

Australian Standard[®]

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)**



This Australian Standard® was prepared by Committee CE-026, Precast Reinforced Concrete Box Culverts. It was approved on behalf of the Council of Standards Australia on 21 March 2013
This Standard was published on 12 August 2013.

The following are represented on Committee CE-026:

- AUSTROADS
 - Australasian Railway Association
 - Concrete Pipe Association of Australasia
 - Engineers Australia
 - National Precast Concrete Association Australia
 - University of Sydney
-

This Standard was issued in draft form for comment as DR AS 1597.2.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting **www.standards.org.au**

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at **mail@standards.org.au**, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

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)

First published as AS 1597.2—1996.
Second edition 2013.

COPYRIGHT

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 1 74342 554 1

PREFACE

This Standard was prepared by the Standards Australia Committee CE-026, Precast Reinforced Concrete Box Culverts, to supersede AS 1597.2—1996, *Precast reinforced concrete box culverts*, Part 2: *Large culverts (from 1500 mm span and up to and including 4200 mm span and 4200 mm height)*.

The objective of this Standard is to provide designers, manufacturers, installers and specifiers of culverts with minimum requirements for the design, manufacture and installation of precast reinforced concrete rectangular box culverts of spans up to 4200 mm.

The objective of this revision is to align the Standard with current manufacturing and installation practices as well as governing design codes.

The revised Standard provides for four types of culvert and a range of standard sizes up to and including 4200 mm width and 4200 mm height. Design requirements are based on the AS 5100 series, *Bridge design* and AS 3600, *Concrete structures*.

Where the Standard departs from these Standards, or includes additional requirements in excess of those specified in these Standards, it identifies that the purchaser has the option to adopt the design requirement in this Standard, or to revert back to AS 5100 series or AS 3600 series requirements. Appendix A also contains advice and recommendations on the information that should be supplied by the purchaser at the time of inquiry or order to assist with these design requirements.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 APPLICATION	5
1.3 NORMATIVE REFERENCES	6
1.4 DEFINITIONS.....	7
1.5 NOTATION.....	9
1.6 TYPES OF CULVERTS.....	12
1.7 CLASSIFICATION	12
SECTION 2 MATERIALS, MANUFACTURE AND DIMENSIONING	
2.1 SCOPE OF SECTION	14
2.2 FORMWORK.....	14
2.3 REINFORCEMENT	14
2.4 CONCRETE MATERIALS	15
2.5 CONCRETE SPECIFICATION AND COVER TO REINFORCEMENT	16
2.6 CONCRETE PRODUCTION, PLACEMENT AND CURING	16
2.7 JOINTS.....	18
2.8 DIMENSIONS.....	18
2.9 MEASUREMENT OF DIMENSIONS	20
2.10 TOLERANCES.....	20
2.11 STORAGE AND HANDLING.....	21
2.12 WORKMANSHIP AND FINISH.....	22
2.13 DEFECTS.....	22
2.14 FINISHING AND REPAIRS	23
2.15 MARKING	23
SECTION 3 DESIGN REQUIREMENTS AND PROCEDURES	
3.1 SCOPE OF SECTION	24
3.2 GENERAL DESIGN REQUIREMENTS.....	24
3.3 DESIGN LOADS.....	25
3.4 LOAD COMBINATIONS	32
3.5 LOAD EFFECT ANALYSIS AND DESIGN	34
3.6 STRENGTH AND SERVICEABILITY DESIGN	34
3.7 REINFORCEMENT	35
3.8 FATIGUE DESIGN	35
SECTION 4 SAMPLING AND TESTING	
4.1 SCOPE OF SECTION	37
4.2 GENERAL.....	37
4.3 PROCESS TESTING.....	37
4.4 ROUTINE SAMPLING AND TESTING	39
SECTION 5 INSTALLATION	
5.1 SCOPE OF SECTION	41
5.2 EXCAVATION	41
5.3 FOUNDATION PREPARATION.....	41
5.4 PLACING PRECAST UNITS	42
5.5 COMPACTION	42
5.6 BACKFILLING.....	42
5.7 CONSTRUCTION LOADS ON CULVERTS	43
5.8 ACCEPTABLE CRACK WIDTHS UNDER SERVICE LOADS	44

APPENDICES

A	PURCHASING GUIDELINES	45
B	MEANS OF DEMONSTRATING COMPLIANCE WITH THIS STANDARD	47
C	LOW PRESSURE STEAM CURING OF CONCRETE UNITS	49
D	METHODS FOR COVER TESTING OF UNITS	51
E	MEASUREMENT OF CRACK WIDTH	53
F	SAMPLING SCHEME FOR ROUTINE TESTING.....	55
G	ADDITIONAL DESIGN INFORMATION	57
H	ALTERNATIVE SHEAR STRENGTH PROVISIONS FOR CULVERTS.....	64
BIBLIOGRAPHY		66

STANDARDS AUSTRALIA

Australian Standard

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)

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the design, manufacture and installation of precast reinforced concrete rectangular box culverts for conveying water not under pressure, and for carrying roadway and railway loadings specified by the AS 5100 series.

