

PART B

Chapter 1

Overview

For many years, concrete masonry has been a mainstay of Australian building. However, unlike its glamorous sisters, reinforced concrete and structural steel, this Cinderella product receives little attention in structural engineering courses and its aesthetic qualities are shunned in favour of clay brickwork.

The purpose of this Part of the Manual is to redress these shortfalls by:

- explaining the requirements of the National Construction Code (NCC) – Building Code of Australia (BCA) and the use of AS 3700 *Masonry structures*, AS 4773.1 *Masonry in small buildings – Part 1 Design* and AS 4773.2 *Masonry in small buildings – Part 2 Construction* to design concrete masonry buildings and building components;
- providing simple design charts which will assist the rapid selection of concrete masonry members; and
- providing comprehensive design examples which show the origin of the charts and the use of the Standard.

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1.1.1 BUILDING TYPES

In this manual, buildings are considered under three broad headings:

A Low-rise commercial and industrial buildings with large wall panels:

Factories
Warehouses
Shopping centres
Auditoriums
Schools and hospitals

B High-rise and medium-rise commercial and residential buildings with loadbearing and non-loadbearing, fire-rated walls:

Home units
Office buildings
Hotels

C Residential buildings:

Single dwellings
Duplexes
Town houses
Villa units

Of the ten building classes in the National Construction Code (NCC) – Building Code of Australia (BCA), the most likely classifications of these buildings are:

Class Building Type and Element*Low-rise commercial and industrial buildings with large wall panels*

- 3 Hotel or motel foyers
- 6 Shopping centres and sales show rooms
- 7 Warehouses and public car parks
- 8 Factories
- 9 Auditoriums and assembly halls

High-rise and medium-rise commercial and residential buildings

- 2 Home units
- 3 Boarding houses, guest houses, hotels, motels, aged accommodation
- 4 Dwellings within other buildings
- 5 Offices
- 6 Shops
- 8 Laboratories

Residential buildings

- 1 Single dwelling houses, multiple dwelling houses such as town houses, row houses, villa houses, boarding houses and group houses
- 10a Non-habitable out-buildings such as garages and sheds



Example of Group 'A' Building



Example of Group 'B' Building



Example of Group 'C' Building

1.1.2 MASONRY WALL TYPES

The main types of masonry wall are as follows.

Single leaf:

Unreinforced single-leaf walls **Figure 1.1(a)**

Reinforced single-leaf walls **Figure 1.1(b)**

Veneer:

Unreinforced veneer walls **Figure 1.1(c)**

Cavity:

Unreinforced cavity walls **Figure 1.1(d)**

Cavity walls with one or more reinforced leaves **Figure 1.1(e)**

Hybrid:

Diaphragm walls **Figure 1.1(f)**

Reinforced-cavity walls **Figure 1.1(g)**

Table 1.1 compares these wall types.

There are many options open to designers for the provision of attractive finishes to concrete masonry. Walls may be face block or brick (plain face, ribbed or split) or may be coated with paint, render or other decorative finishes.

To avoid the ingress of rainwater, single-leaf masonry walls should be coated with a continuous membrane such as three coats of 100% acrylic-based paint. Clear water-repellents may be satisfactory, provided reinforcement has been incorporated into the masonry to control cracking and special attention has been given to the permeability of the masonry units and mortar, and quality of laying. Where practical, large eaves should be provided to shield walls, with clear sealers, from rain.

Table 1.1 *Comparison of Masonry Wall types*

Aspect	Single-leaf walls	Veneer walls	Cavity walls	Hybrid walls
Construction	Hollow or cored concrete block	Hollow, cored or solid brick or block	Brick or hollow or cored concrete block	Brick or hollow or cored concrete block
Reinforcement	Can include vertical reinforcement or bond beams	Requires structural support	Not usual, but there is no reason why one leaf should not be reinforced	Diaphragm wall is not reinforced. Reinforced-cavity wall has horizontal and vertical reinforcement
Waterproof	No, requires painting or sealing to prevent water penetration	Yes, provided construction is flashed	Yes, provided construction is flashed	Yes, generally
Aesthetics	Depends on the coating system, painted split or painted ribbed units are attractive	Face masonry does not require painting	Face masonry does not require painting	Face masonry does not require painting
Cost	Most economical form of masonry but must be waterproofed	Structural support adds considerably to cost	Approximately 50% more expensive than single-leaf	More expensive than cavity wall



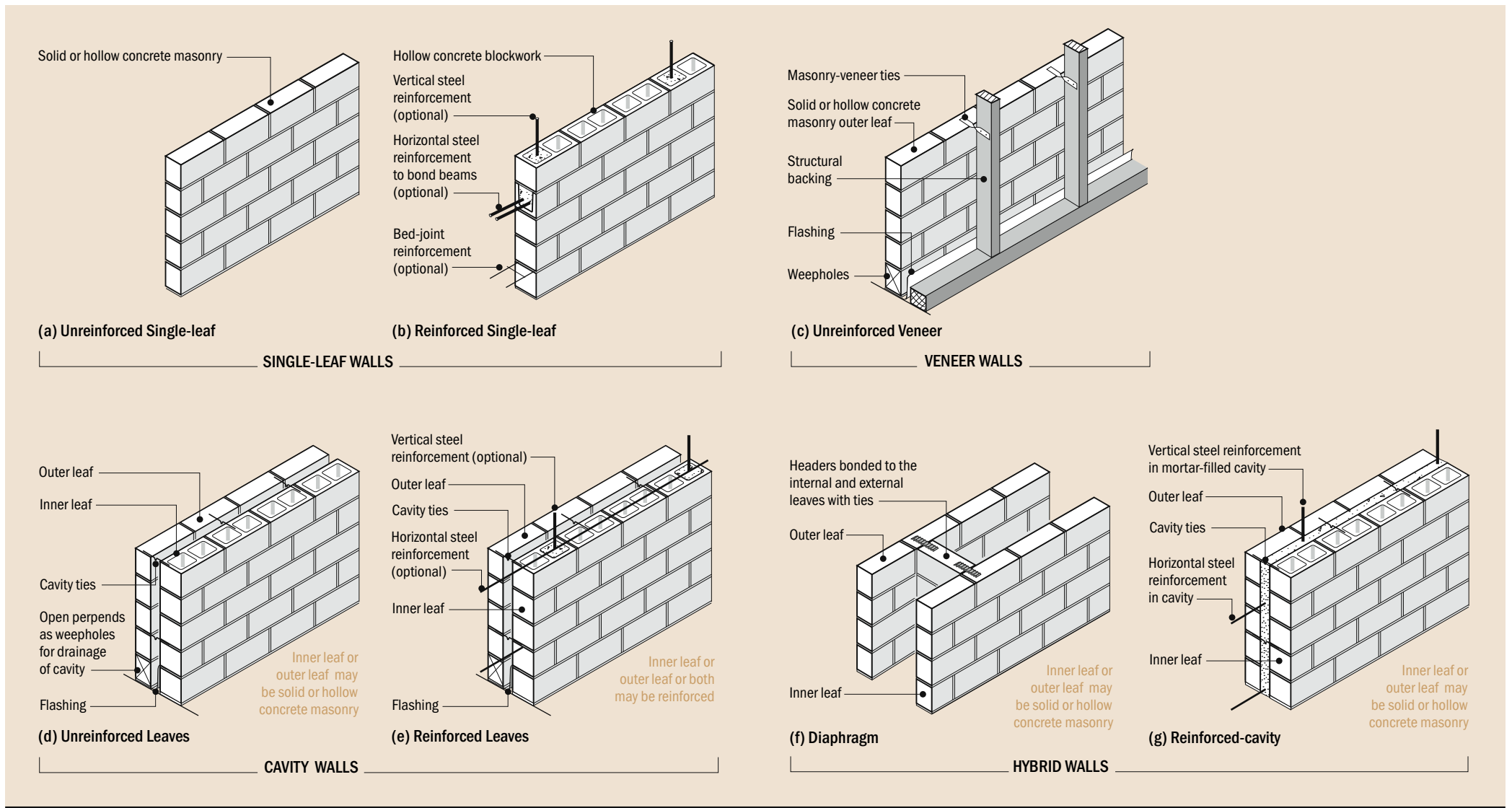


Figure 1.1 Masonry Wall Types



1.1.3 LOW-RISE COMMERCIAL AND INDUSTRIAL BUILDINGS WITH LARGE WALL PANELS

Selection of the appropriate masonry system will depend on the wall panel sizes, the support conditions and the magnitude of the design out-of-plane horizontal wind, earthquake or fire loads.

Once the masonry walling system has been selected and checked for these out-of-plane horizontal loads, it must be checked for in-plane horizontal shear load, vertical load and combined load.

If masonry walls are continuous over two or more storeys, the fixing of walls to intermediate floors will greatly improve the structural efficiency by reducing the wall spans. Reinforcement may be continuous at intermediate floors, thus reducing the bending moments at mid span (**Figure 1.2**).

In buildings with large internal clear spans (eg factories and warehouses), the spacing of portal frames, trusses, beams and columns will generally be dictated by the roof system. Historically, the frame spacing has been six to seven metres. With the more widespread use of high-strength deep purlins, frame spacings of seven to eight metres are more likely.

Once the roof-beam spacing is determined, the column spacing logically follows. Thus, in these buildings, walls spanning six to seven metres vertically and seven to eight metres horizontally could be required.

