



Masonry structures



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Australian Standard®

Masonry structures

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PREFACE

This Standard was prepared by the Standards Australia Committee BD-004, Masonry Structures, to supersede AS 3700—2011.

The objective of this Standard is to provide minimum requirements for the design and construction of unreinforced, reinforced and prestressed masonry, including built-in components.

The principal changes from the 2011 edition of the Standard include the following:

- (a) Increased capacity reduction factor for compression in hollow masonry with wide spaced reinforcement.
- (b) Inclusion of provisions for stack bonded masonry.
- (c) Compressive strength of grouted masonry.
- (d) Compression design of reinforced masonry.
- (e) Concentrated loads in reinforced masonry.
- (f) Minor changes to ensure consistency with AS 4773.
- (g) New Appendix I on the relationship between ISO 9223 corrosivity categories and durability class. Also includes solutions for wall ties, connectors and accessories, and lintels and shelf angles, as provided in AS/NZS 2699.1, AS/NZS 2699.2 and AS/NZS 2699.3 respectively.
- (h) Changes to Table 10.3 to align with changes made to AS 1170.4.

The following are excluded:

- (i) Thermal performance.
- (ii) Acoustic insulation.

Statements expressed in mandatory terms in notes to tables and figures 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.

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STANDARDS AUSTRALIA

Australian Standard
Masonry structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the design and construction of masonry of the following types:

- (a) Unreinforced, reinforced and prestressed masonry using manufactured units of clay or concrete laid in mortar.
- (b) Unreinforced masonry using manufactured calcium silicate units laid in mortar.
- (c) Autoclaved aerated concrete (AAC) masonry laid in thin-bed mortar.
- (d) Square-dressed natural stone laid in mortar.

This Standard does not provide for the following:

- (i) Design values or material properties for the design and construction of masonry incorporating square-dressed natural stone. The wide variations in properties of natural stone require that each case be considered individually for the determination of relevant design values.
- (ii) Specific requirements for prefabricated masonry panels or masonry in composite action with steel or concrete structural members; however, the principles of this Standard may be used for such types of construction.
- (iii) Specification for design and construction of AAC laid in other than thin-bed mortar; however, for masonry so constructed the principles of this Standard may be used.

NOTE: This Standard assumes the structural design of masonry is entrusted to experienced structural engineers or similar appropriately qualified persons, and that the execution of such work is carried out under the direction of appropriately qualified persons who are experienced in masonry construction and who understand the structural requirements specified herein.

1.2 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard:

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

AS	
1170	Structural design actions
1170.4	Part 4: Earthquake actions in Australia
1316	Masonry cement
1391	Metallic materials—Tensile testing at ambient temperature
1478	Chemical admixtures for concrete, mortar and grout
1478.1	Part 1: Admixtures for concrete
1530	Methods for fire tests on building materials, components and structures
1530.4	Part 4: Fire-resistance tests of elements of building construction

AS	
1672	Limes and limestones
1672.1	Part 1: Limes for building
2193	Calibration and classification of force-measuring systems
2701	Methods of sampling and testing mortar for masonry construction
2758	Aggregates and rock for engineering purposes
2758.1	Part 1: Concrete aggregates
2870	Residential slabs and footings
3582	Supplementary cementitious materials
3582.2	Part 2: Slag—Ground granulated blast-furnace
3600	Concrete structures
3972	General purpose and blended cements
4055	Wind loads for housing
4100	Steel structures
5100	Bridge design (all parts)
AS/NZS	
1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
1170.3	Part 3: Snow and ice actions
2699	Built-in components for masonry construction
2699.1	Part 1: Wall ties
2699.2	Part 2: Connectors and accessories
2699.3	Part 3: Lintels and shelf angles (durability requirements)
2904	Damp-proof courses and flashings
3582	Supplementary cementitious materials
3582.1	Part 1: Fly ash
3582.3	Part 3: Amorphous silica
4455	Masonry units, pavers, flags and segmental retaining wall units
4455.1	Part 1: Masonry units
4456	Masonry units, segmental pavers and flags—Methods of test
4456.4	Method 4: Determining compressive strength of masonry units
4456.10	Method 10: Determining resistance to salt attack
4456.11	Method 11: Determining coefficients of expansion
4456.12	Method 12: Determining coefficients of contraction
4671	Steel reinforcing materials
4672	Steel prestressing materials
4672.1	Part 1: General requirements

EN	
10088	Stainless Steel
10088-1	Part 1: List of Stainless Steels
10088-5	Part 5: Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes
12878	Pigments for the colouring of building materials based on cement and/or lime. Specifications and methods of test
BS	
6744	Stainless steel bars—Reinforcement of concrete—Requirements and test methods
EC	
6-1	Design of Masonry Structures

1.3 USE OF ALTERNATIVE MATERIALS OR METHODS

Provided the requirements of Section 2 are met, this Standard shall not be interpreted in a way that prevents the use of alternative materials or methods of design or construction not specifically referred to herein.

NOTE: Where the intended use is subject to the control of a building authority, approval for the use of alternative materials or methods should be obtained from the relevant authority.

1.4 INFORMATION TO BE PROVIDED ON DOCUMENTS

1.4.1 General

Documents shall show the following information to construct the masonry:

- (a) Category, type and work sizes of the masonry units as defined in Clauses 1.5.2.23 and 1.5.2.24. This shall include the face shell width for units that are to be face-shell bedded (see Clause 3.2).
- (b) The characteristic unconfined compressive strength (f'_{uc}) required for the masonry units.
- (c) Design thickness of the mortar joints, if other than 10 mm.
- (d) Mortar class or mix proportions or, for proprietary thin-bed mortar, the relevant specification.

NOTE: If mortar is specified by class, a range of deemed-to-conform mortar mixes is given in Table 11.1. If it is desired to use a mix other than those deemed to conform, the standard requires that evidence of performance be provided [see Clause 11.4.1(ii)]. In all cases, the designer should ensure that the requirements for mortar are adequately communicated to the builder.

- (e) Finish and depth of raking (if any) of the mortar joints.
- (f) Bond pattern for the masonry.
- (g) Salt attack resistance grade of the masonry units (see Clause 5.5).
- (h) Duty rating and durability class of wall ties (see Clause 3.4 and Clause 5.7).
- (i) The strength and stiffness of accessories (see Clause 3.4).
- (j) The characteristic lateral modulus of rupture (f'_{ut}) (see Clause 3.2).
- (k) The coefficient of expansion or contraction of the units that has been used in the design.

- (l) Values required for any other properties of the masonry or its components, where those values differ from values given in this Standard.
- (m) For special masonry, where applicable, the values of the characteristic compressive strength (f'_m) and the characteristic flexural tensile strength (f'_{mt}) used in design of the masonry.
- (n) For special masonry, the site control testing requirements for the masonry or its components.
- (o) For reinforced masonry, the grade and type of reinforcement.
- (p) For prestressed masonry, the grade and type of tendons.
- (q) For grouted masonry—
 - (i) cement content;
 - (ii) the characteristic compressive cylinder strength of grout at 28 days (f'_c);
 - (iii) maximum aggregate size; and
 - (iv) workability or site mix proportions.
- (r) Principal dimensions of the masonry, including the positions of supports, piers, openings, length of returns and all features affecting the strength and stability of the structure.
- (s) Positions and details (including dimensions, durability rating, and material types) of the following:
 - (i) Subfloor or cavity ventilation.
 - (ii) Termite barriers.
 - (iii) Damp-proof courses (DPCs).
 - (iv) Flashings.
 - (v) Slip materials.
 - (vi) Control joints.
 - (vii) Lintels.
 - (viii) Roof anchorage.
 - (ix) Bracing to walls.
 - (x) Connectors.

1.4.2 Provision for demolition

A note shall be included on the documents for any building or structure that is identified as being one that cannot be demolished without danger of unintended collapse.

NOTE: For information on demolition of structures, see AS 2601.

1.5 DEFINITIONS

For the purpose of this Standard the definitions below apply.

1.5.1 Administrative definitions

1.5.1.1 *Approved*

Except as otherwise stated, approved by the building authority.

1.5.1.2 *Building authority*

Body having statutory powers to control the design and erection of buildings or structures in the area in which the buildings or structures are to be erected.

1.5.1.3 *Documents*

Drawings and specifications that set out the work to be executed.

1.5.1.4 *Supervision*

Site control of work directed towards obtaining compliance with the design and the provisions of this Standard.

1.5.2 **Technical definitions**

1.5.2.1 *Areas*

Bedded areas, combined cross-sectional areas, design cross-sectional areas and grout areas.

NOTE: See Clauses 4.5.4, 4.5.5, 4.5.6 and 4.5.7 for requirements relating to these areas.

1.5.2.2 *Bed face*

The face of the masonry unit that is in direct contact with bed joint mortar.

1.5.2.3 *Bed joint*

See joints.

1.5.2.4 *Bedding*

One of the following:

- (a) *Bedding planes* Those planes in the masonry formed by the horizontal joints between the bed faces of the units.
- (b) *Full bedding* Bedding covering the entire plan area of the masonry unit with mortar during laying.
- (c) *Face-shell bedding* Bedding covering the plan area of the face shells, but not the webs, of hollow masonry units with mortar during laying.

1.5.2.5 *Bond beam*

Horizontal reinforced masonry member forming part of the masonry.

1.5.2.6 *Buttress*

An engaged pier that provides lateral support.

NOTE: See Clause 1.5.2.22; see also Clause 1.5.2.18 for dimensions.

1.5.2.7 *Cavity*

In members consisting of two leaves of masonry, the space between the leaves.

1.5.2.8 *Cement*

Cement as defined in AS 3972 or AS 1316.

1.5.2.9 *Characteristic lateral modulus of rupture (f'_{ut})*

The characteristic value of the flexural tensile strength of the masonry unit obtained when subjected to bending in the direction normal to the plane of the wall.

NOTE: See AS 4456.15 for more information on the lateral modulus of rupture.

1.5.2.10 *Characteristic value*

One of the following:

- (a) *For strength properties*, the value of the material property that is exceeded by 95% of the material.
- (b) *For coefficients of expansion and contraction*, the value that is exceeded by 5% of the material.

1.5.2.11 *Coefficients of expansion and contraction*

The coefficients of expansion and contraction of masonry units as determined in accordance with AS/NZS 4456.11 and AS/NZS 4456.12.

1.5.2.12 *Column*

See pier.

1.5.2.13 *Compressive strength*

One of the following:

- (a) *For masonry units*, the characteristic unconfined compressive strength of masonry units (f'_{uc}) when tested in accordance with AS/NZS 4456.4.
- (b) *For masonry*, the characteristic unconfined compressive strength of masonry (f'_m) determined in accordance with Clause 3.3.2.

1.5.2.14 *Concrete*

A mixture of portland cement, aggregate and water, with or without the addition of fly ash, ground granulated blast-furnace slag, silica fume and/or chemical admixtures.

1.5.2.15 *Connectors*

Masonry connectors of the following categories:

- (a) *Collar joint tie* A tie connecting two masonry leaves through a collar joint.
- (b) *Control joint tie* A tie connecting a leaf of masonry across a control joint for the purpose of maintaining alignment.
- (c) *Head and column ties* Ties connecting masonry to a structural support.