This Standard is applicable to the design of culverts in dry or intermittently wet conditions.

NOTES:

- 1 For culverts to be designed for embankments that occasionally impound water, specialist design advice should be sought regarding the overall embankment stability.
- 2 Culvert units, lids and base slabs manufactured in accordance with this Standard can be expected to achieve a design life of 100 years.
- 3 Design requirements are based on the methods of limit state design, using theoretical strength and serviceability calculations. Alternatively, design by prototype testing in accordance with the general principles and requirements of the AS 5100 series or AS 3600 is acceptable.
- 4 The testing procedure and test loads for prototype testing should demonstrate that the units tested satisfy the design loads and manufacturing requirements of this Standard.

1.2 APPLICATION

This Standard is applicable to rectangular precast culvert units having a standard length of 1200 mm, a maximum height of 4200 mm and a span exceeding 1200 mm up to 4200 mm.

NOTES:

- 1 Guidelines to purchasers on requirements that may need to be agreed upon at the time of calling for tenders or quotations are detailed in Appendix A.
- 2 Information on means for demonstrating compliance with this Standard is given in Appendix B.
- 3 Lengths greater than 1200 mm may be ordered, preferably in multiples of 1200 mm (e.g. 2400 mm and 3600 mm).
- 4 For precast reinforced concrete box culverts of internal dimensions not exceeding 1200 mm nominal span and 1200 mm nominal height, refer to AS 1597.1.
- 5 Additional design considerations may be required for special culverts (e.g. larger spans, skewed ends, culvert units with large holes, roadway culverts subjected to loadings other than standard roadway loadings and railway culverts).

1.3 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard:

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

AS

1012	Methods of testing concrete
1012.1	Method 1: Sampling of fresh concrete
1012.8.1	Method 8.1: Method of making and curing concrete—Compression and indirect tensile test specimens
1012.9	Method 9: Determination of the compressive strength of concrete specimens
1289	Methods of testing soils for engineering purposes
1289.3	Method 3: Soil classification tests
1289.3.6.1	Method 3.6.1: Determination of the particle size distribution of a soil—Standard method of analysis by sieving
1289.5	Method 5: Soil compaction and density tests
1289.5.1.1	Method 5.1.1: Determination of the dry density/moisture content relation of a soil using standard compactive effort
1289.5.3.2	Method 5.3.2: Determination of the field dry density of a soil—Sand replacement method using a sand pouring can, with or without a volume displacer
1289.5.3.5	Method 5.3.5: Determination of the field dry density of a soil—Water replacement method
1289.5.4.1	Method 5.4.1: Compaction control test—Dry density ratio, moisture variation and moisture ratio
1289.5.5.1	Method 5.5.1: Determination of the minimum and maximum dry density of a cohesionless material—Standard method
1289.5.6.1	Method 5.6.1: Compaction control test—Density index method for a cohesionless material
1379	Specification and supply of concrete
1478	Chemical admixtures for concrete, mortar and grout
1478.1	Part 1: Admixtures for concrete
1726	Geotechnical site investigations
2758	Aggregates and rock for engineering purposes
2758.1	Part 1: Concrete aggregates
3582	Supplementary cementitious materials for use with portland and blended cement
3582.1	Part 1: Fly ash
3582.2	Part 2: Slag—Ground granulated iron blast-furnace
3600	Concrete structures
3972	General purpose and blended cements
5100	Bridge design
5100.2	Part 2: Design loads
5100.5	Part 5: Concrete
5100.7	Part 7: Rating of existing bridges

AS/NZS

1554	Structural steel welding
1554.3	Part 3: Welding of reinforcing steel
3582	Supplementary cementitious materials for use with portland and blended cement
3582.3	Part 3: Amorphous silica
4671	Steel reinforcing materials

1.4 DEFINITIONS

For the purpose of this Standard, the definitions below and those depicted in Figure 1.1 apply.

1.4.1 Administrative**1.4.1.1** *Informative*

Not an integral requirement of this Standard and provided for information only.

1.4.1.2 *Manufacturer*

Person(s) or corporate body responsible for the manufacture of precast reinforced concrete box culverts.

1.4.1.3 *Normative*

An integral and mandatory requirement of this Standard.

1.4.1.4 *Purchaser*

Person(s), corporate body or regulatory authority to whom the manufacturer is contracted to manufacture the precast reinforced concrete box culverts.

1.4.1.5 *Regulatory authority*

An authority that is empowered by statute to exercise jurisdiction over the manufacture, supply and installation processes of a culvert.

1.4.1.6 *Specified*

Stated in writing in any document (including orders, drawings or specifications, or both) that forms a part, or the whole, of the contract between the purchaser and the manufacturer.

1.4.1.7 *Supplier*

Person(s) or corporate body responsible for the supply of components and other items and materials used in the manufacture of precast reinforced concrete box culverts.

1.4.2 Technical**1.4.2.1** *Batch*

A group of culvert units, lids, link or base slabs of the same class and design, and produced under uniform conditions during a given production period, by the same process.