Walls may be supported by steel portal

frames, concrete beams and columns, steel or timber mullions, steel or timber girts or masonry piers.

Notwithstanding the limitations placed on the frame spacing by the roof system, the most expedient wall support system will be determined by the positions of doors, windows, shutters, loading docks and partition walls.

Full-height roller shutter openings could negate designs based on horizontal bond beams. Articulation of the walls could prevent continuity of the bond beams. A bank of windows could make vertical reinforcement difficult. All these points require consideration.

Two systems of large wall panels are available to designers depending on the size of the panels and the horizontal loads expected.

- Unreinforced hollow blockwork supported by horizontally reinforced concrete masonry bond beams. This is suitable for 190 mm walls up to 6.84 metres long between vertical supports (**Figure 1.3**).
- Reinforced masonry consisting of unreinforced blockwork supported by vertically-reinforced cores at up to 2 metre centres. This is suitable for 190 mm walls up to 6.84 metres high and supported at the top (**Figure 1.4**).

There are several variations on each of these systems employing different block types, different methods of

fixing reinforcement and different construction sequences.

Each system is particularly suited to single-leaf construction but can also be constructed as the structural leaf of a cavity wall.

Each system can be either loadbearing (supporting roof or floor loads) or non-loadbearing, eg contained within a grid of supporting members.

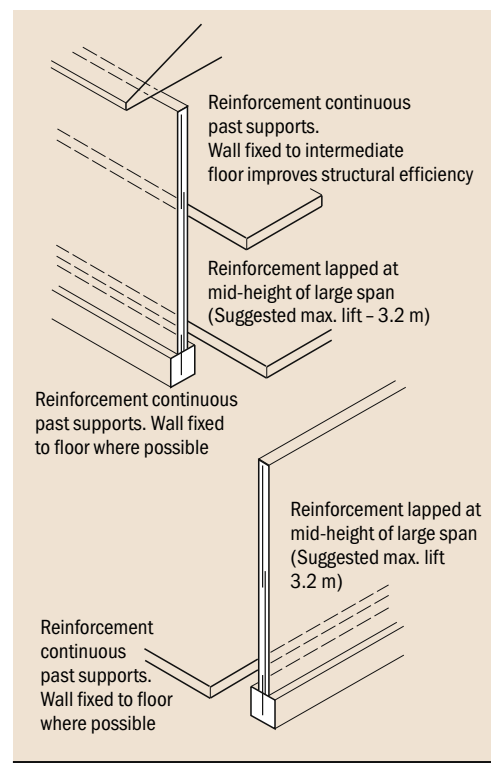


Figure 1.2 Large Wall Panels Continuous Over Two or More Storeys

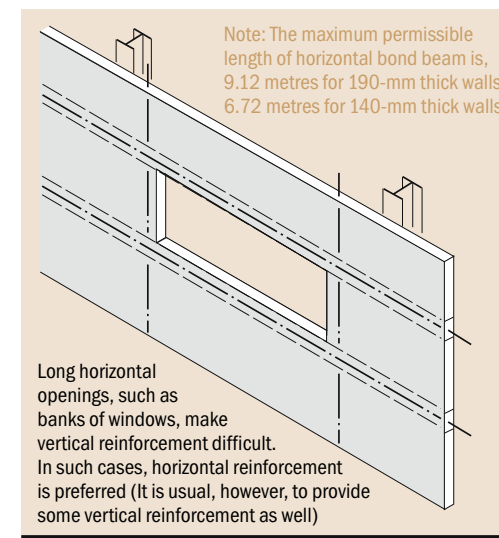


Figure 1.3 Unreinforced Masonry Between Horizontally-Reinforced Bond Beams

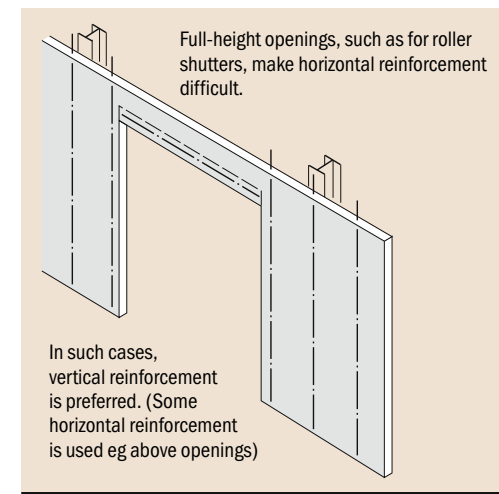


Figure 1.4 Reinforced Wall System with Vertically-Reinforced Cores



1.1.4 HIGH-RISE AND MEDIUM-RISE COMMERCIAL AND RESIDENTIAL BUILDINGS

These buildings commonly incorporate walls in the range 2.4 to 3.0 metres high although there could be some applications such as auditoriums and foyers where larger panels are involved. Reinforced masonry is ideal for these large-panel applications.

Within most commercial and residential applications, two masonry walling systems are available to designers:

- Non-loadbearing panels or partitions, which are supported laterally within a structural frame but receive no imposed load from it, **Figure 1.5**. Where non-loadbearing walls are built between concrete floor slabs, they should be adequately attached at the top to the underside of the slab, and at the sides, to prevent lateral movement, **Figure 1.6**. Bonded or tied piers and cross walls will provide further lateral support. These walls may be either cavity wall or single-leaf construction.
- Loadbearing walls supporting imposed vertical loads, commonly used in buildings up to five storeys high, either with or without a reinforced concrete or concrete masonry shear core to provide lateral stability, **Figures 1.7 and 1.8**. These walls may be either cavity wall or single-leaf construction. It is common for the internal leaf of an external wall to be loadbearing, while the external leaf is treated as a non-loadbearing veneer.

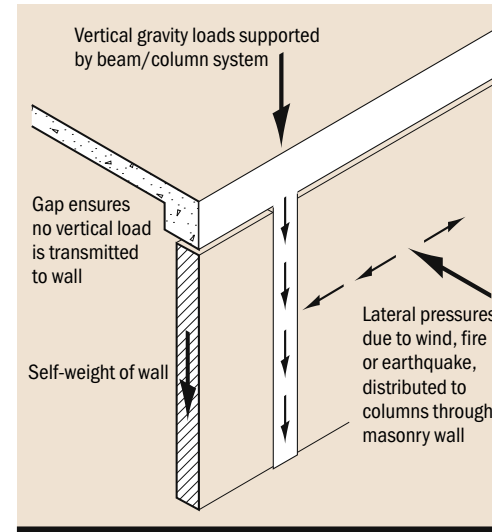


Figure 1.5 Non-Loadbearing Wall System

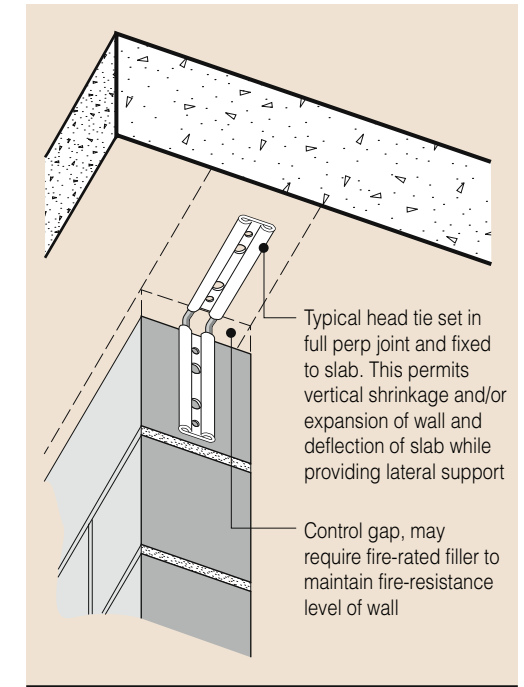


Figure 1.6 Tying Non-Loadbearing Walls to Slabs to Prevent Lateral Movement



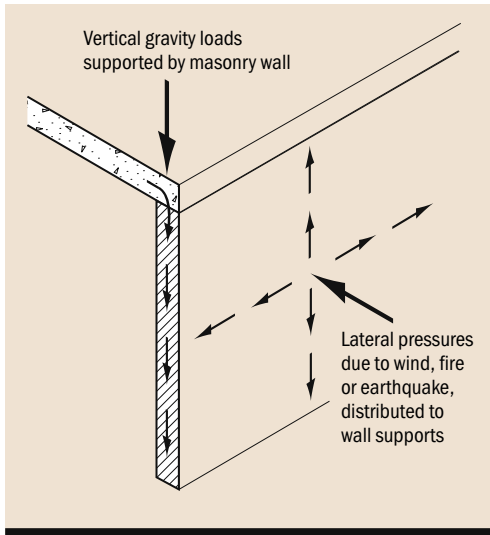


Figure 1.7 Loadbearing Wall System

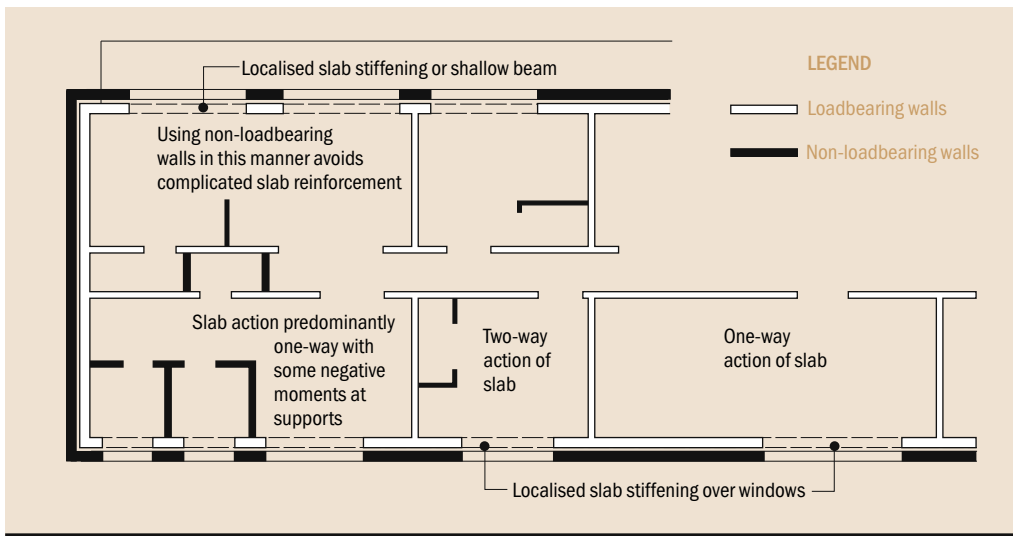


Figure 1.8 Typical Layout of Loadbearing Wall System for Commercial and Residential Buildings