1.5.2.16 *Control joint*

See Clause 1.5.2.21.

1.5.2.17 *Core*

The void within the cross-section of a cored, hollow or horizontally cored masonry unit.

1.5.2.18 *Dimensions of buttresses and piers*

One of the following:

- (a) *Width and thicknesses of an isolated pier* The larger and smaller horizontal dimensions, respectively.
- (b) *Width of a buttress or engaged pier* Horizontal dimension parallel to the wall to which it is bonded.
- (c) *Thickness of a buttress or engaged pier* Horizontal dimension at right angles to the wall to which it is bonded, including the wall thickness.

1.5.2.19 *Efflorescence*

Salts left on the surface of units after the evaporation of water. The surface deposits can take the form of either loose crystalline salts or amorphous films of non-crystalline salts.

1.5.2.20 *Grout*

Highly workable concrete placed in cores or cavities to produce grouted masonry. See Clause 11.7.

1.5.2.21 *Joint*

One of the following:

- (a) *Bed joint* A joint (typically horizontal) formed by the mortar on which the masonry units are laid.
- (b) *Perpend joint* A joint (typically vertical) formed between adjacent masonry units laid in the same course.
- (c) *Collar joint* A vertical joint filled with mortar between two leaves of masonry.
- (d) *Control joint* A joint or gap constructed in masonry to control and absorb movements in that masonry. Control joints include the following:
 - (i) Contraction joint (or opening control joint), which opens as the masonry contracts or shrinks.
 - (ii) Expansion joint (or closing control joint), which closes as the masonry expands.
 - (iii) Articulation joint, which opens or closes to allow structural movements.

1.5.2.22 *Lateral support*

The support (including a footing, buttress, cross-wall, beam, floor, or braced roof structure) that effectively restrains a wall or isolated pier in the direction of its thickness, except that an isolated pier may also have lateral support in the direction of its width.

NOTE: A lateral support is required to satisfy Clause 2.7.

1.5.2.23 *Masonry*

Assemblage of masonry units properly bonded with mortar. The term includes the following:

- (a) *Plain masonry* Masonry that is not grouted, reinforced or prestressed.
- (b) *Grouted masonry* Masonry in which some or all of the cavities in the masonry, or cores in hollow units, are filled with grout.
- (c) *Unreinforced masonry* Masonry that is not reinforced.
- (d) *Reinforced masonry* Masonry in which some or all of the grouted cavities or cores are reinforced with steel reinforcement to comply with the provisions of Section 8.

NOTE: Accessories, including bed joint mesh, that do not comply with the requirements of Section 8 are not regarded as reinforcement for the purposes of this definition.
- (e) *Prestressed masonry* Masonry in which some or all of the cavities or cores are reinforced with stressed tendons to comply with the requirements of Section 9.
- (f) *Member of mixed construction* A member composed of more than one type of masonry system (e.g. unreinforced and reinforced), or more than one type of masonry unit, strength, durability grade or mortar.
- (g) *Stack bonded masonry* Masonry in which the overlap of masonry units in successive courses is less than $\frac{1}{4}$ of the unit length or 50 mm, whichever is greater.

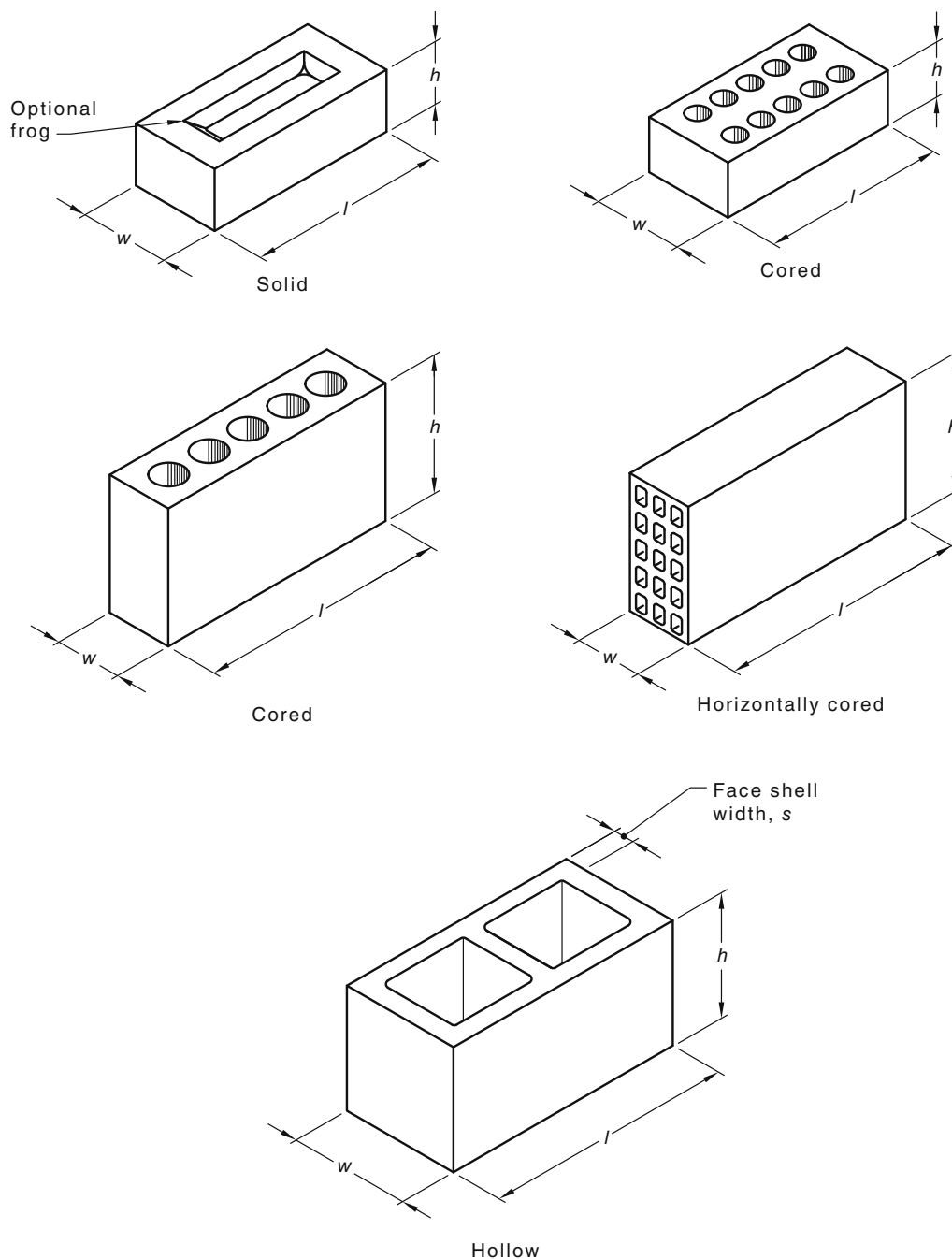
- (h) *Special masonry* Masonry with specified strength values higher than those specified in this Standard, which is tested during its construction to verify that the specified strength values have been achieved (see Clause 12.7).

The methods of testing for compressive and flexural strength of masonry are given in Appendices C and D.

1.5.2.24 *Masonry unit*

A preformed component, intended for use in masonry construction (see Figure 1.1). The term covers the following:

- (a) Categories:
 - (i) *Solid unit* A unit without cores, but which may contain recesses (commonly called frogs) not greater than 10% of the gross volume, intended to be laid with full bed joints.
 - (ii) *Cored unit* A unit with cores, intended to be laid with its cores vertical and with full bed joints.
 - (iii) *Hollow unit* A unit with cores, intended to be laid with its cores vertical and with face-shell-bedded joints.
NOTE: Hollow units are tested using the face-shell area.
 - (iv) *Horizontally cored unit* A unit with cores, intended to be laid with its cores horizontal and with full bed joints.
 - (v) *Special purpose unit* A unit intended for a special purpose that does not fall within the categories of Items (i) to (iv).
- (b) Types:
 - (i) *Calcium silicate masonry unit* A unit manufactured from calcium silicate and in accordance with AS/NZS 4455.1.
 - (ii) *Clay masonry unit* A unit manufactured from burnt clay or shale and in accordance with AS/NZS 4455.1.
 - (iii) *Concrete masonry unit* A unit manufactured from concrete and in accordance with AS/NZS 4455.1.
 - (iv) *Autoclaved aerated concrete masonry unit (AAC)* A unit manufactured from autoclaved aerated concrete and in accordance with AS/NZS 4455.1.
 - (v) *Natural stone masonry units* A unit of square-dressed natural stone in accordance with EC6-1.
- (c) Dimensions:
 - (i) *Height* The height based on work size (see h in Figure 1.1).
 - (ii) *Length* The length based on work size (see l in Figure 1.1).
 - (iii) *Width* The width based on work size (see w in Figure 1.1).
 - (iv) *Face shell width* The width of the face shell based on work size (see s in Figure 1.1).
 - (v) *Full bed width* The overall width of the unit based on work size (see w in Figure 1.1).



NOTES:

- 1 The figures above show only the basic shapes of the principal units. There are many commercially available 'fittings' and 'special' units used for particular applications.
- 2 The figures above are indicative only and are for the purpose of illustrating terms.

FIGURE 1.1 TYPICAL MASONRY UNITS

1.5.2.25 Member

A wall or portion thereof (including a pier, buttress, bond beam or lintel), or an isolated pier.

1.5.2.26 Mortar

One of the following:

- (a) A mixture of cementitious material, sand (fine aggregate) and water, with or without additives or chemical admixtures.
- (b) Thin-bed mortar—a proprietary material specifically manufactured to bond masonry units with a design joint thickness of not less than 2 mm and not greater than 4 mm.

1.5.2.27 Mortar joints

One of the following:

- (a) *Flush joint* A joint that is finished flush with the surface of the masonry units.
- (b) *Raked joint* A joint that is raked out to a specified depth behind the face of the masonry.
- (c) *Tooled joint* A joint, including flush joint and raked joint, in which the surface is trowelled or ironed to a smooth, dense finish.

NOTE: Mortar joints for other than AAC are classified according to the types of finish given to their exterior surface.

1.5.2.28 Pier

One of the following (see also Clause 1.5.2.18 for dimensions):

- (a) *Engaged pier* Pier bonded integrally with the wall, which it stiffens locally.
NOTE: An engaged pier has insufficient strength and stiffness to provide lateral support to the wall (see Clauses 2.6.3 and 7.3.4.3).
- (b) *Isolated pier* Isolated vertical element whose width and thickness do not exceed one-fifth of the height.

NOTE: If either the width or thickness exceeds one-fifth of the height, the member is a wall.

1.5.2.29 Prestressing tendon

Any bar, wire or strand used to prestress masonry.

1.5.2.30 Rotational restraint

The restraint against rotation of a wall edge or isolated pier by supports that allow the transfer of moment.

1.5.2.31 Shear wall

A wall that carries in-plane lateral forces and transfers them to other parts of the structure.

1.5.2.32 Structural backing

One of the following:

- (a) *Flexible structural backing* A structural system supporting a veneer and having a stiffness (E_1) less than or equal to 0.5 times the uncracked stiffness of the veneer.
- (b) *Stiff structural backing* A structural system that is not classed as a flexible structural backing.