1.4.2.2 *Bed zone*

The area between the foundation and the underside of the culvert (see Figure 1.1).

1.4.2.3 *Cover*

Distance between the outside of the reinforcing steel and the nearest permanent surface of the member excluding any surface finish, tie wire, bar chairs, nibs or spacers.

1.4.2.4 Culvert

A single cell or a multiple cell structure, and associated lids, link and base slabs.

1.4.2.5 Culvert cell

A complete conduit made up of a number of units placed end-to-end.

1.4.2.6 Exposure classification

A classification representing the degree of severity of exposure to the environment.

NOTE: For more information of and determination of exposure classification, see AS 5100.5.

1.4.2.7 Fill

One or more of the following:

- (a) *Backfill or embankment fill* Material placed over the overlay zone or adjacent to the side zone for the purpose of refilling a trench or creating an embankment (see Figure 1.1).
- (b) *Ordinary fill* Material obtained from excavation of the trench or elsewhere and containing no more than 20% by mass of stones with a size between 75 mm and 150 mm and none larger than 150 mm.
- (c) *Select fill* Material obtained from excavation of the trench or elsewhere with a particle size not greater than 75 mm, and which conforms with the following soil classes, as defined in AS 1726:
 - (i) SC clayey sands with fines of low plasticity.
 - (ii) SP poorly graded sands.
 - (iii) SW well-graded sand.
 - (iv) GC clayey gravels with fines of low plasticity.
 - (v) GW well-graded sand and gravel mixtures with little or no plastic fines.
 - (vi) GP poorly graded sand and gravel mixtures with little or no plastic fines.

1.4.2.8 Foundation

Naturally occurring or replaced material beneath the bed zone (see Figure 1.1).

1.4.2.9 Height

Height of culvert leg (see Figures 1.1 and 2.1).

1.4.2.10 Height of fill

Height of fill over the culvert, lid or link slab (see Figure 1.1).

1.4.2.11 Lifting inserts

An insert cast into the culvert unit, lid link or base slab that is designed specifically to facilitate handling of the precast unit.

1.4.2.12 Load class

Culvert strength classification system designated by the height of fill over the culvert, in metres, followed by the design live load description, separated by a hyphen.

1.4.2.13 Maturity

The product of the time, in hours, and the temperature of the concrete, in degrees Centigrade. The period commences at the completion of the mixing of the last batch of concrete to be included in the product.

1.4.2.14 *Monolithic*

Defines a culvert that has at least two cell corner joints that are fully rigid.

1.4.2.15 *Overlay zone*

The fill or ballast directly above the top of the culvert, which has a depth of not less than 150 mm (see Figure 1.1).

1.4.2.16 *Precast unit*

Culvert units, lid, link or base slabs as described in Figures 1.1 and 2.1.

1.4.2.17 *Side zones*

The areas bounded by the outside of the culvert leg, the top of the bed zone, the level of the top of the culvert and for a lateral extent as shown in Figure 1.1.

1.4.2.18 *Size class*

Culvert size classification system designated by the nominal span of the culvert unit, in millimetres, followed by the nominal height of the culvert unit, in millimetres, separated by an 'X'.

1.4.2.19 *Span*

Span of culvert unit, lid or link slab (see Figures 1.1 and 2.1).

1.4.2.20 *Standard feeler gauge*

A feeler gauge of the shape and thicknesses specified in Appendix E.

1.5 NOTATION

The symbols used in this Standard are listed in Table 1.1. Symbols that occur in more than one clause are defined in Table 1.1 and used in the various clauses without further reference. Symbols that occur only in one clause are defined in that clause.

Unless a contrary intention appears, the following applies:

- (a) The symbols used in this Standard shall have the meanings ascribed in Table 1.1, with respect to the structure, member, or condition to which a clause is applied.
- (b) Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.
- (c) The dimensional units for length, force, pressure and material strength in all expressions or equations are to be taken as metres (m), kilonewtons (kN), kilopascals (kPa) and megapascals (MPa) respectively, unless noted otherwise.