1.1.5 RESIDENTIAL BUILDINGS

The structural design considerations for houses centres around:

- Analysis for wind uplift and lateral pressures in high wind areas,
- Detailing for earthquake resistance,
- Selection of a slab or footing system that is compatible with the proposed masonry superstructure, and
- Detailing appropriate movement joints to account for movement of the foundations, slabs and footing and shrinkage in the masonry.

The most common form of house construction in Australia is masonry veneer (usually brick veneer), although single-leaf reinforced masonry is very popular in northern Australia due to its ability to withstand high wind loads and earth movement. The older form of cavity masonry exhibits superior thermal properties and sound insulation, but is more expensive than the other two forms of masonry for housing.

1.2

DESIGN FOR ACOUSTICS

Designing for acoustics is a primary consideration, usually dealt with by the architect. Selection of a suitable masonry system either with or without cladding must be made early in the design process.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

There are no specific acoustic requirements for these buildings.

High-Rise and Medium-Rise Commercial and Residential Buildings

The NCC–BCA Volume One, Part F5 sets out the requirements for airborne sound insulation and impact sound insulation between various parts of Class 2 and Class 3 buildings.

The NCC–BCA Volume One requires that walls that separate sole-occupancy units or walls that separate a sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, hallway or the like, have certain values of R_w (Note 1). It also requires that walls between a bathroom, sanitary compartment, laundry or kitchen and a habitable room (other than a kitchen) in an adjoining unit have higher values of R_w (Note 1), provide a satisfactory level of insulation against impact sound and not incorporate a duct that reduces the R_w value of the wall. (Figure 1.9).

Residential Buildings

There are no specific acoustic requirements for single dwellings. However, the NCC–BCA Volume Two, Section P2.4.6 and Part 3.8.6, set out the requirements for airborne sound insulation and impact sound insulation between adjoining dwellings in Class 1

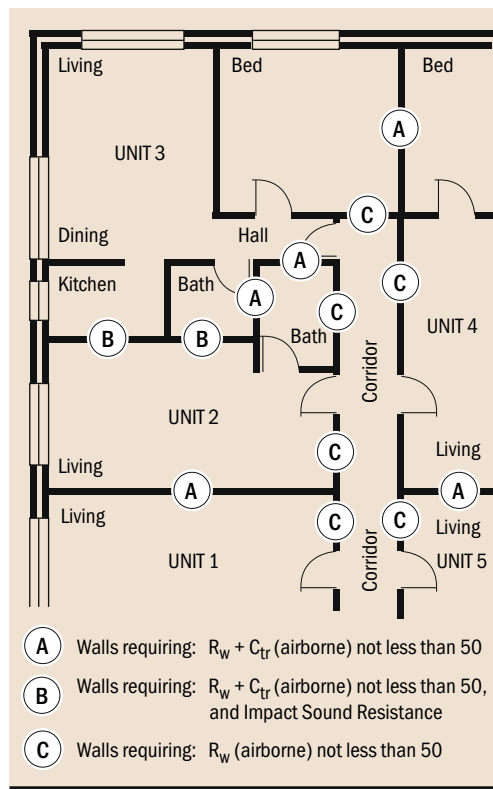


Figure 1.9 Example of NCC–BCA Requirements for Sound and Impact Insulation in Class 2 and Class 3 Buildings (Note 1)

buildings. The requirements are similar to those listed above.

NOTES:

1 Values given are the basic NCC–BCA requirements, however, different states have elected to vary some of these values which will require checking with the local authority.

1.3

DESIGN FOR ROBUSTNESS

All walls must meet the robustness criteria of AS 3700 which provide an upper limit on sensible design. Walls must be capable of withstanding an out-of-plane pressure of 0.5 kPa. The robustness criteria for piers are geometric limits. However, compliance with the robustness criteria must not be considered to be a substitute for rational design for calculated wind, earthquake, fire and gravity loads.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

If large walls of low-rise buildings do not meet the robustness criteria, consideration should be given to using thicker units or cavity construction, increasing the support system (perhaps by using steel mullions) or introducing reinforcement into unreinforced elements.

High-Rise and Medium-Rise Commercial and Residential Buildings

The walls of high-rise or medium-rise buildings that are most likely to fail the robustness criteria are those where:

- there are long runs without intersecting cross walls;
- there are isolated piers between window or door openings; or
- there are chases or control joints that destroy two-way action which may have been assumed in the design.

In all cases, the top of the wall must be tied to the slab or roof above with connectors capable of supporting the applied lateral loads. All intersecting cross walls should be bonded or tied into the wall. If the thickness

of masonry unit can not be increased, the most practical solution is the inclusion of reinforcement or steel mullions into the wall.

Residential Buildings

Provided veneer ties are used at the spacings specified in AS 4773, masonry veneer construction will meet the robustness provisions.

Except perhaps for unsupported gable end walls, most cavity masonry construction will also satisfy the robustness requirements.

Single-leaf partition walls may exceed robustness limits and should be checked. Reinforcement or steel mullions can be used to ensure that isolated piers between window or door openings do not present a problem.

Certain walls defined in the NCC–BCA must meet the three fire resistance levels (FRLs) of structural adequacy (stability against collapse), integrity (resistance to cracking) and insulation (resistance to the passage of heat). Insulation and integrity can be improved by using masonry units with a greater material thickness (measure of the equivalent solid thickness) or by using units incorporating lightweight materials (usually scoria, blast furnace slag or boiler ash, depending on availability). In large wall panels, structural adequacy under fire loading can be a major consideration. If there are problems, consider using a thicker unit, increase the support system (perhaps by using steel mullions) or introduce reinforcement into unreinforced elements. Reinforced masonry is usually an effective way of achieving structural adequacy.

See **Table 1.2** for the type of construction required by the NCC–BCA, then **Tables 1.3 to 1.5** for the required fire resistance levels.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

Most single-storey commercial or industrial buildings require Type C construction except where area or building volume limitations determine otherwise.

High-Rise and Medium-Rise Commercial and Residential Buildings

High-rise and medium-rise commercial and residential buildings require Type A or B construction except for two-storey non-residential building which may be of Type C construction.

Residential Buildings

The NCC–BCA requires that:

- In a Class 1 building (residential), any external walls that are within 1 metre of an allotment boundary or within 2 metres of another building on the same allotment (other than a Class 10a shed, garage or carport) shall be of concrete, masonry or masonry veneer construction with a minimum thickness of 90 mm and a Fire Resistance Level (FRL) of 60/60/60 (ie able to provide structural adequacy, integrity and insulation for 60 minutes).
- In a Class 10a garage or shed (excluding open garage), any external walls that are within 1 m of an allotment boundary shall be non-combustible material or lined with non-combustible material.
- Any common walls must be of concrete or masonry construction and extend to the underside of a non-combustible roof or not less than 450 mm above a combustible roof. If a common wall separates a Class 1 residential building from another Class 1 residential building or from a Class 10 shed or garage on a different allotment, it shall have a minimum Fire Resistance Level of 90/90/90 (ie able to provide structural adequacy, integrity and insulation for 90 minutes).
- If a common wall separates a Class 10a shed or garage from another Class 10a building, it shall be of non combustible material.

