>Drainage, Retaining Structures and Protective Treatments</td>
</tr>
<tr>
<td>MRTS24</td>
<td>Manufacture of Precast Concrete Culverts</td>
</tr>
<tr>
<td>MRTS25</td>
<td>Manufacture of Precast Concrete Pipes</td>
</tr>
<tr>
<td>MRTS26</td>
<td>Manufacture of Fibre Reinforced Concrete Drainage Pipes</td>
</tr>
<tr>
<td>MRTS70</td>
<td>Concrete</td>
</tr>
<tr>
<td>MRTS71</td>
<td>Reinforcing steel</td>
</tr>
<tr>
<td>MRTS72</td>
<td>Manufacture of Precast Concrete Elements</td>
</tr>
<tr>
<td>MRTS78</td>
<td>Fabrication of structural steelwork</td>
</tr>
<tr>
<td>MRTS78A</td>
<td>Fabrication of structural stainless steelwork</td>
</tr>
<tr>
<td>Design Criteria for Bridges and Other Structures</td>
<td>Bridge Design and Assessment Criteria, Volume 1: Design Criteria for Bridges and Other Structures</td>
</tr>
</tbody>
</table>

\(^1\) 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
### 3 Size of precast headwalls

Standard Drawing 1243 is used for precast headwalls are used for single cell and multi-cell culverts of pipe diameters from 450 mm to 2550 mm and box culverts from 450 mm height to 2400 mm height maximum size.

### 4 Precast headwall to culvert connection

#### 4.1 Connection for small culverts

For small culverts diameter or height up to 450 mm, the use of the connection details specified in Clause 4.2 and 4.3 (refer SD1243) 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, ease of maintenance in the event of separation can be considered in the assessment.

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

#### 4.2 Bolted headwall connections

Where the concrete supply is limited for cast in-situ concrete, steel bracket with bolted headwall connection as shown in the standard drawing 1243-Drawing 1 is suitable for culvert diameters or heights up to 1200 mm. In this case, the cut off wall can also be a precast concrete arrangement. The precast cut off wall shall be connected to the precast apron slab using bolts. In addition to the bolted connection, the gap between the precast culvert and headwall penetration shall be filled with 1:3 cement grout.

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

#### 4.3 Cast in-situ headwall extension

Cast in-situ headwall as shown in the standard drawing 1243 Drawing 2 and 3 shall be used for culverts diameter or height greater than 1200. A cast in-situ headwall extension with minimum thickness as specified in the standard drawing 1243 – Drawing 2 and 3 shall be used to connect the precast headwall and the pipe or box culvert.

The actual headwall extension dimensions shall be determined to suit the project specific culvert dimensions. The precast culvert surface within the contact area with the headwall extension shall be prepared as a construction joint as per MRTS70 to establish connection between the headwall extension and the precast culvert by interface friction.
Galvanised cast-in ferrules (minimum 12 mm diameter) at a maximum spacing of 300 mm shall be provided in the precast headwall during casting of the precast headwall. These ferrules shall be used to connect the threaded bar anchors to construct the connection between the headwall extension and the precast headwall. All cast-in ferrules shall maintain the minimum cover requirements. Alternatively, instead of cast in ferrules, bolts can be installed on site by coring through the headwall without damage to the reinforcing steel, by locating these with a “cover meter”.

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

4.4 **Cast in-situ cutoff wall**

A cast in-situ cutoff wall with minimum thickness and depth as specified in the standard drawing 1243 Drawing 2 and 3 shall be constructed in front of the Headwall unit and connected to the apron for scour protection. The depth of the cutoff wall shall be modified to suit the project specific scour situation.

Connection between the precast apron and the in-situ cutoff wall using threaded bar anchors shall be as shown on the Standard Drawings. Galvanised cast-in ferrules (minimum 12 mm diameter) at a maximum spacing of 400 mm shall be provided in the precast apron during casting of the precast headwall unit to connect the threaded bar anchors to construct connection between apron and cut-off wall. All cast-in ferrules shall maintain the minimum cover to reinforcement.

4.5 **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 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, minimum exposure classification, minimum concrete strength and cover to reinforcement shall be as shown in Table 4.0.

Refer to Clause 6.1 and 6.2 for minimum concrete strength for higher exposure classifications than in Table 5.0.

**Table 5.0: Concrete durability for culvert headwall units, headwall extensions and cutoff walls**

<table>
<thead>
<tr>
<th>Design life</th>
<th>100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum exposure classification</td>
<td>B2 to AS 5100</td>
</tr>
</tbody>
</table>
| Minimum concrete strength | S40/20 - Cast in-situ  
|                      | S50/20 - Precast |
| Cover to reinforcement | to AS 5100   |

Minimum concrete grade and cover to reinforcement for higher exposure classification of C1 and C2 shall be in accordance with AS 5100.

6 **Design loads**

The design loads, load factors and load combinations shall be as stated below.
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 is 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 calculated similar to Clause 6.1 of this document.

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.

The minimum concrete strength shall be in accordance with Table 5.0 for the relevant minimum exposure classification. The minimum concrete strength for higher exposure classifications shall be in accordance with AS 5100.

7.2 Cast in-situ concrete

Concrete shall be in accordance with MRTS70.

The minimum concrete strength shall be in accordance with Table 5.0 for the relevant minimum exposure classification. The minimum concrete strength for higher exposure classifications shall be in accordance with AS 5100.

7.3 Steel reinforcement

Steel reinforcement shall be in accordance with MRTS71 and AS/NZS 4671.

8 Handling

8.1 Steel stress for transportation and lifting

Precast 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 3600 but not greater than 0.6fsy.

8.2 Lifting anchors

All precast headwall units shall be provided with cast-in lifting devices. Dynamic lifting factors, factor of safety for lifting devices and concrete pullout capacity shall be in accordance with MRTS72. 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.

9 Structural analysis

Due to the shape of the precast 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 3600.

10.1 Crack control for shrinkage and temperature effects

To control the cracking due to shrinkage and temperature effects of precast headwalls, the minimum area of reinforcement required in primary and secondary direction shall be in accordance with Clause 9.4.3.2 and Clause 9.4.3.3 of AS 3600 respectively.

10.2 Position of reinforcement

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

11 Manufacturing requirements

11.1 Precast elements

Manufacture of precast concrete elements shall be in accordance with MRTS72. The lifting points designed in accordance with Clause 8.2 shall be shown in the drawings.

12 Staple joints

Where the precast 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.

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

13 Structural steel fabrication

Structural steel works and structural stainless-steel works shall be fabricated in accordance with MRTS78 and MRTS78A 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 elements in accordance with Standard Drawing referred in Table 2.2B
e. Lifting point locations, rigging diagram and lifting anchor specifications
f. Project location
g. Design loads and design standards including Technical Note 27
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)
l. RPEQ certification of drawings.