TABLE 1.1
NOTATION

Symbol	Description	Reference
A	Roadway wheel load rectangular distribution area at the top of the culvert, in metres squared	Clause 3.3.5.5.2
A_g	Gross concrete cross-sectional area, in millimetres squared or metres squared	Clause 3.7.2
a	Length of road wheel contact area, in millimetres or metres	Clause 3.3.5.5
B_C	Overall outside width of culvert, in metres	Clause 3.3.2
B_D	Horizontal width of trench, in metres	Clause 3.3.2(b)
b	Width of road wheel contact area, in millimetres or metres	Clause 3.3.5.5
C_D	Load coefficient for trench installations	Clause 3.3.2(b)
DLA	Dynamic load allowance for vehicle loads (the symbol α is used in AS 5100.2)	Clauses 3.3.5, 3.3.5.5.3, 3.3.6.4, Table 5.3, Paragraph G5, Appendix G
d_v	Effective depth of reinforcement for shear, in millimetres	Figure 3.2
e	Base of natural logarithms	Clause 3.3.2(b)
e_w	Effective width of culvert for consideration of moment and shear effects under live load, in metres	Clause 3.5.3
F_E	Soil-structure interaction factor for embankment installations	Clause 3.3.2
F_T	Soil-structure interaction factor for trench installation	Clause 3.3.2(b)
f'_c	Characteristic compressive (cylinder) strength of concrete at 28 days, in megapascals	Clauses 2.6, 5.6, Tables 2.3, 2.4 Paragraph G6, Appendix G
G	Centre to centre distance between wheels, in metres	Clause 3.3.5.5.2
g	Acceleration due to gravity, in metres per second per second	Clause 3.4.3
H	Height of fill over culvert, in metres	Clauses 3.3.2, 3.3.5.5.2, Figure 1.1
h	Depth below finished surface at culvert location, in metres	Clauses 3.3.3, 3.3.5.5.5, Figure 1.1
h_i	Depth below top of culvert, in metres	Clause 3.3.4, Figure 1.1
J	Distance between axles, in metres	Clause 3.3.5.5.2
k_L	Coefficient of earth pressure for railway load	Clause 3.3.6.3
k_o	Coefficient of earth pressure at rest	Clauses 3.3.3, 3.3.5.5.5
L	Span of the culvert unit, link or base slab, in metres	Clause 3.5.3
L_1	Width of distribution area (A), in metres	Clauses 3.3.5.5.2, 3.3.5.5.4
$L1$	Width of load distribution area at the top of culvert for railway load, in metres	Paragraph G5, Figure G1, Appendix G
L_2	Length of distribution area (A), in metres	Clauses 3.3.5.5.2, 3.3.5.5.4
$L2$	Length of load distribution area at the top of culvert for railway load, in metres	Paragraph G5, Figure G1, Appendix G
N	Concentration factor for Boussinesq analysis	Paragraph G4.3.2, Appendix G
P	Roadway wheel load or railway axle load; <i>or</i> for Boussinesq analysis, a point load at the surface of an elastic infinite half-space, in kilonewtons	Clauses 3.3.5.5.1, 3.3.5.5.4, Paragraph G4.3.2, Figure G1, Appendix G

(continued)

TABLE 1.1 (continued)

Symbol	Description	Reference
R	Shortest distance from point load P to the location of V , being the vector addition of the vertical depth and the plan distance, for Boussinesq analysis, in metres	Paragraph G4.3.2, Appendix G
R_u	Ultimate strength of a member or cross-section, in kilonewtons or kilonewton metres	Clause 3.6.1
V	Vertical pressure within the elastic half-space due to point load P for Boussinesq analysis, in kilopascals	Paragraph G4.3.2, Appendix G
V_{uc}	Ultimate shear strength of cross-section, in kilonewtons, unless noted otherwise	Clause 3.8, Paragraph G6, Appendix G
W_{AH}	Horizontal pressure due to compaction, in kilopascals	Clauses 3.3.4, 3.4
W_{CH}	Construction live load induced horizontal earth pressure, in kilopascals	Clauses 3.3.5.4, 3.4
W_{CV}	Construction live load induced vertical earth pressure, in kilopascals	Clauses 3.3.5.4, 3.4
W_{DC}	Culvert unit self weight, in kilonewtons	Clauses 3.3.1, 3.4
W_{FH}	Horizontal earth pressure due to fill, in kilopascals	Clauses 3.3.3, 3.3.4, 3.4, Paragraph G3, Appendix G
W_{FV}	Vertical earth pressure due to fill, in kilopascals	Clauses 3.3.1, 3.3.2, 3.4
W_{LH}	Roadway live load induced horizontal earth pressure, in kilopascals	Clauses 3.3.5.5.5, 3.4
W_{LV}	Roadway live load induced vertical earth pressure, in kilopascals	Clauses 3.3.5.5.4, 3.3.5.5.5, 3.4
W_{LVS}	Roadway serviceability live load induced vertical earth pressure, in kilopascals	Clauses 3.3.5.5.2, Paragraphs G4.3, G4.3.3, Table G2, Appendix G
W_{LVU}	Roadway ultimate live load induced vertical earth pressure, in kilopascals	Clauses 3.3.5.5.2, Paragraphs G4.3.1, G4.3.4, Table G3, Appendix G
W_{PH}	Heavy load platform live load induced horizontal earth pressure, in kilopascals	Clauses 3.3.5.3, 3.4
W_{PV}	Heavy load platform live load induced vertical earth pressure, in kilopascals	Clauses 3.3.5.3, 3.4
W_{RH}	Railway live load induced horizontal earth pressure, in kilopascals	Clauses 3.3.6.3, 3.4
W_{RV}	Railway live load induced vertical earth pressure, in kilopascals	Clauses 3.3.6.2, 3.3.6.3, 3.4, Paragraph G5, Table G4, Appendix G
Y	Ultimate load factor	Clause 3.3.5.5.1
z	Depth at the location of V for Boussinesq analysis, in metres	Paragraph G4.3.2, Appendix G
γ	Gravity force per unit volume of fill material, in kilonewtons per metre cubed	Clauses 3.3.2, 3.3.3
θ	Angle of internal friction of soil or fill, in degrees	Clause 3.3.3
ϕ	Capacity reduction factor	Clause 3.6.1

1.6 TYPES OF CULVERTS

The types of culverts covered by this Standard are specified in Table 1.2.