1.5.2.33 *Surf coast*

An area of saltwater where breaking waves are a normal occurrence (see Clauses 5.3.1 and 5.3.2).

NOTES:

- 1 'Breaking waves' applies to beaches where surf breaks regularly and does not apply to wind-driven white caps or choppy water.
- 2 As an indication of 'normal occurrence' breaking waves on an average of 4 d week or 60% of the time would satisfy this definition.

1.5.2.34 *Ties*

Ties of categories and types as follows:

(a) Categories:

- (i) *Veneer tie* A tie connecting a masonry veneer to a frame or wall designed to resist lateral forces.
- (ii) *Cavity tie* A tie connecting two leaves of masonry that are separated by a cavity of any width.

(b) Types:

- (i) *Type A tie* A tie designed primarily for wind loading.
- (ii) *Type B tie* A tie designed primarily for seismic ductility.

NOTE: Type B ties are commonly used in New Zealand and are not generally available in Australia.

1.5.2.35 *Wall*

One of the following:

- (a) *Cavity wall* A wall consisting of two leaves of masonry separated by a cavity.
- (b) *Diaphragm wall* A wall consisting of at least two leaves of masonry with vertical masonry diaphragms joining the leaves, constructed so as to achieve monolithic structural action.
- (c) *Masonry veneer wall* A wall consisting of a leaf of masonry together with a backing system that provides lateral support.
- (d) *Single leaf wall* A wall whose thickness is equal to the width of the masonry unit used in that wall.
- (e) *Solid wall* A wall whose thickness is greater than the width of one unit and in which the vertical joint between masonry leaves is filled solidly with mortar and which is intersected with header units or wire ties to give monolithic structural action.
- (f) *Wall of geometric section* A wall, other than rectangular section, that is constructed so as to achieve monolithic structural action.

1.5.2.36 *Work sizes*

The sizes of the masonry unit specified for manufacture and from which deviations are measured.

NOTE: Work sizes refer to the principal dimensions of the masonry unit and are used for the calculation of all section properties in design and testing (see Figure 1.1).

1.6 NOTATION

Unless a contrary intention is expressed—

- (a) the notations used in this Standard shall have the meanings given below with respect to the structure or member or condition to which a clause is applied;
- (b) where non-dimensional ratios are involved, both the numerator and denominator are expressed in consistent units; and
- (c) dimensional units used in expressions or equations shall be consistent unless otherwise specified.

A_b	= the bedded area of a masonry member cross-section (Clause 4.5.4)
A_c	= the cross-sectional area of a grouted or reinforced masonry member (Clause 4.5.5)
A_d	= the design cross-sectional area of a member (Clause 4.5.6) = the design cross-sectional area of the shear resisting portion of the member
A_{de}	= the effective area of dispersion of the concentrated load on the member at mid-height (Figure 7.3 and Clause 7.3.5.4)
A_{ds}	= the bearing or dispersion area of a concentrated load in a member at the design cross-section under consideration (Clauses 7.3.5.2, 7.3.5.3 and 7.3.5.4)
A_g	= the design cross-sectional area of grout in a grouted or reinforced masonry member (Clause 4.5.7)
A_p	= the cross-sectional area of prestressing tendons (Clauses 9.3.3.2 and 9.5.3)
A_s	= the total cross-sectional area of the main reinforcement in a reinforced masonry member (Clauses 8.5, 8.7.2 and 8.8)
A_{sd}	= the portion of the cross-sectional area of the main tensile reinforcement used for design purposes in a reinforced masonry member (Clause 8.6)
A_{st}	= the cross-sectional area of fully anchored longitudinal reinforcement in the tension zone of the cross-section under consideration (Clause 8.6)
A_{sv}	= the cross-sectional area of shear reinforcement per spacing interval (Clauses 8.7.4 and 8.8)
a_f	= an aspect factor (Clause 7.4.4.2 and Table 7.5)
a_v, a_h	= slenderness coefficients for assessing slenderness ratio (Clauses 6.3.2.2, 7.3.3.4 and 7.3.4.3)
a_{vf}	= a slenderness coefficient for assessing slenderness ratio in design for fire resistance for structural adequacy (Clause 6.3.2.2)
a_l	= the distance from the end of the wall or pier to the nearest end of the bearing area (Clause 7.3.5.4 and Figure 7.3)
B	= a height factor used in calculating diagonal bending moment capacity (Clause 7.4.4.3)

b	= the width of a masonry member of solid rectangular cross-section; or = the effective width of a member in accordance with Clause 4.5.2
b_v, b_h	= vertical and horizontal bending coefficients for out-of-plane loads on walls (Clause 7.4.4.4)
b_w	= the width of the web of the shear-resisting area of a member; for a solid rectangular cross-section, $b_w = b$ (Clause 8.8)
C_c	= the coefficient of creep (Clause 9.3.3.2)
C_i	= a coefficient evaluated from the test results (Clause 6.5.4)
C_s	= a coefficient evaluated from the test results (Clause 6.3.3)
C_v	= robustness coefficient (Clause 4.6.3)
D	= the overall depth of a cross-section in the plane of bending (Clause 8.9)
d	= the effective depth of a reinforced masonry member or wall (Clauses 8.3, 8.6 and 8.8)
d_p	= the effective depth of the tendon (Clauses 9.2.2, 9.5.1, 9.5.2 and 9.5.3)
d_{sc}	= the diameter of shear connector (Clause 7.5.6)
d_1, d_2	= the eccentricities of masses used in the bond test (Paragraph D6.4, Appendix D)
E_m	= the modulus of elasticity of masonry (short-term loading) (Table 3.4)
E_L	= the modulus of elasticity of masonry (long-term loading) (Table 3.4)
E_p	= the modulus of elasticity of prestressing tendons (Clause 3.7.2)
E_s	= the modulus of elasticity of reinforcement (Clause 3.6.2)
E_I	= stiffness of a structural system (Clause 1.5.2.32)
e	= the eccentricity of prestress (Clause 9.5.4)
e_1, e_2	= the eccentricities of vertical force (Clause 7.3.4.5 and Table 7.3)
e_m	= coefficient of expansion of the masonry unit determined in accordance with AS/NZS 4456.11
F_d	= the design compressive force acting on the cross-section of a member, assessed from loads complying with Clause 2.6 for strength (in unreinforced masonry, F_d is typically that value of the design compressive force that acts simultaneously with a bending moment, shear force or other load action)
F_{dt}	= the design tension force acting on the cross-section of a member, assessed from loads complying with Clause 2.6 for strength (Clauses 8.10 and 9.7)
F_o	= the basic compressive strength capacity of a plain or grouted masonry cross-section (Clause 7.3.2)
F_{sp}	= the total load at which the specimen fails (Paragraphs C7.2, Appendix C and D6.6, Appendix D)

F_t	= the mean strength of the tie in accordance with Tables 3.5 and 3.6, Clauses 3.4 and 7.7.4
F_{td}	= the design compressive or tensile tie force (Clauses 7.7.4)
f'	= a characteristic strength value (Paragraph B2, Appendix B)
f'_c	= the characteristic compressive cylinder strength of grout at 28 days (Clause 3.5)
f'_{cg}	= the design characteristic compressive strength of the grout (Clause 3.5)
f'_m	= the characteristic compressive strength of masonry (Clause 3.3.2)
f'_{mb}	= the characteristic compressive strength of masonry specimens for masonry units whose ratio of height to mortar bed joint thickness is 7.6 (Clause 3.3.2)
f'_{mp}	= the characteristic compressive strength of prestressed masonry at the transfer of prestress (Clause 9.5.1)
f'_{mg}	= the characteristic compressive strength of grouted masonry specimens manufactured and tested in accordance with Appendix C and determined in accordance with Appendix B (Clause 7.3.2)
f'_{ms}	= the characteristic shear strength of masonry (Clause 3.3.4)
f'_{mt}	= the characteristic flexural tensile strength of masonry (Clause 3.3.3)
f'_t	= the equivalent characteristic torsional strength (Clause 7.4.4.3)
f'_{uc}	= the characteristic unconfined compressive strength of masonry units (Clauses 3.2)
f'_{ut}	= the characteristic lateral modulus of rupture of masonry units (Clause 1.5.2.9)
f'_{vm}	= the characteristic shear strength of reinforced masonry (Clause 8.8)
f_d	= the minimum design compressive stress on the bed joint at the cross-section in a member (Clauses 7.4.3.2 and 7.4.3.3) = F_d/A_d
f_{ksp}	= the (lower) 5 percentile value for a set of test results (Paragraph B2, Appendix B)
f_p	= the tensile strength of prestressing tendons (Clause 3.7.1 and Table 3.8)
f_{pe}	= the effective stress in the tendon after losses (Clause 9.5.2)
f_{pt}	= the stress in prestressing tendons at transfer (Clause 9.3.3.2)
f_{py}	= the yield strength of prestressing tendons (Clause 3.7.1)
f_{sp}	= the unconfined compressive or flexural strength of a masonry test specimen (Paragraphs B2, Appendix B, C7.2, Appendix C and D6.6 and D7.2, Appendix D)
$f_{sp\ell}$	= the least value of a set of specimen test results (Paragraph B2, Appendix B)

$f_{sp}(1), f_{sp}(i), f_{sp}(n)$	= the group of test results in the assessment of characteristic value (Paragraph B2, Appendix B)
f_{sy}	= the design yield strength of reinforcement (Clause 3.6.1 and Table 3.7)
f_{vr}	= effective shear strength (Clause 8.7.2)
f_{vs}	= the design shear strength of main reinforcement (Clause 8.8)
f_{yc}	= the characteristic tensile yield strength of the connector (Clause 7.5.6)
G	= the assumed slope of the crack line (Clause 7.4.4.2)
G_g	= the gravity load (Clause 7.5.5.2)
H	= the clear height of a member between horizontal lateral supports (Clause 6.3.2.2)
	= for a member without top horizontal support, the overall height from the bottom lateral support (Clause 6.3.2.2)
	= the height of the member perpendicular to the direction of the shear load (Clause 8.7)
H_d	= the design height (Clause 7.4.4.2)
H_1	= the height of taller opening (Clause 7.3.4.3)
h_u	= the height of masonry unit in a wall (Clauses 7.4.3.4 and 7.4.4.2)
I	= second moment of area of a cross-section
j	= the number of results remaining in assessment of strength values from test results (Paragraph A3.2, Appendix A)
K_{wt}	= wall tie stiffness coefficient (Clause 7.7.3)
k	= a reduction factor for slenderness and eccentricity (Clauses 7.3.3.2, 7.3.4.2 and 7.3.4.5)
k_1, k_2	= coefficients to assess lateral load capacity (Clause 7.4.4.2 and Table 7.5)
k_3, k_4	= coefficients used for prestressed bending moment (Clause 9.5.2)
k_a	= the aspect ratio factor for the specimen (Paragraph C7.2 and Table C1, Appendix C)
k_b	= the concentrated bearing factor (Clause 7.3.5.4)
k_c	= a strength factor for grout in compression (Clauses 7.3.2 and 8.5)
k_{es}	= a reduction factor to account for the eccentricity in loading and slenderness of the member in the design of the reinforced masonry walls and columns (Clause 8.5)
k_h	= a factor reflecting the influence of the ratio of the masonry unit height to mortar bed joint thickness, used in assessing characteristic compressive strength for masonry other than special masonry (Table 3.2)
k_k	= a characteristic value factor used to assess a characteristic strength value of a population from a set of representative test results (Paragraph B2 and Table B1, Appendix B)