Table 1.2 *Type of Construction Required*

[Extract from NCC– BCA Volume One Table C1.1]

Rise (storeys)	Class of Building	
	2,3 and 9	5,6,7 and 8
4 or more	A	A
3	A	B
2	B	C
1	C	C



Table 1.3 Fire Resistance Levels (minutes) for Structural Adequacy/Integrity/Insulation in **Type A Construction**, Excluding Carparks
[Extract from NCC–BCA Volume One Table 3 in Specification C1.1]

Building Element	Class of Building			
	2, 3 or 4 part (Residential)	5 or 9 (Offices)	6 (Retail)	7 or 8 (Factories, Warehouses)
External Walls (including any column and other building element incorporated therein) or other external building element excluding a roof, where the distance from any fire-source feature to which it is exposed is: For loadbearing parts –				
less than 1.5 m	90/90/90	120/120/120	180/180/180	240/240/240
1.5 to less than 3 m	90/60/60	120/90/90	180/180/120	240/240/180
3 or more	90/60/30	120/60/30	180/120/90	240/180/90
For non-loadbearing parts –				
less than 1.5 m	–/90/90	–/120/120	–/180/180	–/240/240
1.5 to less than 3 m	–/60/60	–/90/90	–/180/120	–/240/180
3 or more	–/–/–	–/–/–	–/–/–	–/–/–
Common Walls and Fire Walls				
	90/90/90	120/120/120	180/180/180	240/240/240
Internal Walls Fire-resisting lift and stair shafts –				
Loadbearing	90/90/90	120/120/120	180/120/120	240/120/120
Non-loadbearing	–/90/90	–/120/120	–/120/120	–/120/120
Bounding public corridors, public hallways and the like –				
Loadbearing	90/90/90	120/–/–	180/–/–	240/–/–
Non-loadbearing	–/60/60	–/–/–	–/–/–	–/–/–
Between or bounding sole-occupancy units –				
Loadbearing	90/90/90	120/–/–	180/–/–	240/–/–
Non-loadbearing	–/60/60	–/–/–	–/–/–	–/–/–
Ventilating, pipe, garbage, and like shafts not used for the discharge of hot products of combustion –				
Loadbearing	90/90/90	120/90/90	180/120/120	240/120/120
Non-loadbearing	–/90/90	–/90/90	–/120/120	–/120/120
Other Loadbearing Internal Walls; and Internal Beams, Trusses and Columns				
	90/–/–	120/–/–	180/–/–	240/–/–

NOTE: A dash (eg, 90/–/– or –/–/–) means there is no requirement for an FRL for that criteria.

Table 1.4

Type B Construction

Table 1.5

Type C Construction



Table 1.4 Fire Resistance Levels (minutes) for Structural Adequacy/Integrity/Insulation in **Type B Construction**, Excluding Carparks
[Extract from NCC–BCA Volume One Table 4 in Specification C1.1]

Building Element	Class of Building			
	2, 3 or 4 part (Residential)	5 or 9 (Offices)	6 (Retail)	7 or 8 (Factories, Warehouses)
External Walls (including any column and other building element incorporated therein) or other external building element excluding a roof, where the distance from any fire-source feature to which it is exposed is: For loadbearing parts –				
less than 1.5 m	90/90/90	120/120/120	180/180/180	240/240/240
1.5 to less than 3 m	90/60/30	120/90/60	180/120/90	240/180/120
3 to less than 9 m	90/30/30	120/30/30	180/90/60	240/90/60
9 to less than 18 m	90/30/-	120/30/-	180/60/-	240/60/-
18 or more	-/-/-	-/-/-	-/-/-	-/-/-
For non-loadbearing parts –				
less than 1.5 m	-/90/90	-/120/120	-/180/180	-/240/240
1.5 to less than 3 m	-/60/30	-/90/60	-/120/90	-/180/120
3 or more	-/-/-	-/-/-	-/-/-	-/-/-
Common Walls and Fire Walls				
	90/90/90	120/120/120	180/180/180	240/240/240
Internal Walls Fire-resisting lift and stair shafts –				
Loadbearing	90/90/90	120/120/120	180/120/120	240/120/120
Non-loadbearing	-/90/90	-/120/120	-/120/120	-/120/120
Bounding public corridors, public hallways and the like –				
Loadbearing	60/60/60	120/-/-	180/-/-	240/-/-
Non-loadbearing	-/60/60	-/-/-	-/-/-	-/-/-
Between or bounding sole-occupancy units –				
Loadbearing	60/60/60	120/-/-	180/-/-	240/-/-
Non-loadbearing	-/60/60	-/-/-	-/-/-	-/-/-
Other Loadbearing Internal Walls; and Internal Beams, Trusses and Columns				
	60/-/-	120/-/-	180/-/-	240/-/-

NOTE: A dash (eg, 90/-/- or -/-/-) means there is no requirement for an FRL for that criteria.

Table 1.3

Type A Construction

Table 1.5

Type C Construction



Table 1.5 *Fire Resistance Levels (minutes) for Structural Adequacy/Integrity/Insulation in Type C Construction, Excluding Carparks*
[Extract from NCC–BCA Volume One Table 5 in Specification C1.1]

Building Element	Class of Building			
	2, 3 or 4 part (Residential)	5 or 9 (Offices)	6 (Retail)	7 or 8 (Factories, Warehouses)
External Walls (including any column and other building element incorporated therein) or other external building element excluding a roof, where the distance from any fire-source feature to which it is exposed is:				
less than 1.5 m	90/90/90	90/90/90	90/90/90	90/90/90
1.5 to less than 3 m	-/-/-	60/60/60	60/60/60	60/60/60
3 or more	-/-/-	-/-/-	-/-/-	-/-/-
Common Walls and Fire Walls				
	90/90/90	90/90/90	90/90/90	90/90/90
Internal Walls				
Bounding public corridors, public hallways and the like	60/60/60	-/-/-	-/-/-	-/-/-
Between or bounding sole-occupancy units	60/60/60	-/-/-	-/-/-	-/-/-
Bounding a stair if required to be fire-rated	60/60/60	60/60/60	60/60/60	60/60/60

NOTE: A dash (eg, 90/-/- or -/-/-) means there is no requirement for an FRL for that criteria.

Table 1.3

Type A Construction

Table 1.4

Type B Construction

1.5.1 GENERAL

Although masonry walls have traditionally been relatively thick, there is an increasing trend towards thinner loadbearing walls. While walls were once 230 mm bonded brickwork, they evolved to two leaves of 110 mm brickwork separated by a cavity and to 110 mm single-leaf masonry. More recently they have continued to evolve to two leaves of 90 mm masonry separated by a cavity and to 90 mm single-leaf masonry, which is now common.

Historically, little attention was paid to the vertical gravity loads on masonry walls, but today, as the designs are being refined and the margins of safety are being trimmed, it is necessary for the design engineer to check the loads and wall capacities.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

Most large wall panels are usually non-loadbearing (being supported within a grid of loadbearing steel or concrete members) or are subject to only light roof loads. If the wall is subjected to externally applied vertical loads, it will be necessary to check the vertical load capacity. If the walls are reinforced vertically, eccentric vertical loads may be assumed to consist of a vertical concentric component and a bending moment, which is resisted by the reinforced section. However, if the walls are unreinforced (or reinforced only with horizontal bond beams) it will be necessary to determine an eccentricity and calculate the reduced load capacity.

High-Rise and Medium-Rise Commercial and Residential Buildings Non-loadbearing Walls

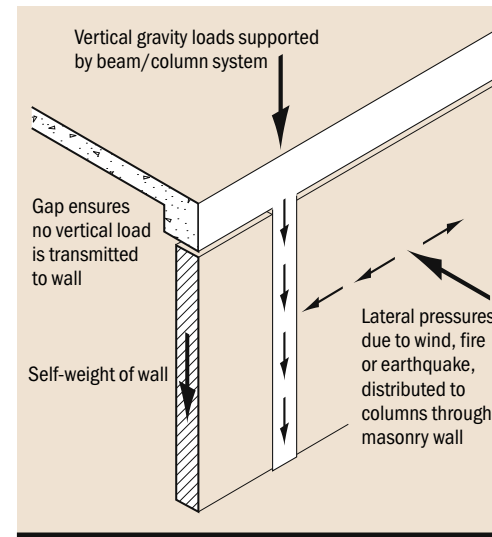
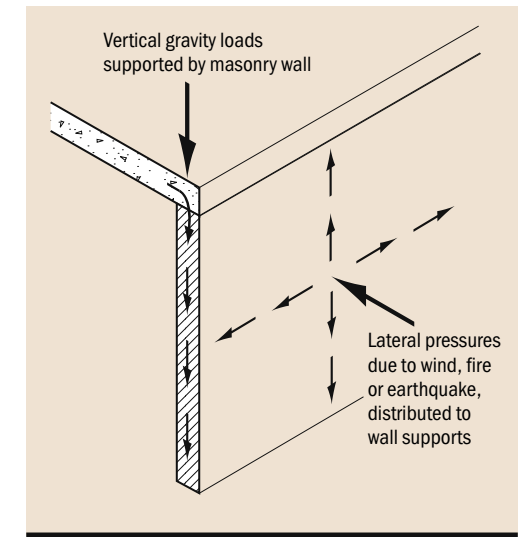
High-rise commercial and residential buildings are most commonly constructed with concrete slabs and beams supported on concrete columns (**Figure 1.10**). In such cases, masonry partition walls are non-loadbearing and there is no need to analyse for vertical load capacity.

Loadbearing Walls

Medium-rise commercial and residential buildings (up to approximately five storeys) are often designed with loadbearing masonry walls supporting concrete floor slabs (**Figure 1.11**). In this case, the walls must be analysed for vertical load capacity. The magnitude of the loads can vary considerably, while loads of approximately 30 to 35 kN/m per supported floor are common.

Residential Buildings

The gravity loads on low rise residential buildings are generally of a low magnitude, thus removing the need for stringent analysis provided the robustness limits are observed, careful engineering judgment is exercised and there is suitable detailing to accommodate wind uplift.

**Figure 1.10** Non-Loadbearing Wall System**Figure 1.11** Loadbearing Wall System

1.5.2 ROOF LOADS

It is necessary to consider the uplift forces applied by the roof structure to masonry walls, tie down and lintels. In areas of high wind, these uplift forces will be particularly severe. This part of the manual is intended to give designers a feel for the more common roof loads, rather than cover all options for the design of roof systems.