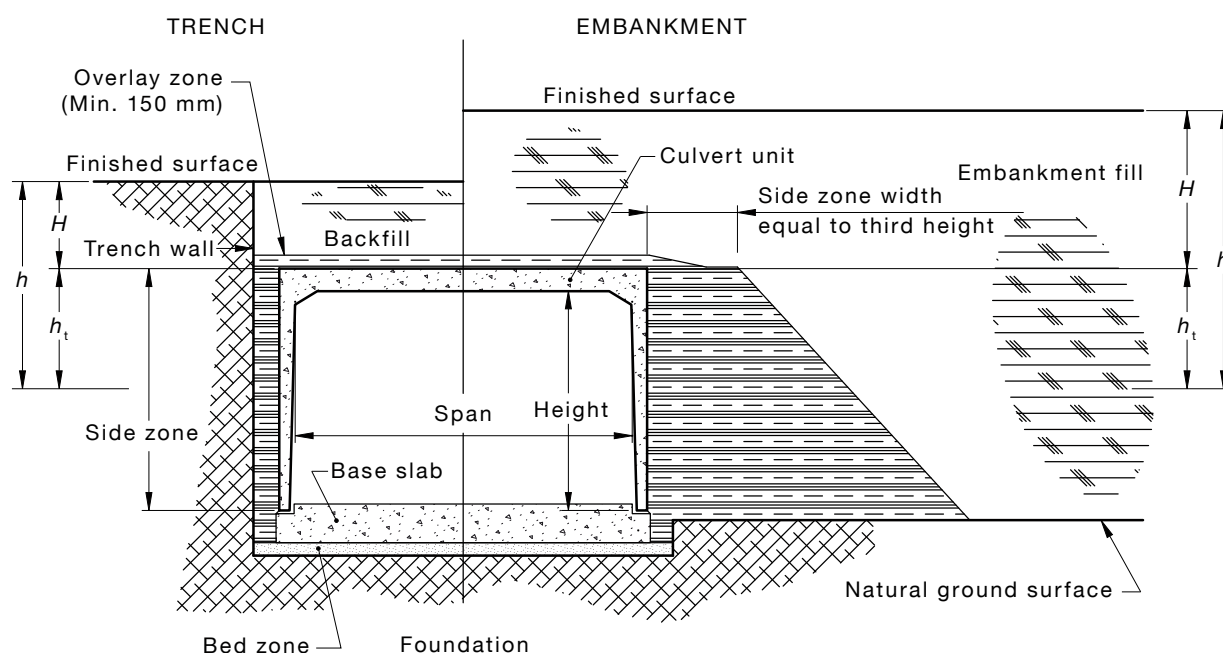


FIGURE 1.1 FILL AND CULVERT TERMS

TABLE 1.2
TYPES OF CULVERTS

Type of culvert	Description	Schematic illustration
U-shape (invert and lid)	A monolithic U-shaped section forming the invert and the two walls, and a separate top slab	
Inverted U-shape (crown unit and base)	A monolithic inverted U-shaped section forming the deck slab and the two walls, and a separate base slab	
One piece	An integral hollow rectangle forming the top slab, the two walls and the base slab	
Link slab (crown and base with link)	A single slab supported by adjacent units or structures	

NOTE: U-shape and inverted U-shape culverts are sometimes supplied without the lid slab or base slab, respectively. The relevant information should be supplied by the purchaser (see Appendix A).

1.7 CLASSIFICATION

1.7.1 General

Precast units shall be classified on the basis of the criteria for size and load given in Clauses 1.7.2 and 1.7.3 respectively.

The classification for a culvert unit shall comprise—

Span × Height/Fill depth – Load class

1.7.2 Size class

Culvert units shall be classified by the numerical value system given in Table 2.5.

Lid, link and base slabs shall be classified by the numerical value system given in Table 2.6.

1.7.3 Load class

Precast units shall be classified as ‘Roadway load class’ or ‘Railway load class’ as follows:

- (a) *Roadway load class* Culvert units, lid, link or base slabs that are subjected to fill material vertically over the culvert, from zero up to and including the design fill height, and road vehicle loadings in accordance with AS 5100.2, shall be designated as Class A.

The minimum roadway load class shall be Class 2-A, i.e. from 0 m up to and including 2 m of fill.

Example:

3600X1800/10-A, which is the designation of a 3600 mm span by 1800 mm high culvert with maximum design fill height of 10 m carrying roadway traffic loads.

- (b) *Railway load class* Culvert units, lid, link or base slabs that are subjected to fill material vertically over the culvert, from 0.3 m up to and including the design fill height, and 300LA railway loadings in accordance with AS 5100.2, shall be designated as Class R300LA.

The minimum range of design fill heights for railway load class shall be 0 m to 2 m of fill.