k_m	= a factor used to derive the characteristic compressive strength of masonry, reflecting the influence of masonry unit type and bedding type (see Clause 3.3.2 and Table 3.1)
k_p	= the perpend spacing factor (Clause 7.4.3.4)
k_s	= a reduction factor used in assessing the capacity of reinforced members in compression (Clause 8.5)
k_{sp}	= masonry pier strength factor (Paragraph D7.2, Appendix D)
k_{sw}	= a reduction factor used in assessing the design overturning capacity of a wall (Clause 8.7.4)
k_t	= a thickness coefficient (Clauses 7.3.3.4, 7.3.4.3 and Table 7.2)
k_u	= the neutral axis parameter, being the ratio, at ultimate strength under any combination of bending and compression of the depth to the neutral axis from the extreme compressive fibre, to d (Clauses 8.3 and 9.2.2)
k_v	= a shear factor (Clause 3.3.5 and Table 3.3)
L	= the clear length of a wall between vertical lateral supports (Clause 7.4.4.4); or = for a wall without a vertical support at one end or at a control joint, the length to that unsupported end or control joint (Clause 7.4.4.4) = the clear length of the wall or pier (Clause 7.3.5.4) = the length of the member in the direction of the shear load (Clause 8.7.4)
L_d	= the design length (Clause 7.4.4.2)
L_e	= the effective dispersion length of the load (Figure 7.3)
L_{es}	= the percentage loss of prestress due to masonry creep and moisture movement (Clause 9.3.3.2)
L_o	= the length of opening (Clause 7.4.4.2)
$\ln$	= the natural logarithm (Clause 6.3.3)
l	= the distance between the anchorages at the ends of the member (Clause 9.5.2)
l'	= the distance from the centroid of the reinforcement under consideration to the tensile end of the member (Clause 8.7.4)
l_u	= the length of masonry unit (Clause 7.4.4.2)
M_{cd}	= the diagonal bending moment capacity per unit length of diagonal crack line (Clause 7.4.4.3)
M_{ch}	= the horizontal bending moment capacity of a wall (Clause 7.4.3.2)
M_{cr}	= the ultimate cracking bending moment (Clause 9.5.4)
M_{cv}	= the vertical bending moment capacity of a member (Clause 7.4.2)
M_d	= the design bending moment acting on the cross-section of a member, assessed from loads complying with Clause 2.6 for strength (Clauses 8.6 and 9.5.1)

M_{dh}	= the design horizontal bending moment resulting from transient out of plane forces acting on a wall in horizontal-spanning action (Clause 7.4.3.2)
M_{dp}	= the bending moment capacity of masonry wall (Clause 9.5.1)
M_{dv}	= the design vertical bending moment resulting from transient out-of-plane forces acting on a member in vertical spanning action (see Clause 7.4.2)
M_{sp}	= the bending moment about the centroid of the bedded area of the test joint at failure in a masonry test specimen (Paragraphs D6.6 and D7.2, Appendix D)
M1, M2, M3, M4	= the classification of mortar types (Clause 11.4 and Table 11.1)
m_1, m_2, m_3	= the masses of components used in flexural strength testing (Paragraphs D6.6, Appendix D)
n	= the number of test results under consideration (Paragraph B2, Appendix B)
P	= the effective prestressing force (after losses) (Clause 9.5.4)
P_v	= the applied uniform vertical load (Clause 8.7.4)
R1, R2, R3, R4, R5	= classification of corrosion resistance ratings (Table 5.1)
R_{f1}, R_{f2}	= restraint factors (Clause 7.4.4.2)
r	= the width of the connector (Clause 7.5.6)
r_h	= the proportion of the vertical shear plane that is intersected by masonry header units (Clause 3.3.4)
S_p	= structural performance factor for earthquake design (Clause 10.2.2)
S_r	= the slenderness ratio of a member (Clause 7.3.4.3)
S_{rf}	= the slenderness ratio of a member, used in design for fire resistance for structural adequacy (Clause 6.3.2.2)
S_{rs}	= the simplified slenderness ratio of a member (Clause 7.3.3.3)
s	= the spacing of shear reinforcement along the member (Clause 8.8)
s_p	= the minimum overlap of masonry units in successive courses (Clause 7.4.3.4)
t	= the overall thickness of a masonry member cross-section perpendicular to the principal axis under consideration (Clauses 6.3.2.2, 7.3.3.4, 7.3.4.3)
t_b	= the bedded thickness of a member (Clause 4.5.1)
t_c	= the period to failure in relation to insulation (Clause 6.5.4)
t_f	= the period to failure in relation to structural adequacy (Clause 6.3.3)
t_{fs}	= the thickness of the face shell for hollow block masonry or the flange thickness for diaphragm walls [Clause 7.3.4.5(b)]
t_j	= the mortar joint thickness (Clause 7.4.4.2)
t_m	= the material thickness of member (Clause 6.5.4)
t_r	= the minimum thickness of the pier (Clause 4.6.3)

t_s	= the thickness of face shell of a hollow masonry unit at the thinnest point (Clause 7.4.4.3)
t_u	= the width of masonry unit (measured through the wall) (Clauses 7.4.3.4, 7.4.4.3 and Paragraph D6.6, Appendix D)
t_w	= the overall thickness of a wall or isolated pier (Clause 7.3.4.5)
t_{wp}	= the overall thickness of a masonry wall plus an engaged pier or buttress (Table 7.2)
u	= the thickness of the connector (Clause 7.5.6)
V	= the coefficient of variation in a set of specimen test results (Paragraph B3, Appendix B)
V_c	= the design shear strength of a shear connector (Clause 7.5.6)
V_d	= the design shear force acting on the cross-section of a member, assessed from loads complying with Clause 2.6 for strength (Clauses 7.5.4 and 8.7.2)
V_o	= the shear bond strength of an unreinforced masonry cross-section (Clause 7.5.4)
V_{sc}	= the characteristic shear strength of a connector (determined by tests) [Clause 7.5.6(b)]
V_l	= the shear friction strength of the section (Clause 7.5.4)
w_d	= the total design wind, earthquake or similar pressure acting on a wall (Clauses 7.4.4.2 and 7.4.4.4)
X_1, X_i, X_n	= a group of test results in the assessment of strength values where n is the number of test results (Paragraph A3.2, Appendix A)
X_i	= the i th result from a group of test results (Paragraph A3.2, Appendix A)
X_m	= the mean of a group of test results (Paragraph A4, Appendix A)
X_1, X_i, X_j	= the group of test results in the assessment of strength values following the exclusion of suspect values from the set of results (Paragraph A3.2, Appendix A)
x	= the depth of compression zone (Clause 9.5.1)
Y_i	= the natural logarithm of the remaining test results (Paragraph A3.2, Appendix A)
Y_m	= the mean of the logarithms (Paragraph A3.2, Appendix A)
Y_s	= the standard deviation of the logarithms (Paragraph A3.2, Appendix A)
Y_u	= the upper rejection limit in the assessment of strength values from test results (Paragraph A3.2, Appendix A)
Y_l	= the lower rejection limit in the assessment of strength values from test results (Paragraph A3.2, Appendix A)
Z	= the section modulus of the uncracked section, referred to the extreme fibre at which cracking occurs (Clause 9.5.4) = hazard factor as per AS 1170.4 (Table 10.3)

Z_d	= the section modulus of the design cross-sectional area, A_d , of a member (Clause 4.5.8 and Paragraph D6.6, D7.2, Appendix D) = for plain masonry, the section modulus of the bedded area (Clauses 7.4.2 and 7.4.3.2)
Z_p	= the lateral section modulus based on mortar contact area of the perpend joints (Clause 7.4.3.2)
Z_t	= the equivalent torsional section modulus measured normal to the diagonal crack line (Clause 7.4.4.3)
Z_u	= the lateral section modulus of the masonry units (Clause 7.4.3.2)
α	= a slope factor (Clause 7.4.4.2 and Table 7.5)
ε_s	= the free moisture shrinkage strain one year after prestressing (Clause 9.3.3.2)
ϕ	= the capacity reduction factor for design strength of unreinforced, reinforced, prestressed masonry, wall ties and accessories (Clauses 4.4 and 7.4.3.2, and Table 4.1)
σ_{pu}	= the tensile stress in the tendons at the ultimate strength limit state (Clause 9.5.2)
μ	= structural ductility factor for earthquake design (Clause 10.2.2)

1.7 EXISTING STRUCTURES

Where the strength or serviceability of an existing structure is to be evaluated, the general principles of this Standard may be used; however, the design values given in Section 3 for the properties of the materials may not be applicable.

Appendix B sets out a method for determining characteristic values of properties from test results.

SECTION 2 REQUIREMENTS FOR DESIGN

2.1 SCOPE OF SECTION

This Section sets out general requirements for the design of masonry. Particular requirements for the structural design of unreinforced masonry are set out in Section 7, for reinforced masonry in Section 8 and for prestressed masonry in Section 9.

2.2 AIM

The aim of design is to provide a structure that is durable, fire resistant and serviceable, and has adequate strength and stability while serving its intended function and satisfying other relevant requirements such as resistance to water penetration, robustness, ease of construction and economy.

2.3 GENERAL REQUIREMENTS

2.3.1 Durability

A masonry member or structure shall withstand the expected wear and deterioration throughout its design life, taking into account the exposure environment and importance of the structure, without the need for undue maintenance.

2.3.2 Fire resistance

A masonry member or structure shall have fire resistance so that the member can perform its structural function for the required period and, if necessary, prevent the spread of fire.

2.3.3 Serviceability

A masonry member or structure shall remain serviceable and fit for the purpose for which it was constructed, throughout its design life.

2.3.4 Strength

A masonry member or structure shall have the capacity to resist the design loads.

2.3.5 Stability

A masonry member or structure shall be designed to be stable throughout its design life.

2.4 DESIGN REQUIREMENTS

2.4.1 Design for durability

A masonry member or structure designed for durability in accordance with Section 5 is deemed to meet the requirements of Clause 2.3.1.

2.4.2 Design for fire resistance

A masonry member or structure designed for fire resistance in accordance with Section 6 is deemed to meet the requirements of Clause 2.3.2.

2.4.3 Design for serviceability

A masonry member or structure designed for serviceability as set out in Clauses 2.5.1 and 2.5.2 is deemed to meet the requirements of Clause 2.3.3.

2.4.4 Design for strength

A masonry member or structure designed for strength as set out in Clauses 2.5.1 and 2.5.3 is deemed to meet the requirements of Clause 2.3.4.

2.4.5 Design for stability

A masonry member or structure designed for stability as set out in Clauses 2.5.1 and 2.5.4 is deemed to meet the requirements of Clause 2.3.5.