AS 1684 gives guidance on suitable timber roof structures for housing. Depending on the type of timber and its stress grade, here can be a wide variation in permissible spans of most structural members. Unfactored permanent loads of timber framing or trusses should be calculated and will be commonly in the range of 0.2 to 0.3 kPa. These may be added to the permanent load for the appropriate roofing/ceiling combination given in **Table 1.6**.

For non-trafficable roofs, excluding street awnings, with an area more than 14 m², AS/NZS 1170.1 requires an unfactored imposed load of 0.25 kPa to be applied. For smaller areas, the load increases. It also specifies various concentrated actions.

Table 1.7 gives the net downwards pressures for factored permanent and imposed loads and the net uplift for factored permanent loads and wind loads.

Table 1.6 *Permanent Loads of Typical Roofing/Ceiling Linings* [Extract From AS 1684]

Roof Type	Description	Permanent Load (kPa)
A	Steel or copper roofing, up to 0.55 mm + battens.	0.1
	Aluminium roofing, up to 3.0 mm + battens	
B	Fibre-cement slates or corrugated fibre-cement up to 6 mm + battens.	0.2
	Steel roofing, 0.90 mm and 0.70 mm + battens	
C	Timber decking 45 mm thick with roofing of mass 10 kg.m ² and battens.	0.4
	Timber plank or plywood 45 mm thick covered by metal-foil-coated bitumen membrane plus 10 mm plaster ceiling and battens.	
	Roofing of mass 10 or 20 kg/m ² plus 10 mm plaster ceiling, battens and lightweight insulation.	
	Strawboard 50 mm thick + roofing of mass 10 kg/m ²	
D	Natural slates or terracotta or concrete tiles with battens.	0.6
	Timber planks or plywood 19 mm thick covered by bituminous membrane with gravel.	
E	Roofing of mass 60 kg/m ² plus 10 mm plaster, ceiling battens and lightweight insulation.	0.9

Table 1.7 *Wind Uplift and Downward Pressures*

Roofing type	Working permanent load, G (kPa)	Working imposed load, Q (kPa)	Ultimate wind load W _u (kPa)	Ultimate uplift pressure p _{up} = 0.9G + W _u (kPa)	Ultimate downward pressure p _{down} = 1.2G + 1.5Q (kPa)
A		0.6	0.25	-1.0	-0.5
			-2.0	-1.5	1.1
			-3.0	-3.5	1.1
			-4.0	-3.5	1.1
			-5.0	-4.5	1.1
B	0.7	0.25	-1.0	-0.4	1.2
			-2.0	-1.4	1.2
			-3.0	-2.4	1.2
			-4.0	-3.4	1.2
			-5.0	-4.4	1.2
C		0.9	0.25	-1.0	-0.2
			-2.0	-1.2	1.5
			-3.0	-2.2	1.5
			-4.0	-3.2	1.5
			-5.0	-4.2	1.5
D	1.1	0.25	-1.0	-0.0	1.7
			-2.0	-1.0	1.7
			-3.0	-2.0	1.7
			-4.0	-3.0	1.7
			-5.0	-4.0	1.7
E		1.4	0.25	-1.0	-0.3
			-2.0	-0.7	2.1
			-3.0	-1.7	2.1
			-4.0	-2.7	2.1
			-5.0	-3.7	2.1

Important Note: *These tables must not be used as a substitute for proper calculations in accordance with Australian Standards and the National Construction Code (NCC) – Building Code of Australia (BCA).*



A simplified approach for the uplift due to wind loads on housing is given in AS 4055 (Table 1.8).

The formulae given in Figure 1.12 may be used to calculate the vertical forces on internal and external walls of a simple building.

Table 1.8 *Wind Pressures on Roof* [Extract from AS 4055]

Wind category	Ultimate wind speed V_u (m/s)	Net pressure coefficient $C_{p,u}$	Uplift pressure on roof, p (kPa)	
			Tile	Sheet
N1	34	-1.1	0.04	0.44
N2	40	-1.1	0.34	0.74
N3	50	-1.1	0.93	1.33
N4	61	-1.1	1.74	2.14
N5	74	-1.1	2.89	3.29
N6	86	-1.1	4.16	4.56
C1	50	-1.6	1.68	2.08
C2	61	-1.6	2.85	3.25
C3	74	-1.6	4.54	4.94
C4	86	-1.6	6.38	6.78

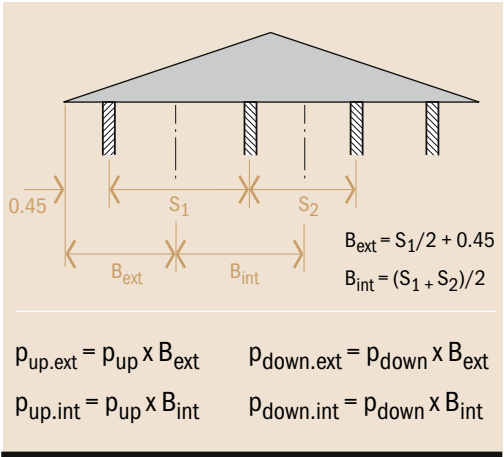


Figure 1.12 *Vertical Forces on External and Internal Walls of Simple Buildings*



It is not uncommon for strong wind or cyclonic wind to cause sufficient uplift on a roof to peel off the cladding or even to remove the rafters or trusses. To prevent this occurrence, roof structures must be properly anchored to the walls or, if uplift is particularly severe, to the footings via the walls. Several alternatives are shown in **Figure 1.13**.

AS 4773.1 provides a comprehensive list of roof anchorage details and the corresponding capacities.

■ In reinforced-masonry construction, the roof structure may be secured by holding-down bolts or brackets to a horizontal bond beam tied to the slab below via vertical reinforcing bars in the masonry cores and starter bars set into the footings. Alternatively, the roof anchorages may be fixed to a reinforced hollow concrete blockwork bond-beam, which is, in turn, tied through the reinforced wall to the concrete floor slab at convenient locations. Refer to AS 4773.1 and AS 4773.2 for full details. Refer also to Figure 1.13A.

■ In cavity-masonry construction, roof anchors may pass down the cavity between the two leaves of masonry. The anchors should be fixed to one leaf of the wall before the second leaf is built. If there is insufficient weight in the wall, there must be a positive connection to the concrete slab or footings.

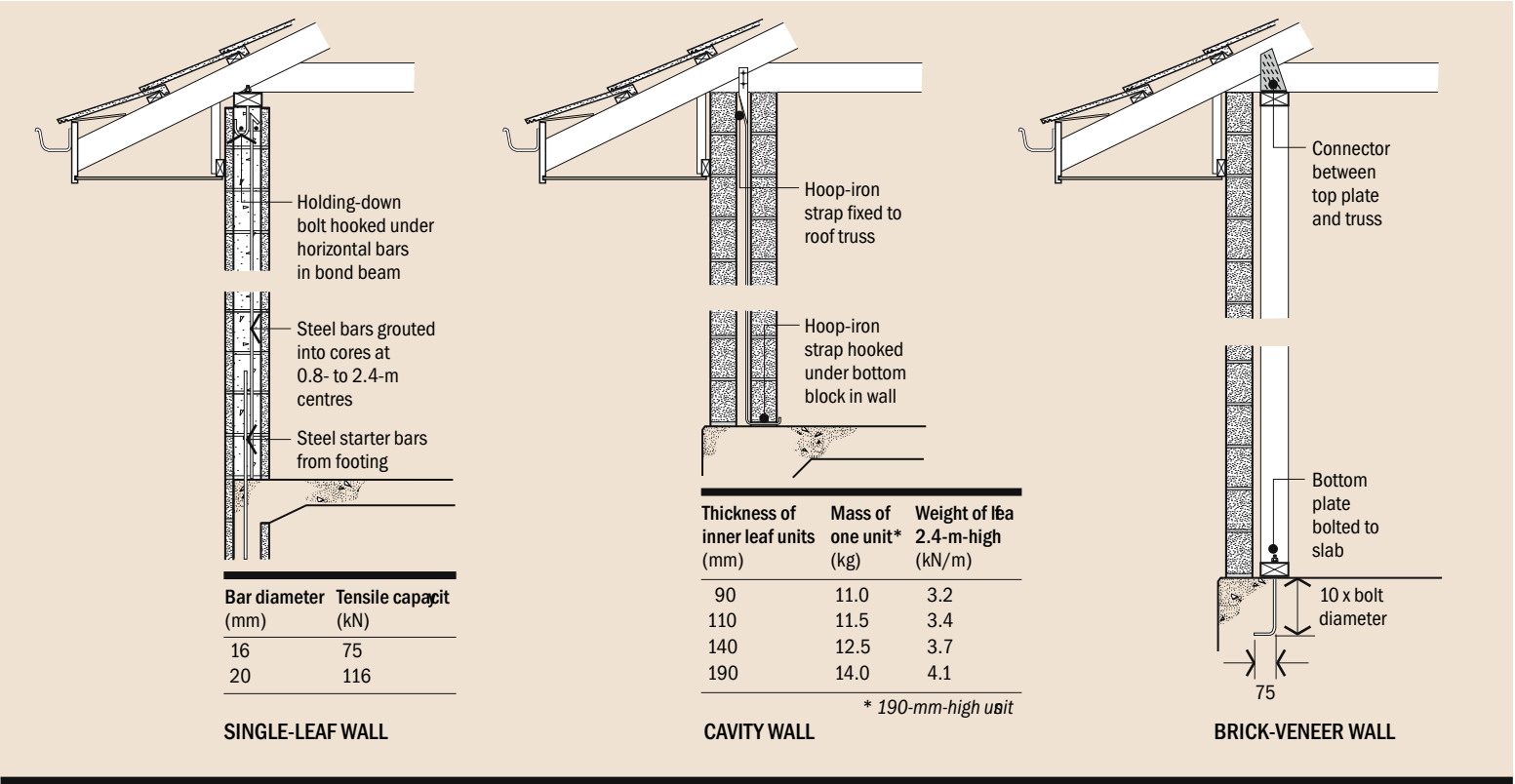
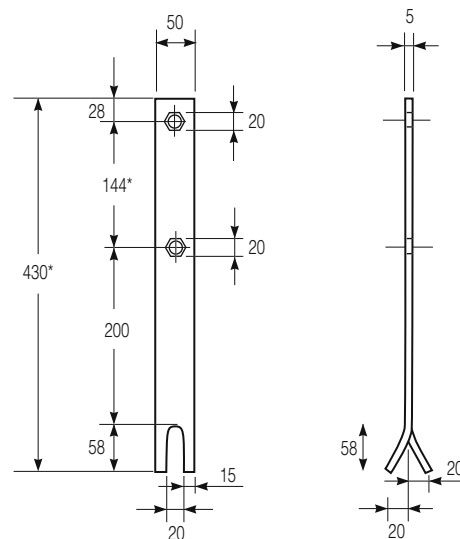
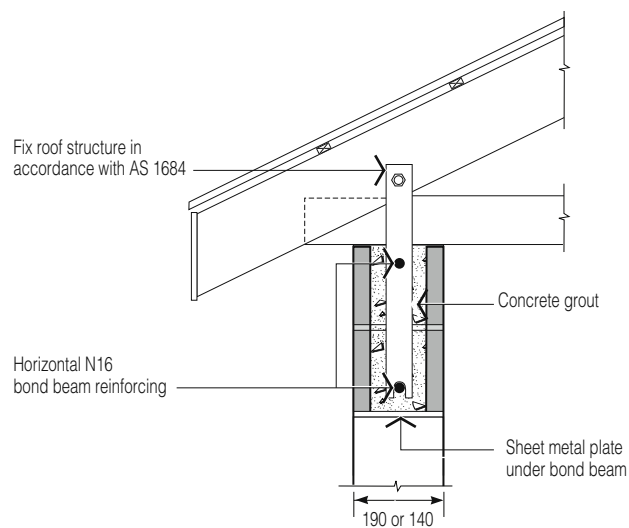