Example:

1800X1500/10-R300LA is the designation of an 1800 mm span by 1500 mm high culvert with maximum design fill height of 10 m carrying 300LA railway loads.

NOTES:

- 1 The 0 m to 2 m of fill includes 300 mm of ballast.
- 2 Other railway loads based on the 300LA axle configuration may also be specified (e.g. 350LA).

SECTION 2 MATERIALS, MANUFACTURE AND DIMENSIONING

2.1 SCOPE OF SECTION

This Section specifies the materials to be used, method of manufacture and dimensional requirements for precast units for compliance with this Standard.

2.2 FORMWORK

Forms shall be rigid and designed for intense compaction of the concrete during placement, such as obtained with vibrating tables or external vibrators. Forms shall be constructed to provide the shapes, dimensions and surface finish in the end product. The forms shall be mortar-tight, braced and tied together to maintain position and shape during placing and compaction of the concrete.

2.3 REINFORCEMENT

2.3.1 General

Steel reinforcement materials shall comply with AS/NZS 4671. At the time of placing concrete, the reinforcement shall be free of materials or coatings likely to impair its bond with the concrete.

If a culvert is designed with Class N reinforcement, Class L reinforcement shall not be substituted for Class N reinforcement unless the culvert is specifically designed for Class L reinforcement.

2.3.2 Fabrication

Reinforcement shall be fabricated so that it can be easily placed and accurately held in the required position during manufacture.

Fixing welds may be used for grid assembly. Where used, they shall not substantially reduce the cross-section of the reinforcing steel nor adversely affect its strength. Locational tack welds to fix reinforcement shall be made in accordance with AS/NZS 1554.3 (see Note 1).

Reinforcement grids shall be located in position within the formwork using steel nibs and spacers whose cross-section is in the plane of the concrete surface and is not more than 8 mm in diameter (see Note 2).

NOTES:

- 1 Reinforcing wire to AS/NZS 4671 may be machine resistance welded.
- 2 Cover provisions do not apply to these steel nibs and spacers.
- 3 Mild steel or stainless steel nibs and spacers may be used.
- 4 For exposure Class C nibs should be stainless steel.

2.4 CONCRETE MATERIALS

2.4.1 Cement

Cement materials shall comply with AS 3972. For concrete exposure classifications B2 and C, blended cements shall be specified.

NOTES:

- 1 Blended cements comprising a minimum of 65% slag or 25% fly ash are often specified by individual authorities for this purpose.
- 2 For more aggressive exposure conditions, in addition to blended cements, other measures may be required to achieve the 100 year design life.

2.4.2 Supplementary cementitious materials

Supplementary cementitious materials shall comply with AS 3582.1, AS 3582.2 and AS/NZS 3582.3.

2.4.3 Aggregates

Aggregates shall generally comply with AS 2758.1 with the following variations in requirements:

- (a) Water absorption of aggregate shall be limited to a maximum of 2.5%, except for slag aggregates where the maximum limit shall be 6%.
- (b) Durability shall be in accordance with Table 2.1.

Lightweight aggregates and non-ferrous metallurgical slag aggregates shall not be used in concrete for culvert units.

TABLE 2.1
AGGREGATE DURABILITY

Exposure classification	Minimum wet strength	Maximum wet/dry strength variation
	kN	%
B1 (see Note 1)	80	35
B2 and C (see Note 2)	100	25

NOTES:

- 1 Includes slag aggregate.
- 2 Includes culverts with surfaces subject to abrasion from traffic.

2.4.4 Water

Water shall comply with the requirements of AS 1379.

2.4.5 Admixtures

Chemical admixtures shall comply with AS 1478.1. Chemical admixtures shall not contain nitrates, calcium chloride, significant chlorides or other strongly ionized salts unless it can be shown that the admixtures do not adversely affect durability.

2.4.6 Restriction on chemical content

The materials shall not contain acid-soluble chloride or sulfate salts in excess of the values given in Table 2.2.

Other strongly ionized salts, such as nitrates, shall not be added to concrete unless it can be shown that durability is not adversely affected.

TABLE 2.2
MAXIMUM VALUES OF ACID-SOLUBLE CHLORIDE
AND SULFATE ION CONTENT IN CONCRETE AS CAST

Condition	Mass of maximum acid-soluble chloride ion content	Mass of maximum acid-soluble sulfate ion content
	kg/m ³ of concrete	% by mass of cement
Concrete cured at ambient temperature	0.8	5.0
Steam-cured concrete	0.8	4.0

NOTES:

- 1 Testing for acid-soluble chloride and sulfate ion content should be conducted in accordance with AS 1012.20.
- 2 For more aggressive exposure conditions, a lower chloride ion content may be required to achieve the 100 year design life.

2.5 CONCRETE SPECIFICATION AND COVER TO REINFORCEMENT

Minimum concrete strength grade and nominal cover to reinforcement, with formwork in accordance with Clause 2.2 and concrete placement in accordance with Clause 2.6.2, shall be as set out in Table 2.3.