2.4.6 Design for earthquakes

A masonry member or structure required to be designed for earthquakes shall be considered as one of the following:

- (a) Part of the seismic force-resisting system and designed accordingly.
- (b) Separated from all structural elements such that no interaction takes place as the structure undergoes deflections, determined in accordance with this Standard, to arise from the earthquake effects.

All masonry members or structures, including those deliberately designed to be independent of the seismic force-resisting system, shall be capable of performing their required function while sustaining the deformation of the structure resulting from the application of the earthquake forces determined for each limit state.

NOTES:

- 1 For multistorey structures where unreinforced masonry is part of the seismic force-resisting system, particular attention should be given to the effects of structural deformations and different material stiffnesses when designing the masonry (see AS 1170.4).
- 2 Where the masonry does not form part of the seismic force-resisting system, an adequate independent force-resisting system should be provided.

2.4.7 Design for other requirements

A masonry member or structure designed for other requirements as set out in Clause 2.8, in accordance with Section 4 and Section 7, 8, 9 or 10, is deemed to meet the requirements of this Standard.

2.5 SERVICEABILITY, STRENGTH AND STABILITY

2.5.1 General

Calculations related to serviceability, strength and stability shall—

- (a) be in accordance with the principles of mechanics;
- (b) provide for all loads and forces to be transferred through the structure to the foundation;
- (c) provide for compatibility between each masonry member and the structural members giving vertical and, where required, lateral support to that masonry member;
- (d) be based on the material properties of the masonry in accordance with Section 3; and
- (e) be consistent with the assumptions that—
 - (i) plane sections remain plane under bending actions;
 - (ii) there is a recognized stress-strain relationship for masonry; and
 - (iii) the tensile strength of unreinforced masonry is taken as zero except for stresses resulting from wind, earthquake and similar forces of a short-term, transient nature.

2.5.2 Design for serviceability

A masonry member or structure shall be designed to allow movements to be controlled or isolated so that damage to the masonry, the building and its components is avoided and structural and other requirements are satisfied.

The movements to be allowed for shall include the following:

- (a) The expansion characteristics of clay masonry and the shrinkage characteristics of concrete masonry, calcium silicate masonry and AAC masonry.
- (b) Thermal movements.
- (c) Deflections, shortening, shrinkage, creep and similar deformations in adjacent or associated materials.
- (d) Foundation movements.
- (e) Deformation due to construction loads or construction sequences.

A masonry member or structure shall be designed for serviceability by controlling or limiting deflections and cracking arising from the actions specified in Clause 2.6 and by providing member robustness as specified in Clause 4.6.

Cracks in finished masonry shall not exceed 1 mm in width.

NOTE: More stringent requirements may be necessary to satisfy aesthetic consideration.

2.5.3 Design for strength

A masonry member or structure shall be designed for strength as follows:

- (a) The loads and other actions shall be as specified in Clause 2.6.
- (b) The design strength shall be determined in accordance with the requirements of Sections 4, 7, 8, 9 and 10 as required.
- (c) The member shall be proportioned so that its design strength is not less than the design action effect.

2.5.4 Design for stability

The structure as a whole and its parts shall be designed to prevent instability due to overturning, uplift and sliding under the loads and other actions specified in Clause 2.6.

The stability shall be checked for each stage during erection, up to completion. Special care shall be taken in design and construction to guard against progressive collapse during construction.

2.6 LOADS AND LOAD COMBINATIONS

2.6.1 Loads, and other forces and actions

2.6.1.1 *Dead, live, wind, snow and earthquake loads*

The dead loads, live loads, wind loads, snow loads and earthquake loads used in structural design shall be those specified in AS/NZS 1170.0, AS/NZS 1170.1, AS/NZS 1170.2, AS/NZS 1170.3, AS 1170.4 and AS 4055. For earthquake actions, the additional requirements of Section 10 shall apply.

2.6.1.2 *Other forces and actions*

Account shall be taken of other forces and actions that could affect the stability, strength and serviceability of the structure and its component members, including the following:

- (a) Earth pressure, with or without groundwater pressure.
- (b) Liquid pressure.
- (c) Construction loads and procedures.
- (d) Foundation movements.
- (e) Shrinkage or expansion effects.

- (f) Axial shortening effects.
- (g) Creep effects.
- (h) Temperature effects.
- (i) Interactions with other materials and members or between different masonry materials.
- (j) Design of masonry members of bridges for loads resulting from floods or collision, which shall be carried out in accordance with the AS 5100 series.

2.6.2 Design load combinations

Structures, as a whole, and component members shall be designed to resist each compatible simultaneous combination of applied forces acting on them, including each of the load-factored combinations for factored loads given in AS/NZS 1170.0 and AS 1170.4.

2.6.3 Design loads for lateral supporting members

The horizontal design load acting on a structural member or system providing lateral support to a masonry member (see Clause 2.7) shall be the greater of the following:

- (a) The sum of the simple static reactions to the applied horizontal forces for the appropriate load combination and 2.5% of the vertical load that the masonry member is designed to carry.
- (b) 0.5 kPa acting on the tributary area.

Design loads specified in this Clause are deemed to meet each of the limit states and do not require additional factoring.

2.6.4 Design loads for connections to lateral supports

The horizontal design load acting on a connection providing lateral support to a masonry member shall be the value derived from Clause 2.6.3 increased by a factor of 1.25.

2.7 LATERAL SUPPORT

A structural member or system is deemed to provide adequate lateral support to a masonry member provided it can resist the loads specified in Clause 2.6.3 without failure and satisfies the following requirements:

- (a) The maximum deflection at the point of support shall not exceed span/500 for unreinforced masonry, under the loads specified in Clause 2.6.3.
- (b) The maximum deflection at the point of support shall not exceed span/250 for reinforced masonry, under the loads specified in Clause 2.6.3 unless specified otherwise for architectural purposes.

NOTE: Steel mullions built into masonry panels are not required to satisfy these limits but should be designed appropriately for serviceability and ultimate conditions considering their interaction with the masonry.

2.8 OTHER DESIGN REQUIREMENTS

2.8.1 General

Requirements such as resistance to water penetration, fatigue, progressive collapse and any special performance requirements shall be taken into account in the design of the structure.

2.8.2 Design for water penetration

When moisture penetration is to be prevented, a masonry member or structure shall be designed, constructed and protected against moisture ingress in accordance with Clause 4.7.

2.8.3 Design for accidental damage

The structure and its component members shall be designed to take into account the possibility of abnormal load conditions and to restrict, to a reasonable level, the adverse consequences, including progressive collapse that could result from failure caused by such load conditions.

2.8.4 Masonry under construction

Account shall be taken of the lower stability, stiffness and strength of newly constructed masonry.

NOTE: See also Section 12, particularly the requirements of Clause 12.9.1 for temporary bracing.

SECTION 3 DESIGN PROPERTIES

3.1 SCOPE OF SECTION

This Section specifies design properties for masonry and its component materials, connectors, reinforcement and prestressing tendons.

NOTE: Requirements for materials are given in Section 11.

3.2 MASONRY UNITS

The work size width, height, length and face shell width (for units that are to be face-shell-bedded) used in the design shall be specified. When used, the design characteristic unconfined compressive strength (f'_{uc}) and the design characteristic lateral modulus of rupture (f'_{ut}) shall also be specified.

NOTE: See AS 4456.15 for more information on the lateral modulus of rupture.

In the absence of test data, the design characteristic lateral modulus of rupture (f'_{ut}) shall not exceed 0.8 MPa.

3.3 MASONRY

3.3.1 General

Where the values of characteristic strengths used in structural design are to be based on the results of tests, including, in the case of special masonry, the values of f'_m or f'_{mt} , the results shall be from tests on specimens made from materials having the same properties and strength characteristics as those to be used in the actual construction.

Masonry constructed from square-dressed natural stone shall be designed as special masonry.

3.3.2 Compressive strength

The characteristic compressive strength of masonry (f'_m) shall be as follows:

- (a) For masonry other than special masonry, one of the following:
 - (i) For masonry constructed with clay, concrete or calcium silicate units, the design characteristic compressive strength shall be taken as $f'_m = k_h f'_{mb}$

where

$$f'_{mb} = k_m \sqrt{f'_{uc}}$$

The values of f'_{mb} in Table 3.1 are deemed to conform to this formula.

k_m = compressive strength factor (see Table 3.1)

k_h = joint thickness factor = $1.3 (h_u/19t_j)^{0.29}$ but to not exceed 1.3

Table 3.2 is deemed to conform to this expression.

f'_{uc} = characteristic unconfined compressive strength of masonry units in megapascals

- (ii) For AAC masonry with thin-bed mortar, the design characteristic compressive strength shall be taken as $f'_m = f'_{uc}$.

For concrete and AAC units, f'_{uc} shall be the 28 day strength. If tested at another age, a correction shall be made to obtain the 28 day strength.

- (b) For special masonry, the design characteristic compressive strength shall be taken as a value determined in accordance with Appendix B from tests carried out in accordance with Appendix C.

TABLE 3.1
CHARACTERISTIC COMPRESSIVE STRENGTH OF MASONRY (f'_{mb})

Type of masonry unit	Bedding type	Mortar class (see Note 2)	Characteristic unconfined compressive strength of unit (f'_{uc}) MPa								Compressive strength factor (k_m)
			5	10	15	20	25	30	40	≥50	
Clay	Full	M2	2.5	3.5	4.3	4.9	5.5	6.0	7.0	7.8	1.1
Clay	Full	M3	3.1	4.4	5.4	6.3	7.0	7.7	8.8	9.9	1.4
Clay	Full	M4	4.5	6.3	7.7	8.9	10.0	10.9	12.7	14.1	2.0
Clay	Face shell	M3	3.6	5.1	6.2	7.2	8.0	8.8	10.1	11.3	1.6
Concrete	Full	M3	3.1	4.4	5.4	6.3	7.0	7.7	8.8	9.9	1.4
Concrete	Face shell	M3	3.6	5.1	6.2	7.2	8.0	8.8	10.1	11.3	1.6
Calcium silicate	Full	M3	3.1	4.4	5.4	6.3	7.0	7.7	8.8	9.9	1.4
Calcium silicate	Full	M4	4.5	6.3	7.7	8.9	10.0	10.9	12.7	14.1	2.0

NOTES:

- 1 Linear interpolation may be used.
- 2 Mortar classification is given in Table 11.1.

TABLE 3.2
JOINT THICKNESS FACTOR (k_h)

Ratio of masonry unit height to mortar bed joint thickness	0.0	3.3	7.6	9.0	11.9	16.2	19.0
Joint thickness factor (k_h)	0.00	0.78	1.00	1.05	1.14	1.24	1.30

3.3.3 Flexural tensile strength

The characteristic flexural tensile strength (f'_{mt}) for unreinforced, reinforced and prestressed masonry shall be as follows:

- (a) Under actions resulting from wind, earthquake loads or similar forces of a short-term, transient nature, and where any simultaneous force due to vertical loads (F_d) is not a negative value (that is, not a net tension force):
- (i) At mortar joints:
 - (A) For clay, concrete and calcium silicate masonry (except special masonry), a value not greater than 0.20 MPa.
 - (B) For AAC masonry with thin-bed joints (except special masonry), a value not greater than 0.26 MPa.