Figure 1.13 *Roof-Fixing Systems*

■ In masonry-veneer construction, timber or metal stud walls of masonry-veneer construction may be used to transmit the roof uplift down to the concrete footings or slab. Connections between the roof and wall framing and between the wall framing and slab must have sufficient tensile capacity to resist pull-out.

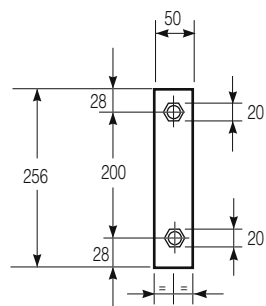
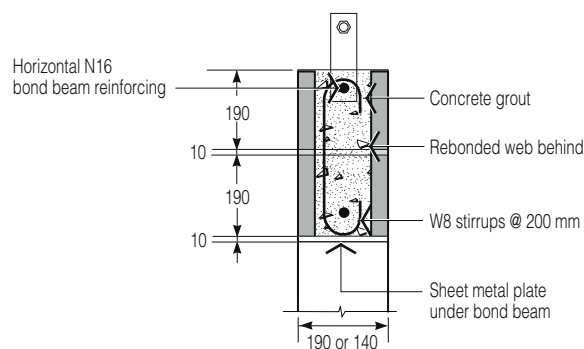




50 X 5 FMS X 430 long hot-dipped galvanized

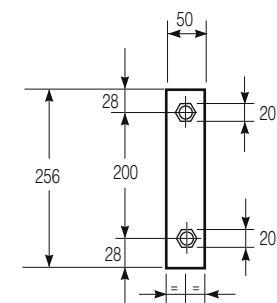
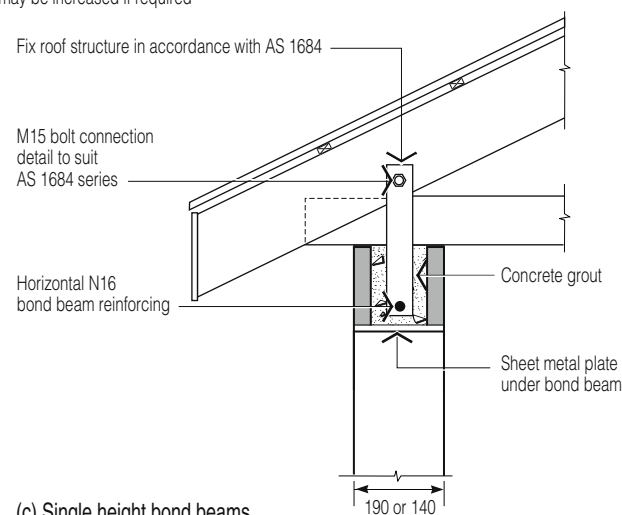
* Standard dimensions are 430 and 144 mm, but these may be increased if required

(a) Long fishtail cleats deep anchorage



50 X 5 FMS X 256 long hot-dipped galvanized

(b) Two courses reinforced – Typical bond beams



50 X 5 FMS X 256 long hot-dipped galvanized

(c) Single height bond beams

Figure 1.13A Anchorage details for reinforced concrete bond beams

Table 1.8A *Anchorage Capacities in Single Leaf Reinforced Concrete Masonry Walls*

	Reinforced concrete masonry wall thickness mm	Design Anchorage Capacity, ϕ P kN per cleat	Permissible load width (A) of sheet roof that may be anchored, m						
N1			N2	N3	N4 C1	N5 C2	N6 C3	C4	
Design uplift pressure, kPa									
Sheet Roof									
Two courses reinforced, with “long fishtail cleats”	190	30.7	8.9	8.9	8.9	8.9	7.8	5.2	3.8
Two courses reinforced, with “long fishtail cleats”	140	23.3	8.9	8.9	8.9	8.9	5.9	3.9	2.9
Two courses reinforced, with W8 stirrups at Approximately 200 mm centres	190	22.0	8.9	8.9	8.9	8.6	5.6	3.7	2.7
Two courses reinforced, with W8 stirrups at approximately 200 mm centres	140	13.0	8.9	8.9	8.1	5.1	3.3	2.2	1.6
Two courses reinforced, with no deep anchorage	190	13.1	8.9	8.9	8.2	5.1	3.3	2.2	1.6
Two courses reinforced, with no deep anchorage	140	11.3	8.9	8.9	7.1	4.4	2.9	1.9	1.4
Tiled Roof									
Two courses reinforced, with “long fishtail cleats”	190	30.7	8.9	8.9	8.9	8.9	8.8	5.6	4.0
Two courses reinforced,with “long fishtail cleats”	140	23.3	8.9	8.9	8.9	8.9	6.7	4.3	3.0
Two courses reinforced, with W8 stirrups at approximately 200 mm centres	190	22.0	8.9	8.9	8.9	8.9	6.3	4.0	2.9
Two courses reinforced, with W8 stirrups at approximately 200 mm centres	140	13.0	8.9	8.9	8.9	6.2	3.7	2.4	1.7
Two courses reinforced, with no deep anchorage	190	13.1	8.9	8.9	8.9	6.3	3.8	2.4	1.7
Two courses reinforced, with no deep anchorage	140	11.3	8.9	8.9	8.9	5.4	3.3	2.1	1.5

These tables have been calculated by the Concrete Masonry Association of Australia from the results of sponsored tests, viz. Cyclone Testing Station School of Engineering James Cook University Report No TS 636 June 2006 Strength Limit State Uplift Load Design Capacities of Bond Beam Truss Hold Down Connections. AS 4773.1 and AS 4773.2 have adopted similar tables and details.

1.5.3 FLOOR LOADS

Suspended floors may be reinforced concrete or timber. This manual is not intended to cover all of the options for floor design but the following information has been included to give designers a feel for the more common systems. Permanent and imposed loads on the suspended floors of residential buildings are given in AS/NZS 1170.1 and typical values are set out in **Table 1.9**.

AS 1684 provides the dimensions of suitable joists and bearers for timber floors for houses.

AS 3600 provides the requirements for the design and construction of concrete suspended floor slabs. These may be designed to span in one direction (supported on two opposite sides) or in two directions (supported on at least three, and commonly four sides) by loadbearing masonry. In both cases they will require steel reinforcement to be placed near the bottom face to resist bending tension. This “positive” tensile reinforcement should span between supports. Transverse reinforcement should be provided to prevent shrinkage cracking and to tie together the main bars. “Negative” tensile reinforcement should be placed in the top face over (and adjacent to) supports to prevent cracking of the top face of the slab.