TABLE 2.3
CONCRETE SPECIFICATION AND NOMINAL COVER
TO REINFORCEMENT

Exposure classification as defined in AS 5100.5	Nominal cover for characteristic compressive strength of concrete at 28 days (f'_c), mm	
	40 MPa	50 MPa
B1	30	25
B2	45	35
C	—	50

NOTES:

- 1 Nibs and spacers for reinforcement are excluded from all the above cover requirements.
- 2 Table 2.3 is based on AS 5100.5.
- 3 For cover tolerances, see Table 2.7.

2.6 CONCRETE PRODUCTION, PLACEMENT AND CURING

2.6.1 Batching

Concrete shall be control batched and mechanically mixed to comply with AS 1379. The batching and mixing shall be controlled to produce fresh concrete of uniform quality throughout each production run.

2.6.2 Placing

The fresh concrete shall be placed using intense compaction such as obtained with vibrating tables or external form vibration, in rigid forms, to produce a dense mass free from defects that would impair the strength, serviceability and durability of the unit.

If used, super-workable concrete shall be supplied and placed to achieve equivalent performance of normal slump concrete.

2.6.3 Curing

2.6.3.1 General

Concrete shall be cured, using one or a combination of the methods described in Clauses 2.6.3.2 to 2.6.3.4.

The concrete shall be protected from moisture loss until curing commences, which shall then continue until the concrete reaches—

- (a) the minimum specified age or maturity, whichever occurs first, as specified in Table 2.4; and
- (b) the strength set out in Table 2.4.

When combinations of curing methods are used, the resulting curing shall conform to Table 2.4.

The unit shall not be stripped of forms or handled off the base forms until the compressive strength exceeds 15 MPa. Where curing is interrupted for more than 30 min, the unit shall be protected from moisture loss.

TABLE 2.4
CONCRETE CURING REQUIREMENTS

Exposure classification	Minimum characteristic compressive strength of concrete at 28 days (f'_c) MPa	Minimum compressive strength of concrete at completion of curing (Note 2) MPa	Minimum concrete curing (i.e. either age or maturity at completion of curing, whichever occurs first)					
			Moist		Membrane		Accelerated	
			Age	Maturity	Age	Maturity	Age	Maturity
			Days	°C.h	Days	°C.h	Days	°C.h
B1	40	25	7	3864	7	3864	Note 4	Note 4
	50	32						
B2	40	25	7	3864	7	3864	Note 4	Note 4
	50	32						
C	50	32	7	3864	See Clause 2.6.3.3		0.25	550

NOTES:

- For concrete exposure classification U, curing should be agreed upon between the purchaser and manufacturer.
- The required concrete compressive strengths at completion of curing are based on AS 5100.5 (i.e. compressive strength at completion of curing = $0.625f'_c$).
- Maturity for moist and membrane curing is calculated by adopting the minimum days $\times 24 \times 23^\circ\text{C}$. Minimum days are based on AS 3600.
- Age and maturity for accelerated curing is dependent on the curing regime adopted. It includes time for placement, temperature ramp up, holding at maximum temperature and cooling down. The age and maturity adopted shall be sufficient to achieve the minimum concrete compressive strength at completion of curing specified in the table, or as agreed with the purchaser. For accelerated curing requirements, see Clause 2.6.3.4.

2.6.3.2 Moist curing

Concrete shall be kept continuously moist, the concrete being maintained at a temperature above 5°C , and all surfaces of the culvert shall remain fully saturated.

2.6.3.3 Membrane curing

Curing compounds approved by the purchaser may be used in accordance with Table 2.4 for exposure classifications B1 and B2. For exposure classification C, curing compounds may be used in lieu of moist or accelerated curing, provided they are approved by the purchaser. Curing compounds shall be applied to all exposed concrete surfaces to the supplier's specifications. The concrete shall be maintained at a temperature above 5°C.

As an alternative to proprietary curing compounds, membrane curing may be carried out using tight, fully sealed plastic wrapping to prevent moisture loss from the concrete surface.

2.6.3.4 Accelerated curing

Accelerated curing shall be carried out by low pressure steam curing in accordance with Appendix C.

NOTE: Other methods may be used with the prior approval of the purchaser.

2.7 JOINTS

Joints between precast units shall be butt joints unless otherwise specified.

2.8 DIMENSIONS

2.8.1 Internal dimensions

The preferred internal dimensions for precast units are listed in Tables 2.5 and 2.6 and shown in Figure 2.1.

2.8.2 Length

The nominal length of precast units shall be either 1200 mm or 2400 mm.

NOTE: The actual length should be checked with the manufacturer.