- (C) For special masonry, a value obtained from tests in accordance with Appendix D but not greater than 1 MPa.
- (ii) At interfaces with other materials:
 - (A) Where results of tests in accordance with Appendix D are available, the design characteristic flexural tensile strength shall be taken as a value derived from those tests.
 - (B) In other cases, the design characteristic flexural tensile strength shall be taken as zero.

Live loads shall not be considered to be of a short-term transient nature.

- (b) In all other loading cases, the design characteristic flexural tensile strength shall be taken as zero.

3.3.4 Shear strength

The design characteristic shear strength (f'_{ms}) shall be as follows:

- (a) For shear in the horizontal direction in continuous horizontal mortar joints:
 - (i) For masonry constructed with clay, concrete or calcium silicate units, the design characteristic shear strength (f'_{ms}) shall be taken as $1.25 f'_{mt}$ but not greater than 0.35 MPa, nor less than 0.15 MPa.
 - (ii) For AAC masonry with thin-bed mortar, the design characteristic shear strength (f'_{ms}) shall be taken as $0.67 f'_{ut}$.
- (b) For shear in the vertical direction:
 - (i) Where neither connectors nor masonry header units cross the shear plane, the design characteristic shear strength (f'_{ms}) shall be taken as zero.
 - (ii) Where connectors in accordance with Clause 4.11 intersect the shear plane, the design characteristic shear strength (f'_{ms}) shall be taken as—
 - (A) for mortar joints— $1.25 f'_{mt}$ or 0.35 MPa, whichever is less; or
 - (B) for thin-bed mortar joints—zero.
 - (iii) For masonry in ordinary running bond, or if there are masonry header units in accordance with Clause 4.11 intersecting the shear plane, the design characteristic shear strength (f'_{ms}) shall be taken as—
 - (A) for masonry constructed with clay, concrete or calcium silicate units, $1.2r_h$ MPa; or
 - (B) for masonry built with AAC units, $0.6r_h$ MPa
 where

$$r_h = \text{proportion of the vertical shear plane that is intersected by masonry header units}$$
- (c) At a joint or interface confined by bonded reinforcement normal to the shear plane, the design characteristic shear strength shall be taken as 0.35 MPa.
- (d) At membrane-type damp-proof courses (DPCs), flashings, and at the interface with materials other than covered by Clause 3.3.4(c), the design characteristic shear strength shall be taken as zero, or a value based on the results of tests in accordance with Clause 3.3.1.

3.3.5 Shear factor

The shear factor (k_v) for calculating the frictional component of shear capacity in accordance with Clause 7.5.4 shall be as given in Table 3.3.

TABLE 3.3
SHEAR FACTOR (k_v)

Type of masonry	Location	k_v
Clay, concrete or calcium silicate	At mortar bed joints	0.3
AAC	At thin-bed mortar joints	0.12
All	At membrane-type DPCs, flashings and similar locations where the membrane is in contact with the unit, or concrete or within the mortar and the DPC membrane consists of—	
	(a) bitumen-coated aluminium or embossed polyethylene	0.3
	(b) Polyethylene and bitumen-coated aluminium	0.15
	At interfaces of masonry with concrete	0.3
	At interfaces of masonry with steel	0.2
	At slip joints comprising two layers of membrane-type DPC material	0.1
	At other locations	zero

3.3.6 Elastic properties of masonry

Where masonry is assumed to have linear elastic properties and in the absence of test results, design values for elastic moduli shall be as given in Table 3.4.

TABLE 3.4
ELASTIC MODULI FOR MASONRY

Masonry unit type	Mortar class	Short-term loading E_m	Long-term loading E_L
Clay units with f'_{uc} in the range 5 to 30 MPa	M2 and M3	$700 f'_m$	$450 f'_m$
Clay units with $f'_{uc} > 30$ MPa	M3 and M4	$1000 f'_m$	$660 f'_m$
Concrete units with density ≥ 1800 kg/m ³ and calcium silicate units	M3 and M4	$1000 f'_m$	$500 f'_m$
Concrete units with density < 1800 kg/m ³	M2 and M3	$750 f'_m$	$500 f'_m$
Grouted concrete or clay masonry	Any	$1000 f'_c$	$350 f'_c$
AAC	Thin bed	$500 f'_m$	$250 f'_m$

NOTES:

- The above values are suitable for use with uncracked reinforced masonry section properties. For cracked reinforced masonry section properties, other values may be assumed based on reinforced concrete principles.
- Mortar classification is given in Table 11.1.

3.4 TIES AND ACCESSORIES

The type and duty rating of wall ties shall be specified. Where they are designed to connect structural elements, the design strength and stiffness of accessories shall also be specified.

The mean tie strength (F_t) of Type A veneer wall ties shall be not less than the values given in Table 3.5. The design strength of Type A cavity wall ties shall be not less than the values given in Table 3.6.

TABLE 3.5
STRENGTH OF TYPE A VENEER TIES

Tie duty rating	Mean tie strength (F_t) kN	
	Tension	Compression
Light duty	0.30	0.36
Medium duty	0.60	0.72
Heavy duty	1.5	1.8

NOTE: The values in the Table represent mean values determined from a tie test in accordance with AS/NZS 2699.1.

TABLE 3.6
STRENGTH OF TYPE A CAVITY TIES

Tie duty rating	Mean tie strength (F_t) kN	
	Tension	Compression
Light duty	0.30	0.36
Medium duty	0.60	0.72
Heavy duty	1.5	1.8

NOTE: The values in the Table represent mean values determined from a tie test in accordance with AS/NZS 2699.1.

3.5 GROUT

The design characteristic compressive strength of grout (f'_{cg}) shall be taken as the characteristic cylinder strength of grout at 28 days (f'_c) measured in accordance with the requirements for concrete in AS 3600, but not less than 12 MPa.

3.6 REINFORCEMENT

3.6.1 Strength

The design yield strength of reinforcement (f_{sy}) shall be in accordance with Table 3.7.

TABLE 3.7
STRENGTH AND DUCTILITY OF REINFORCEMENT

Reinforcement		Design yield strength (f_{sy}) MPa	Ductility class
Type	Designation grade		
Bar plain to AS/NZS 4671	R250N	250	Normal
Bar deformed to AS/NZS 4671	D500L (fitments only)	500	Low
	D500N	500	Normal
Welded mesh, plain, deformed and indented to AS/NZS 4671	D500L	500	Low
	D500N	500	Normal
Stainless steel plain bar to EN 10088-5 (see Notes 2 and 3)	250	250	Normal
Stainless steel ribbed bar to BS 6744 (see Notes 2 and 3)	500	650	Normal

NOTES:

- 1 Reference should be made to AS/NZS 4671 for explanation of designations.
- 2 Stainless steel bar with physical and mechanical properties shown above and otherwise in accordance with BS 6744 or EN 10088-5 and the chemical composition conforming to one of designations 1.4311, 1.4162, 1.4362, 1.4462, 1.4404 or 1.4429 to EN 10088-1.
- 3 Stainless steel bar to BS 6744 and EN 10088-5 are deemed to meet the requirements for Ductility Class N reinforcement as in AS/NZS 4671.

3.6.2 Modulus of elasticity

The modulus of elasticity of reinforcement (E_s), for all stress values not greater than the design yield strength of reinforcement (f_{sy}), shall be either—

- (a) taken as equal to 200×10^3 MPa; or
- (b) determined by test.

3.6.3 Stress-strain curves

The stress-strain curve for reinforcement shall be either—

- (a) assumed to be of a form defined by recognized simplified equations; or
- (b) determined from suitable test data.

3.7 TENDONS

3.7.1 Strength

The strength of prestressing tendons shall be as follows:

- (a) The tensile strength of prestressing tendons (f_p) shall be taken as the minimum tensile strength specified in Table 3.8.
- (b) The yield strength of prestressing tendons (f_{py}) shall be taken as—
 - (i) for wire used in the as-drawn condition $0.75f_p$;
 - (ii) for stress-relieved wire $0.85f_p$; and
 - (iii) for all grades of strand and bar tendons $0.85f_p$.

3.7.2 Modulus of elasticity

The modulus of elasticity of prestressing tendons (E_p), shall be either—

- (a) taken as—
- (i) for stress-relieved wire to AS/NZS 4672.1 200×10^3 MPa;
 - (ii) for stress-relieved steel strand to AS/NZS 4672.1 195×10^3 MPa; and
 - (iii) for cold-worked high tensile alloy steel bars to AS/NZS 4672.1 170×10^3 MPa;

or

- (b) determined by test.

3.7.3 Stress-strain curves

The stress-strain curve for prestressing tendons shall be determined from testing in accordance with AS 1391.

3.7.4 Other properties

Where other properties of prestressing tendons are required, reference shall be made to AS 3600.

TABLE 3.8
TENSILE STRENGTH OF PRESTRESSING TENDONS (f_p)

Material type and Standard	Nominal diameter mm	Area mm ²	Minimum breaking load kN	Minimum tensile strength MPa
Wire, AS/NZS 4672.1	5	19.6	30.4	1550
	5	19.6	33.3	1700
	7	38.5	65.5	1700
7-wire super strand, AS/NZS 4672.1	9.3	54.7	102	1860
	12.7	100	184	1840
	15.2	143	250	1750
7-wire regular strand, AS/NZS 4672.1	12.7	94.3	165	1750
Bars, AS/NZS 4672.1 (Super grade only)	23	415	450	1080
	295	660	710	1080
	32	804	870	1080
	38	1140	1230	1080

SECTION 4 GENERAL DESIGN ASPECTS

4.1 SCOPE OF SECTION

This Section sets out requirements for the general design aspects of masonry members and structures, including prevention of moisture penetration, joints, bonding and tying, connections, arches and lintels, sills and corbelling. It also provides capacity reduction factors and cross-sectional dimensions and properties required for design.

4.2 MEMBERS OF MIXED CONSTRUCTION

Members of mixed construction shall comply with one of the following:

- (a) A member constructed of more than one type of masonry unit or mortar shall be designed assuming the least favourable combination of unit and mortar type when determining properties for strength and durability.
- (b) A member composed of more than one type of masonry system (e.g. unreinforced and reinforced) shall be designed for composite action between the systems.

In each case, account shall be taken of the different material properties of the parts and the potential for differential movement.

4.3 CHASES, HOLES AND RECESSES

The effect of any chases, holes and recesses required in the masonry shall be taken into account in the design to ensure that the masonry achieves the required performance, including structural, moisture-resistance, fire-resistance, insulation and other properties required of the masonry.

NOTES:

- 1 The need for chases, holes and recesses to masonry should be minimized.
- 2 See also Clause 4.5.9.

4.4 CAPACITY REDUCTION FACTORS

The value of the capacity reduction factor (ϕ) used to evaluate the strength capacity of a member shall be taken from Table 4.1.