Table 1.9 Floor Permanent Loads and Imposed Loads in Self-contained Houses [Extract From AS/NZS 1170.1]

Floor construction	Permanent load unfactored		Permanent load factored (1.2 x unfactored)	
	Uniform (kPa)		Uniform (kPa)	
Concrete slab of thickness:				
100 mm	2.5		3.0	
125 mm	3.1		3.8	
150 mm	3.8		4.5	
175 mm	4.4		5.3	
200 mm	5.0		6.0	
Timber – including bearers, joists, flooring, blocking, ceiling battens and sheeting	1.0		1.3	
Location	Imposed load unfactored		Imposed load factored (1.5 x unfactored)	
	Uniform (kPa)	Concentrated (kN)	Uniform (kPa)	Concentrated (kN)
General	1.5	1.8 on 350 mm ²	2.25	2.7 on 350 mm ²
Balconies less than one metre above ground	1.5	1.5 per metre-run along edge and 1.8 on 350 mm ²	2.25	2.25 per metre-run along edge and 2.7 on 350 mm ²
Other balconies	2.0	1.5 per metre-run along edge and 1.8 on 350 mm ²	3.00	2.25 per metre-run along edge and 2.7 on 350 mm ²
Stairs and landings	2.0	2.7	3.00	4.05 on 350 mm ²
Parking, driveways and ramps	2.5	13.0	3.75	19.5

Important Note: *These tables must not be used as a substitute for proper calculations in accordance with Australian Standards and the National Construction Code (NCC) – Building Code of Australia (BCA).*

1.6

DESIGN FOR HORIZONTAL LOADS

Wind, earthquake and fire loads will be exerted on the masonry walls as out-of-plane horizontal pressures, transmitted from any unreinforced masonry to any reinforced sections within the walls and then to the supporting structure, footings and foundations. The masonry walls may also contribute to the shear resistance of the structure.

1.6.1 WIND LOAD

AS/NZS 1170.2 gives a method of calculating the ultimate horizontal wind pressure acting on masonry walls. This ultimate pressure may be used to calculate the ultimate moments and shear loads and compared directly with the ultimate capacities given in **Part B:Chapter 6** of this manual.

A simplified system of calculating wind pressures on the walls of houses is set out in AS 4055 and reproduced in **Table 1.10**.

Table 1.10 *Wind Pressures on Walls of Houses*
[Extract from AS 4055]

Wind category	Ultimate wind speed V_u (m/s)	Net pressure coefficient $C_{p,u}$	Horizontal wall pressure p (kPa)
N1	34	1.00	0.7
N2	40	1.00	1.0
N3	50	1.00	1.5
N4	61	1.00	2.2
N5	74	1.00	3.3
N6	86	1.00	4.4
C1	50	1.35	2.0
C2	61	1.35	3.0
C3	74	1.35	4.4
C4	86	1.35	6.0

1.6.2 EARTHQUAKE LOAD

AS 1170.4 gives the method for calculating the loads resulting from earthquakes acting on masonry buildings and masonry components in buildings. The method of calculating the horizontal in-plane and out-of-plane earthquake forces is given in **Part B:Chapter 6**.

The loads are influenced by:

- Location - Different parts of the country are more susceptible to movements in the earth's crust that cause earthquakes.
- Soil type - In general, soft soils magnify earthquake movements more than strong rock.
- Building type and geometry – Stiff buildings, such as unreinforced masonry, magnify the earthquake movements experienced at the base. Thus, the top of a building experiences more extreme movements than those at the base. Ductile buildings, such as fully reinforced masonry, are able to absorb movement due to the ductile nature of the structure, the magnification is less.

Hazard Factors, Z , used to describe ground acceleration for a particular geographical location, are determined from AS 1170.4 Table 3.2. Typical values are shown in **Table 1.11**.

Site Sub-soil Classes, used with Hazard Factor to determine the equivalent ground acceleration for a particular soil type, are as designated in AS 1170.4 Clause 4.2 (see **Table 1.12**).

Table 1.11 *Hazard Factors*

Hazard Factor, Z	Location
0.03	Hobart
0.04	Launceston
0.05	Brisbane, Gold Coast
0.06	Cairns
0.07	Tamworth, Townsville
0.08	Sydney, Melbourne, Canberra, Alice Springs, Rockhampton
0.09	Perth, Darwin, Wollongong, Gosford
0.10	Adelaide
0.11	Newcastle, Bundaberg
0.12	Broome, Dampier
0.20	Meckering, Dowerin

Table 1.12 *Site Sub-Soil Classes*

Sub-soil Class	Soil type
A	Strong rock
B	Rock
C	Shallow soil
D	Deep or soft soil
E	Very soft soil



1.6.3 FIRE

The horizontal forces on masonry walls due to fire are difficult to quantify. AS 3700 requires that reinforced masonry walls be designed for a pressure of 0.5 kPa. Refer to **Part B:Chapter 4** of this manual.

1.6.4 DESIGN CONSIDERATIONS

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

Typical load paths for large wall panels using mixed construction are shown in **Figure 1.14**. The first step is to design any unreinforced masonry for out-of-plane horizontal loading. The next is to design any

reinforced cores or bond beams for out-of-plane horizontal loading including those exerted from the unreinforced masonry. Finally the combination of reinforced and unreinforced masonry should be checked for in-plane shear capacity. (If the reinforced cores and bond beams are sized and spaced such that the wall qualifies as wide-spaced reinforced masonry as defined in AS 3700 Clauses 8.5 and 8.6, it will be unnecessary to check the unreinforced components separately.)

Once the masonry elements have been determined, any supporting structures that are needed to transmit horizontal loads

to the ground can be designed. Portal frames, beams and columns should have adequate strength to support the masonry for the loads given in AS/NZS 1170.0, AS/NZS 1170.1, AS/NZS 1170.2 and AS 1170.4. Additional horizontal loads on supports are given in AS 3700 Clause 2.6.3 (ie the greater of 0.5 kPa or sum of the calculated reactions plus 2.5% of vertical load). Supporting members should also have sufficient stiffness to prevent excessive deflection which could cause uncontrolled cracking in unreinforced elements.

Ties, anchors and other connections between the masonry and the supporting

structures must be sized and sufficiently embedded in the masonry such as to ensure that they do not pull out under load. AS 3700 Clause 2.6.4 requires that connections be designed for 1.25 times the calculated load. This is to ensure that the connection is unlikely to be the weakest component in the load path. Many commercially available head ties and column ties do not have much shear capacity and, for large wall panels, the selection of the appropriate tie and spacing should be done carefully. It is good practice to embed connections in reinforced and grouted cores or bond beams where possible.

High-Rise and Medium-Rise Commercial and Residential Buildings

The masonry walls of high-rise and medium-rise buildings should be designed for horizontal loads as described above, except that for loadbearing masonry walls, the compression applied from above significantly increased the wall's resistance to bending failure.

Residential Buildings

Wind loads are exerted on masonry walls as out-of-plane horizontal pressures and in-plane shears. In northern Australia, these pressures are commonly of such a magnitude that reinforced hollow concrete blockwork superstructures are most economical.

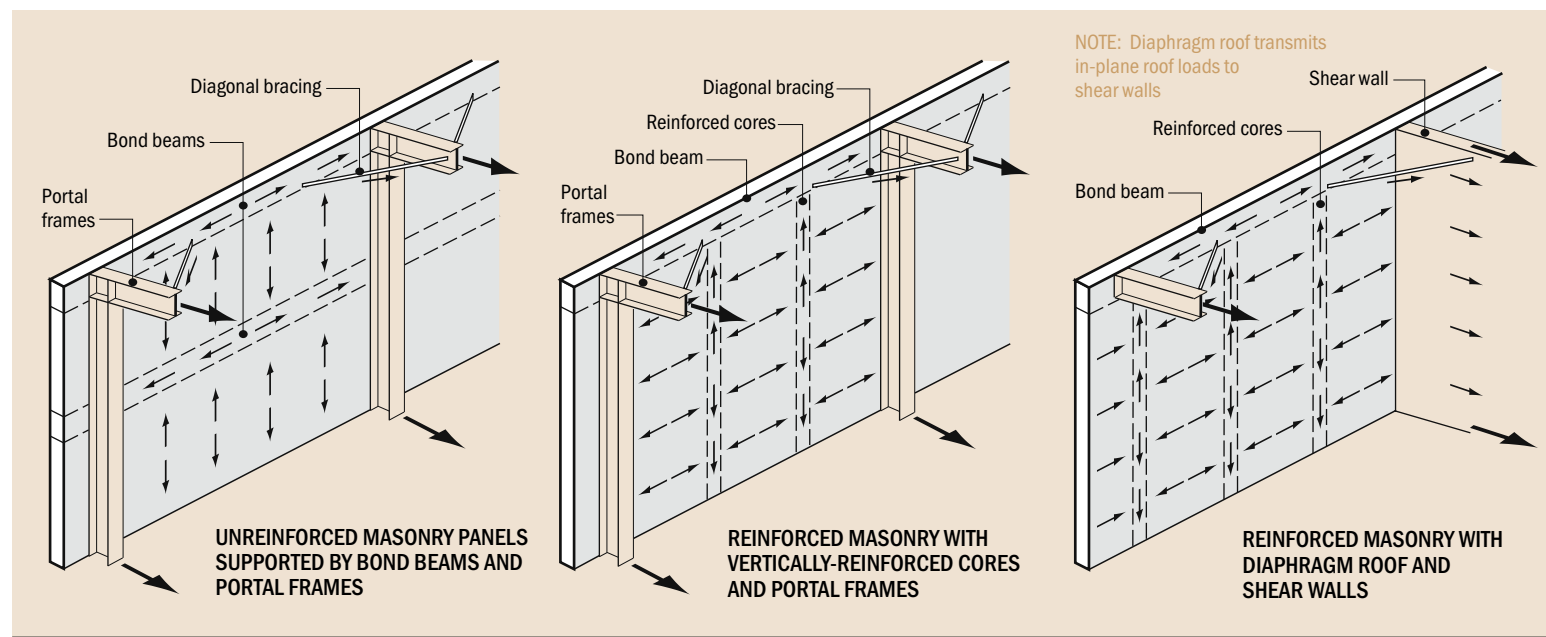


Figure 1.14 Typical Load Paths for Large Wall Panels Using Mixed Construction

1.7

DESIGN FOR MOVEMENT

Unreinforced concrete masonry is a brittle material, prone to cracking due to shrinkage, thermal movement, foundation and other structural movements. Movement joints should be provided in large unreinforced masonry panels to ensure that indiscriminate cracking does not occur. It is suggested that movement joints be placed at points of weakness such as door or window openings and at a maximum of 8.0 metre centres.