TABLE 2.5
PREFERRED INTERNAL DIMENSIONS—
CULVERT UNITS

Size class mm	Nominal span mm	Nominal height mm
1500 × 900	1500	900
1500 × 1200	1500	1200
1500 × 1500	1500	1500
1800 × 1200	1800	1200
1800 × 1500	1800	1500
1800 × 1800	1800	1800
2400 × 1200	2400	1200
2400 × 1500	2400	1500
2400 × 1800	2400	1800
2400 × 2400	2400	2400
3000 × 1200	3000	1200
3000 × 1800	3000	1800
3000 × 2400	3000	2400
3000 × 3000	3000	3000
3600 × 1200	3600	1200
3600 × 1800	3600	1800
3600 × 2400	3600	2400
3600 × 3000	3600	3000

(continued)

TABLE 2.5 (continued)

Size class mm	Nominal span mm	Nominal height mm
3600 × 3600	3600	3600
4200 × 1800	4200	1800
4200 × 2400	4200	2400
4200 × 3000	4200	3000
4200 × 3600	4200	3600
4200 × 4200	4200	4200

NOTES:

- 1 The size class is designated as 'the nominal span' × 'the nominal height' in millimetres (e.g. '1800 × 1200').
- 2 Other size culverts, including larger sizes, may be made to a specific order.
- 3 Actual size should be checked with manufacturer.

TABLE 2.6
PREFERRED INTERNAL DIMENSIONS—
LIDS, LINK AND BASE SLABS

Size class mm	Nominal span mm
1500	1500
1800	1800
2400	2400
3000	3000
3600	3600
4200	4200

NOTES:

- 1 The size class is designated by the nominal span, in millimetres.
- 2 Other size culverts, including larger sizes, may be made to a specific order.
- 3 Actual size should be checked with manufacturer.

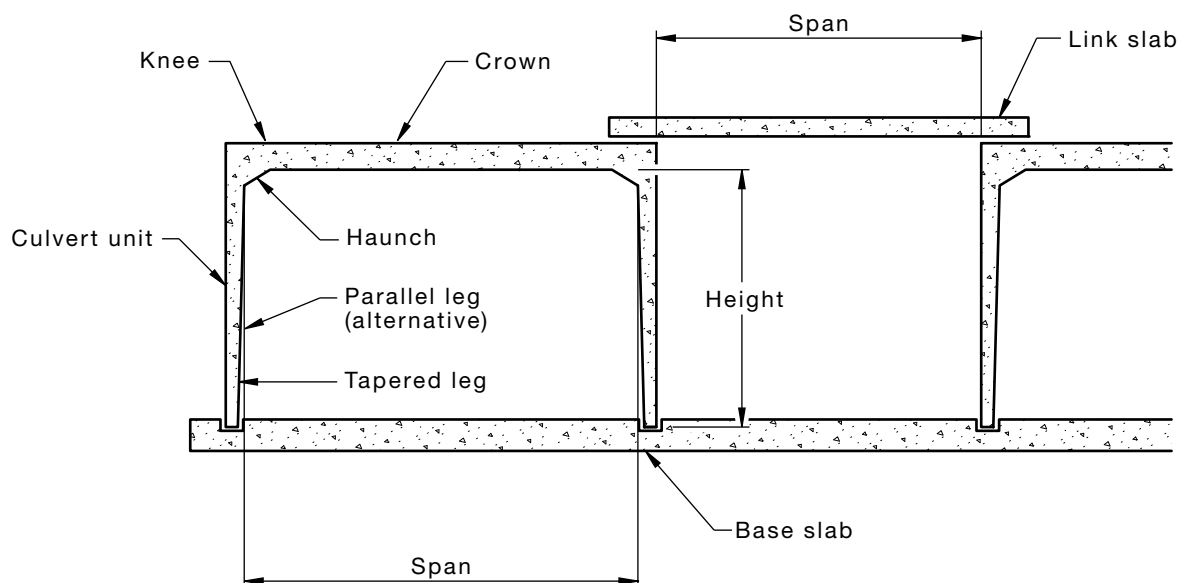


FIGURE 2.1 CULVERT AND LINK SLAB TERMS

2.9 MEASUREMENT OF DIMENSIONS

2.9.1 General

The dimensions of a precast unit shall be determined in accordance with Clauses 2.9.2 to 2.9.5, at the place of manufacture.

2.9.2 Size dimensions

The internal size dimensions of span and height of a culvert unit and span of a lid, link or base slab shall be determined by taking measurements at 200 mm from each end and at the middle of the length of the unit. The size dimension for span and height of a culvert unit and span of a lid, link or base slab shall be taken as the mean of the three values.

2.9.3 Thickness

The thickness of the culvert unit crown, lid, link or base slab shall be determined by taking measurements at the end and middle of the span at locations 300 mm from each end of the unit. The thickness shall be taken as the mean of the six values.

The thickness of culvert unit legs shall be measured 50 mm up from the base of the legs and at the junction of the inside corner radius or haunch and the top of the legs, and 300 mm from each end of the unit. The leg thickness at each horizontal plane shall be taken as the mean of the four values.

2.9.4 Cover

The concrete cover to reinforcement shall be measured in accordance with Appendix D.

2.9.5 Length

The length of a precast unit shall be determined by taking measurements at the base of the legs (or ends of span for a lid, base or link slab) and at the middle of the span. The length dimension shall be the mean of the three values.

2.10 TOLERANCES

2.10.1 General

The tolerance on a dimension shall be the difference between the manufacturer's stated dimension and the value determined in accordance with Clause 2.9. The tolerance on the basic shape shall be applied to the measurement at the location.