TABLE 4.1
CAPACITY REDUCTION FACTORS

Type of masonry or accessory and action effect	Capacity reduction factor (ϕ)
(a) Unreinforced masonry:	
(i) Compression	
(A) Solid or cored	0.75
(B) Hollow	0.50
(C) Grouted	0.60
(ii) Flexure	0.60
(iii) Shear	0.60
(iv) Other actions	0.60
(b) Reinforced and prestressed masonry	0.75
(c) Wall ties, connectors and accessories:	
(i) Wall ties in tension or compression	0.95
(ii) Connectors across a joint in masonry	0.75
(iii) Accessories and other actions	0.75

4.5 CROSS-SECTION PROPERTIES

4.5.1 Bedded thickness

The bedded thickness (t_b) of a masonry member for design shall be taken as follows:

- (a) If the mortar bed joints are finished flush or are tooled to a depth not exceeding 3 mm, t_b shall be equal to the overall thickness of the masonry member.
- (b) If the mortar bed joints are raked, t_b shall be equal to the overall thickness of the masonry, less the depth of raking.

NOTES:

- 1 The dimensions used to determine bedded thickness are based on the work size dimensions of the masonry units.
- 2 The effects of occasional deep raking, such as that required for overflashing set into mortar joints, should also be considered in the structural design.

4.5.2 Effective width of compression faces and flanges

Provided the outstanding portions of the face or flange are built to act in monolithic structural action with the diaphragm or web, the effective width (b) of each outstanding portion of the compression face or flange of an I, T, L or similar cross-sectional form shall be assumed to extend beyond the face of the connecting diaphragm or web portion by an amount not exceeding the least of—

- (a) six times the thickness of the compression face or flange;
- (b) half the clear distance to the next adjacent diaphragm or web;
- (c) the distance to the structural end of the masonry in the outstanding face or flange;
- (d) in a member spanning between lateral supports, 0.10 times the span distance between those supports; or
- (e) in a shear wall with returns, acting as a cantilever—
 - (i) where the outstands project from both sides of the web portion of the wall, 0.08 times the total height of the wall above the level being analysed; or

- (ii) where the outstand projects from only one side of the web portion of the wall, 0.06 times the total height of the wall above the level being analysed.

The effects of any holes or openings in the flange on the effective flange width shall be taken into account.

NOTE: Clause 8.6 provides criteria for the design width of the compression face for hollow unit reinforced masonry walls in bending.

4.5.3 Structural end of a masonry member

The structural end of a masonry member shall be the vertical cross-section in the member across which vertical shear cannot be transferred, and shall include—

- (a) the actual end or face of the member;
- (b) a control joint in the member; and
- (c) a vertical mortar joint in the masonry (other than perpend joints in normal running bond), unless that joint is intersected by masonry bonding or tying complying with Clause 4.11 or is otherwise constructed to give the required monolithic structural action.

4.5.4 Bedded area

The bedded area of a masonry member cross-section (A_b) shall be as follows:

- (a) For solid, cored and horizontally cored unit masonry, the bedded area of the mortar based on the bedded thickness in accordance with Clause 4.5.1.
- (b) For hollow unit masonry, the bedded area of the mortar based on the face shell width and not including the area of webs in the units.

4.5.5 Combined cross-sectional area

The combined cross-sectional area of a grouted or reinforced masonry member (A_c) shall be as follows:

- (a) For a fully grouted member, the product of the overall width less the depth of raking (if any), and the length.
- (b) For a partially grouted member, the product of the overall width less the depth of raking (if any), and the portion of the length represented by the grouted cores, plus the bedded area of the portion of the length represented by the ungrouted cores.

4.5.6 Design cross-sectional area

The design cross-sectional area of a member (A_d) shall be as follows:

- (a) For unreinforced and ungrouted masonry, the bedded area (A_b) in accordance with Clause 4.5.4.
- (b) For grouted or reinforced masonry, the combined cross-sectional (A_c) area in accordance with Clause 4.5.5.

4.5.7 Grout area

The design cross-sectional area of grout in a grouted or reinforced member (A_g) shall be as follows:

$$A_g = A_d - A_b \quad \dots 4.5.7$$

where

A_d = design cross-sectional area of a masonry member in accordance with Clause 4.5.6

A_b = bedded area of a masonry cross-section or member in accordance with Clause 4.5.4

4.5.8 Section modulus and second moment of area

The section modulus of a cross-section shall be derived from the dimensions of the design cross-sectional area at the nearest mortar joint.

In ungrouted hollow unit masonry, the contributions of the webs of the units may be taken into account for determining the stiffness and deflection of masonry members.

4.5.9 Chases, holes and recesses

The design properties of the member shall take into account any chases, holes and recesses in the member.

NOTE: See also Clause 4.3.

4.6 DESIGN FOR ROBUSTNESS

4.6.1 General

Masonry members and their connections shall have an adequate degree of robustness. This requirement shall be deemed to be met provided the members are proportioned in accordance with Clause 4.6.2 or Clause 4.6.3.

This requirement is in addition to other design requirements, including structural design in accordance with Sections 7, 8 or 9.

4.6.2 Robustness of walls

Walls shall be proportioned to resist an ultimate uniformly distributed out-of-plane load of 0.5 kPa in accordance with Clauses 7.4, 8.6 or 9.5. No load factor is required to be applied to this load.

A control joint in a wall, or an edge to an opening in a wall, shall be regarded as an unsupported edge to that wall unless specific measures are taken to provide adequate lateral support at that edge (see Clause 2.7).

The robustness of walls of geometric section may be checked by determining an equivalent thickness of a rectangular section from first principles and applying the provisions of this Clause.

In the case of loadbearing members, vertical loads applied to the top of the member shall be ignored when determining its robustness.

4.6.3 Robustness of isolated reinforced and unreinforced masonry piers

Isolated piers shall be proportioned such that—

$$\frac{H}{t_r} \leq C_v \quad \dots 4.6.3$$

where

H = the clear height of the pier between horizontal lateral supports, in metres

t_r = the minimum thickness of the pier, in metres

C_v = robustness coefficient—

(a) for isolated piers unreinforced vertically, 13.5; and

(b) for isolated piers reinforced vertically or prestressed, 30.

NOTE: Reinforced vertically means complying with the reinforcement requirements of Clause 8.6, and prestressed means complying with the prestressing requirements of Clause 9.5, for bending in the vertical direction.

The robustness of isolated piers of geometric section may be checked by determining an equivalent thickness of a rectangular section from first principles and applying the provisions of this Clause.

4.7 PREVENTION OF MOISTURE PENETRATION

4.7.1 Cavities

In cavity walls and masonry veneer walls, cavities with a width of at least 40 mm, which are properly detailed and constructed, shall be regarded as being resistant to the passage of moisture from the exposed face through to the inner, unexposed face of the wall.

Where insulating material is placed in a cavity, the moisture resistance of the wall shall be maintained.

4.7.2 Weepholes

Weepholes shall be provided to drain moisture from or through masonry construction. Where flashings are incorporated in the masonry, weepholes shall be provided in the masonry course immediately above the flashing, at centres not exceeding 1200 mm.

4.7.3 Damp-proof courses (DPCs) and flashings

DPCs or flashings shall be incorporated into masonry construction to—

- (a) provide a barrier to the upward or downward passage of moisture through masonry;
- (b) prevent moisture from entering into the interior of a building from the exterior;
- (c) prevent moisture passing across a cavity to the inner leaf; and
- (d) shed moisture through masonry to the outer face.

Bituminous damp-proof course materials without metal strips shall not be used where the superimposed masonry exceeds either two storeys or 8 m in height.

Sheet material used as a DPC shall be at least 20 mm wider than the thickness of the masonry member in which it is placed.

Overflashings shall be designed such that they can be set to a depth of at least 15 mm into the masonry.

NOTE: Clause 12.4.16 gives construction requirements for DPCs and flashings.

4.7.4 Single-leaf and solid walls

Where the prevention of moisture penetration is required, external single-leaf walls and solid walls shall be protected on the outside face by a suitable weather-resistant coating (see Notes below).

Where a coating is to be applied for the purpose of this Clause, all mortar joints shall be tooled and be free of cracks and holes, or the surface to be coated shall be bagged or rendered.

The following weather-resistant coating systems are deemed to be satisfactory:

- (a) Three coats of 100% acrylic-based exterior quality paint. The first coat shall be worked thoroughly into the texture of the masonry by brush to ensure complete coverage of all voids and irregularities (see Note 1).
- (b) A first coat of waterproof cement paint, worked into the surface and over-coated with two coats of 100% acrylic-based paint (see Note 1).
- (c) Where the masonry texture and jointing are to be obscured, rendering with a proprietary cement-based high-build waterproof render, followed by an elastomeric acrylic polymer coating.

- (d) Clear water repellent coatings, provided there is a weatherproof overhang of not less than 1500 mm.

NOTES:

- 1 For guidance on the painting of buildings, see AS/NZS 2311.
- 2 Regular maintenance of any coating should be in accordance with the manufacturer's instructions to maintain the integrity of the weatherproofing.
- 3 The above coatings may also be used to protect the outer leaf and cavity space of a cavity wall (see Clause 5.4.2).

4.8 CONTROL JOINTS

4.8.1 General

Control joints shall be incorporated in masonry, to control and limit the movements allowed for in Clause 2.5.2. Locations of joints shall be determined in accordance with Clause 4.8.2, 4.8.3 or 4.8.4. Where a control joint is incorporated, the joint is deemed to be a structural end (see Clause 4.5.3).

Control joints shall be detailed in accordance with Clause 4.8.5.

4.8.2 Contraction joints

4.8.2.1 General

Contraction joints shall be placed in unreinforced concrete masonry or calcium silicate masonry in accordance with the following locations:

- (a) In straight continuous walls having no openings, at centres not more than the values specified in Table 4.2 or calculated in accordance with Clause 4.8.2.2.
- (b) Where the height of the wall changes abruptly by more than 20% of its lesser height.
- (c) Where walls change thickness.
NOTE: Engaged piers are not deemed to be changes of thickness. Chases that have less than 75% of the leaf thickness remaining are deemed to be changes of thickness.
- (d) At control or construction joints in footings or slabs.
- (e) At junctions of walls constructed of different masonry or other materials.
- (f) In straight continuous walls having openings greater than 900 mm in height, at not more than the value specified in Table 4.2.

4.8.2.2 Spacing

The maximum spacing of contraction joints shall be calculated on the following basis and comply with:

- (a) The design contraction shall be taken as the coefficient of contraction of the masonry units determined in accordance with AS/NZS 4456.12.
- (b) The spacing of joints shall be such that, at each joint, the calculated opening movement does not exceed 10 mm.

In straight continuous walls, the spacing shall not exceed the values in Table 4.2.

NOTE: Guidance on design and location of contraction joints is available in masonry industry publications (see AS 3700 Supp 1).

TABLE 4.2
SPACING OF CONTRACTION JOINTS
FOR UNREINFORCED MASONRY WALLS

Masonry wall construction and surface finish	Maximum joint spacing m
External masonry that is face-finished, rendered and/or painted	7.0
Internal masonry that is face-finished or sheeted	6.0
Internal masonry that is rendered and/or painted	5.0
External masonry with openings more than 900 mm in height	5.0

4.8.3 Expansion joints

4.8.3.1 General

Expansion joints shall be placed in unreinforced clay masonry walls at the following locations:

- (a) In straight, continuous walls having no openings, at centres not more than the values calculated in accordance with Clause 4.8.3.2.
- (b) Where the height of a wall changes abruptly by more than 20% of its lesser height.
- (c) Where walls change thickness.
 NOTE: Engaged piers are not considered to be changes of thickness. Chases that have less than 75% of the leaf thickness remaining are considered to be changes of thickness.
- (d) At control or construction joints in footings or slabs.
- (e) At a distance from all corners not greater than 4500 mm and as close to the corner as practical.
- (f) At junctions of walls constructed of different masonry or other materials

Expansion joints shall be vertical, not toothed, free of mortar and shall extend to the full height of the masonry.

NOTE: Expansion joints may be omitted below the DPC if there is not more than 600 mm of masonry below the DPC at the position of the joint.

4.8.3.2 Spacing

The maximum spacing of expansion joints shall be calculated on the following basis:

- (a) The design expansion shall be taken as the following proportions of the coefficient of expansion of the masonry units (e_m):
 - (i) Vertical expansion joints in walls 35%.
 - (ii) Vertical expansion joints in parapets 70%.
 - (iii) Horizontal joints in walls 70%.
- (b) At each joint, the calculated closing movement shall not exceed 15 mm.
- (c) After the full design expansion has taken place, the remaining width of each joint shall be not less than 5 mm.
- (d) Allowance shall be made for thermal expansion in walls and parapets.
- (e) Allowance shall be made for the effect of frame shortening in reinforced concrete frame buildings when calculating the spacing of horizontal joints.

NOTE: Guidance on design and location of expansion joints is available in masonry industry publications.

4.8.4 Articulation joints

Articulation joints shall be incorporated in all masonry walls that are supported on slabs and footings designed in accordance with AS 2870 for articulated masonry, except in the following cases:

- (a) Class A and Class S sites.
- (b) Reinforced masonry designed in accordance with Section 8.

Where articulation joints are required, they shall be provided in accordance with the following locations:

- (i) In straight, continuous walls having no openings, at centres such that cracking due to foundation movements are avoided. The values given in Table 4.3 are deemed to meet this requirement for the circumstances described therein.
- (ii) Where the height of the wall changes abruptly by more than 20% of its lesser height.
- (iii) Where openings more than 900 mm × 900 mm occur, at not more than 5000 mm centres.
- (iv) Where walls change thickness.
- (v) Engaged piers are not considered to be changes of thickness. Chases that have less than 75% of the leaf thickness remaining are considered to be changes of thickness.
- (vi) At control or construction joints in footings or slabs.
- (vii) At a distance from all corners not greater than 4500 mm and not less than 470 mm for cavity walls or 230 mm for veneer walls.

TABLE 4.3
**SPACING OF ARTICULATION JOINTS FOR UNREINFORCED CAVITY,
 SINGLE LEAF AND MASONRY VENEER WALLS**

Site class (see Note)	Masonry wall construction and surface finish	Joint spacing up to 4 m high for 10 mm joints	Joint spacing 4 m up to 8.5 m high for 10 mm joints	Joint spacing 4 m up to 8.5 m high for 15 mm joints
		m	m	m
M, M-D	External face finish masonry	6.0	4.2	6.0
M, M-D	External rendered and/or painted masonry	5.5	3.9	5.5
M, M-D	Internal face finish or sheeted masonry	6.0	4.2	6.0
M, M-D	Internal rendered and/or painted masonry	5.5	3.9	5.5
H, H1-D	External face finished masonry	5.5	3.9	5.5
H, H1-D	External rendered and/or painted masonry	5.0	3.5	5.0
H, H1-D	Internal face finish or sheeted masonry	5.5	3.9	5.5
H, H1-D	Internal rendered and/or painted masonry	5.0	3.5	5.0
H, H2-D	External face finished masonry	5.0	3.5	5.0
H, H2-D	External rendered and/or painted masonry	4.5	3.2	4.5
H, H2-D	Internal face finish or sheeted masonry	5.0	3.5	5.0
H, H2-D	Internal rendered and/or painted masonry	4.5	3.2	4.5

NOTE: Site class is defined in AS 2870.

4.8.5 Detailing

Control joints shall comply with the following:

- (a) Expansion joints and articulation joints shall be free of mortar.
- (b) Any material used to fill joints shall be of a type that will not inhibit the performance of the joints during the life of the building.
- (c) Joints shall be vertical and not toothed, unless this toothing is specifically considered in the design.
- (d) Joints shall extend to the full height of the masonry but may be omitted below the damp-proof course (DPC) if there is not more than 600 mm of masonry below the DPC at the position of the joint.

4.9 MORTAR JOINTS

4.9.1 Thickness

The design thickness of mortar joints shall be as follows:

- (a) For other than thin-bed mortar, including bed joints and perpends, not greater than 10 mm, unless the effects of greater thickness on compressive and flexural strength are taken into account in the design.
- (b) For thin-bed mortar, not less than 2 mm and not greater than 4 mm.

4.9.2 Finishing

With the exception of thin-bed mortar, the surfaces of joints exposed to aggressive soils and those in exposure environments classed as marine, severe marine and special, as given in Table 5.1, shall be tooled to give a dense, water-shedding finish.

For walls constructed with hollow unit, ungrouted masonry joints shall not be raked. In other masonry, the depth of raking, if any, shall be not closer than 5 mm to any perforation in cored unit masonry or 20 mm in hollow unit masonry.

4.10 WALL TIES

Wall ties for cavity walls and masonry veneer walls shall be as follows:

- (a) Of Type A and a duty rating appropriate to the structural requirements of the masonry (see Clauses 7.6.2, 7.6.3 and 7.7.4).
- (b) Designed to transfer the design loads.
- (c) Embedded at least 50 mm into the mortar joint and, where applicable, into the grout, have at least 15 mm cover from any exposed surface of the joint and be positively attached to the structural backing as follows:
 - (i) For face-fixed ties in masonry veneer more than 3.0 m above the ground, by screw fixing.
 - (ii) For side-fixed ties, by either screw or nail fixing.

NOTES:

- 1 AS 2699 (all parts) requires the manufacturer to supply the fasteners with the ties.
- 2 Tests have shown that nail fixing for face-fixed ties in timber veneer construction and clip-on ties in steel stud veneer construction do not provide the required attachment to the structural backing under earthquake loading.
- 3 Reduction of embedment within the limits of wall tolerance (see Table 12.1) is assumed not to affect performance.

- (d) Spaced to comply with the following:
 - (i) Not greater than 600 mm in each direction.
 - (ii) Adjacent to horizontal or vertical lateral supports and control joints, and around openings in the masonry, with the first row of ties located within 300 mm from the line of lateral support, the control joint or the perimeter of opening.

When a masonry veneer connected to a flexible structural backing is continuous past a horizontal floor support, this edge distance applies to the first row of ties immediately above and below the line of the floor.

Where ties are required to be designed for double the design tie force (see Clauses 7.6.2 and 7.7.4) and this is achieved by doubling the number of ties in the row, all the ties in the row are required to satisfy the edge distance requirement.

NOTE: A row of ties may be in a single bed joint or distributed between up to two adjacent bed joints, provided both bed joints are within 300 mm of the line of the floor or support.

4.11 BONDING, TYING AND SUPPORTING

4.11.1 General

Where monolithic structural action is required across a vertical joint between two masonry members or between two components of a member, the interface shall be intersected by either—

- (a) masonry header units that provide engagement across the interface and comply with Clause 4.11.2; or
- (b) connectors that tie the two members or components together across the interface and comply with Clause 4.11.3.

The vertical joint at the interface shall be filled with mortar.

4.11.2 Bonding with masonry header units

Masonry header units used to obtain monolithic structural action shall be—

- (a) of a masonry material compatible with the masonry in the wall, or detailed so that any incompatibility does not impair the structural integrity of the wall;
- (b) spaced—
 - (i) between the leaves in solid masonry construction—either in header courses at centres of 600 mm or less, in which at least each alternate unit is a header, or with the equivalent number of header units distributed uniformly throughout the wall; and
 - (ii) at other interfaces—either with at least every fourth course of masonry at the interface fully engaged, or with the equivalent number of header units distributed uniformly throughout the interface area;
- (c) properly bonded with each section of the masonry in accordance with the selected bond pattern, and providing engagement of at least 90 mm into the masonry on each side of the interface; and
- (d) built in as the work progresses.

4.11.3 Tying with connectors

4.11.3.1 Other than diaphragm walls and walls of geometric section

For other than diaphragm walls and walls of geometric section, connectors used at an interface to obtain monolithic structural action shall comply with the following:

- (a) Connectors shall have a characteristic tensile capacity of 0.4 kN.
Medium duty Type A cavity wall ties are deemed to meet this requirement.
- (b) Connectors shall be spaced—
 - (i) between the leaves in solid masonry construction—not more than 400 mm in each direction; and
 - (ii) at other interfaces—at a horizontal spacing of one connector for each 200 mm width (or part thereof) of the interface area, and at a vertical spacing of 300 mm average and 400 mm maximum between connectors, or at such alternative spacing as is substantiated by calculation or tests.
- (c) Connectors shall be placed in aligning mortar bed joints to tie the masonry members or components together across the interface, and built into the masonry in accordance with Clause 12.4.7.

4.11.3.2 *Diaphragm walls and walls of geometric section*

For diaphragm walls and walls of geometric section, at the engagement of diaphragms with leaves, it shall be permissible to use shear connectors to obtain monolithic action at the interface. The spacing of the connectors shall be as calculated but not greater than 600 mm.

NOTE: The method for the design of shear connectors is given in Clause 7.5.6.

4.11.4 **Fixing to supporting structures**

Where a load is to be transferred from a masonry member to a supporting structure, this shall be achieved by one of the following methods:

- (a) Bedding the masonry on a mortar bed on the supporting structure, with or without a DPC.
- (b) Provision of bonded reinforcement normal to the joint between the masonry member and the support.
- (c) Provision of connectors such as column ties or head ties of sufficient strength and stiffness, spaced such that they are capable of transferring the calculated loads.

The shear transfer capacity, as determined in accordance with Clause 7.5 or 8.7, shall be greater than the magnitude of the loads to be transferred to the supporting structure determined in accordance with Clause 2.6.

4.12 **STACK BONDED MASONRY**

4.12.1 **Solid and cored unit masonry**

Solid and cored unit masonry laid in a stack bond pattern, including masonry in veneer walls, shall be reinforced using anchored bed joint reinforcement, of area not less than $0.00035 \times$ gross vertical cross-sectional area of the wall. The reinforcement shall comply with Clauses 5.9.3 and 11.8, shall be continuous between lateral supports and shall be spaced vertically at centres not exceeding six times the thickness of the stack bonded leaf.

Bed joints in the following locations shall be reinforced, see Figure 4.1:

- (a) In the first bed joint above or below an unrestrained horizontal edge of the masonry.
- (b) With at least one bed joint within 300 mm above a horizontal line of lateral support.
- (c) With at least one bed joint within 300 mm below a horizontal line of lateral support.

Such masonry shall be designed as follows:

- (i) As unreinforced for compression in accordance with Clause 7.3.
- (ii) As unreinforced for shear in accordance with Clause 7.5.
- (iii) As unreinforced for vertical bending in accordance with Clause 7.4.2.
- (iv) As reinforced for one way horizontal bending in accordance with Clause 8.6, except that the requirements of this Clause 4.12 shall take precedence over the requirements of Clause 8.6, Items (a) and (b).