Reinforced masonry does not suffer the same cracking problems as unreinforced masonry and it is generally not necessary to place movement joints in reinforced masonry or in the reinforced part of mixed construction. Although it is not normal to break the continuity of reinforced members, consideration should be given to relieving the effects of possible excessive foundation movement. A limiting maximum of 16.0 metres length is suggested for reinforced masonry.

When walls intersect, it is most often a requirement to provide lateral support, thus rendering it difficult to provide for movement at the same location.

As buildings move under the action of material shrinkage or expansion, soil shrinkage or heave, wind load or earthquake load, there may be a tendency for any suspended concrete slabs to move relative to their masonry supports. The slabs may be structurally connected to the masonry walls so that they move as one or, alternatively, structurally separated from the walls so that

slab movement does not induce cracking in the masonry walls, **Figure 1.15**.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

Movement joints in the external unreinforced or mixed construction walls of low-rise commercial and industrial buildings should be provided at the locations of the supporting frames, ie at 6 to 8 metre centres. Horizontal reinforced bond beams do not need to be broken at these centres and may be continuous over a greater distance (perhaps up to 16 metres), which would enable them to span over two panels. For internal walls, the general recommendations noted above should be observed.

High-Rise and Medium-Rise Commercial and Residential Buildings

Movement joints should be placed at points of weakness in unreinforced masonry such as door or window openings and at a maximum of 6.0 metre centres.

Residential Buildings

For houses and similar small buildings, it is suggested that movement joints be placed at points of weakness in unreinforced masonry such as door or window openings and at a maximum of 6.0 metre centres.

Since reinforced masonry houses and small buildings do not suffer the same cracking problems as those of unreinforced masonry, it is generally not necessary to place movement joints in the reinforced masonry or in the bond beams which form part of it.

1.8

DESIGN FOR DURABILITY

The durability requirements of AS 3700 Table 5.1 should be checked and the appropriate salt attack resistance grade of the masonry units, the correct mortar type, the corrosion resistance of built-in components and the required cover to reinforcement specified.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

Because many of these buildings are located in industrial areas, they may be subject to chemical pollutants that are particularly corrosive, cover to reinforcement will require particular attention.

High-Rise and Medium-Rise Commercial and Residential Buildings

High- and medium-rise buildings located close to the sea will require particular attention.

Residential Buildings

Masonry houses near the sea and unpainted will require care in specifying the units, mortar and built-in components such as ties and lintels. Most reinforced single-leaf houses should be sealed and painted, thus eliminating the potential corrosion of the reinforcement and other durability problems.

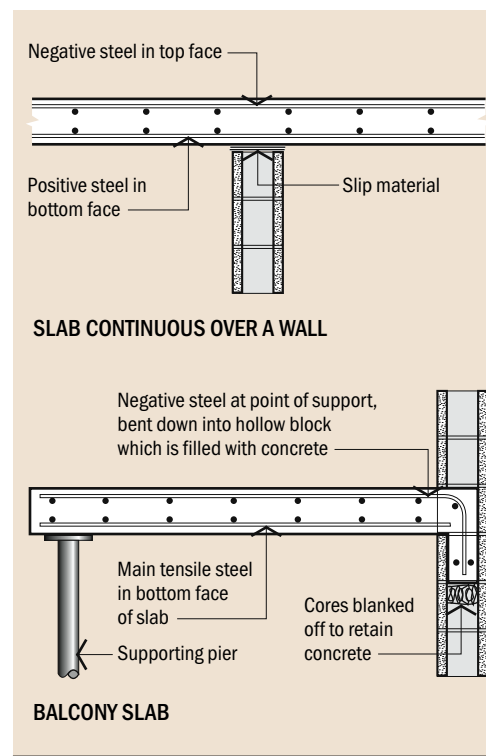


Figure 1.15 Typical Concrete Suspended Floor Slabs Showing a Structurally-Separated and a Structurally- Connected Detail, Respectively

1.9

DESIGN FOR THERMAL PERFORMANCE

Concrete masonry has good thermal insulating properties and thermal mass. If required, the contribution of the masonry walls to the thermal performance of the building envelope should be checked. Considerable cost benefits may accrue through the thermal mass of dense concrete masonry and the enhanced insulation of lightweight concrete masonry.

The National Construction Code (NCC) – Building Code of Australia (BCA), Volume One Section J, sets out the energy provisions for Class 2 to 9 buildings^[1].

The National Construction Code (NCC) – Building Code of Australia (BCA), Volume Two Part 3.12, sets out the energy provisions for Class 1 Buildings (House).

The energy provisions in both parts of the NCC–BCA have been progressively increased during period 2003-2010.

The energy consumption levels in the NCC–BCA approximate “6 Star” for houses as defined in the National House Energy Rating Scheme, and the energy consumption levels in NCC–BCA Volume One Part JV for Class 2 to 9 buildings.

Note 1

There are no NCC–BCA requirements for Class 7a buildings (carparks) or Class 7b buildings (building for storage, or display of goods or produce for sale by wholesale).



Sustainability issues are taking on a major focus in building design and certification. To date, the approach in the building regulations has been to concentrate on the in-service performance of buildings, making provision for both Deemed-to-Satisfy Solutions and Alternative Solutions (based on computer simulation and the published verification methods). This is a soundly-based decision, given that, in many cases, in-service energy performance far outweighs the other energy expenditure associated with building products. However, there is now a strong push to consider the energy involved in winning the raw materials, manufacture, transport, construction and demolition of building products.

There are various schemes currently being promoted in Australia for determining the overall sustainability of building products. However, there is a real danger that they may fail to provide enough precise data on the in-service performance for each product, under a range of applications and climates. If unchecked, this could lead to poor decision-making and the selection of products, which appear to be environmentally friendly, but are, in fact, inappropriate for the actual application. Any ecolabelling scheme must be based on the complete life-cycle analysis including both embodied and in-service characteristics (accounting for thermal mass), and should be properly benchmarked against the most common acceptable alternative form of construction



A comprehensive system of ecolabelling building products known as the “whole-of-building, whole-of-life, benchmarked, LCA method”, has been developed.

This uses an array of sixteen combinations (four building types in four climate zones) to compare the whole-of-life effects of various buildings products against the corresponding performance of forms of construction deemed to satisfy the requirements of NCC–BCC Volumes One and Two as appropriate. Refer to draft National Standards NS 12000 .

When houses and other small buildings are constructed on clay or similar soils, moisture movements in the soils will lead to expansion or contraction of the soil causing the building to either cantilever beyond a shrinking soil mound or sag between an expanded soil rim. Reinforced masonry panels in the ground floor of a building may be designed to act compositely with concrete footings to which they are connected by starter bars. This form of construction can lead to significant savings in footing costs.

Low-Rise Commercial and Industrial Buildings with Large Wall Panels

The piers and footings of large low-rise buildings are beyond the scope of this manual. However, slabs and footings for relatively small low-rise buildings are within the scope of AS 2870 and this manual. Considerable cost savings are achievable when reinforced masonry walls are structurally connected to footings of reduced cross section as described below.

High-Rise and Medium-Rise Commercial and Residential Buildings

Piers and footings of high-rise buildings are beyond the scope of this manual.

Residential Buildings

The most common form of construction for new housing in Australia is unreinforced brick walls (either cavity or brick veneer) supported by reinforced concrete strip footings or stiffened raft slabs. As the supporting soil contracts or expands, the cantilevering or spanning concrete

footings or rafts are forced by the mass of the supported building to deflect. Any unreinforced brickwork may crack, moving sympathetically with the deflected concrete supporting structures. The design solutions adopted in AS 2870 Figure 3.1 cater for this scenario by ensuring that the internal and external concrete beams or footings have sufficient depth to minimise the possible deflection, and articulating the masonry wall at points of weakness ensuring that indiscriminate cracking is minimised. For relatively stable soils, these systems will provide effective and economical solutions.

However, there is another practical approach to house and small-building design that is common throughout northern Australia. Walls may consist of strong panels of reinforced hollow concrete blockwork tied monolithically to the concrete footings or slabs. The strong, stiff combination of wall and slab or footing span discrete distances over expanding or shrinking foundations, without cracking or showing other signs of distress. Integrated footing/wall deep-beam systems in which the reinforced concrete slab or footing and the concrete masonry wall are structurally connected may be considered to act compositely to resist the loads when soil movement occurs. The concrete ground beams or footings may be poured integrally with reinforced concrete floor slabs, or they may be separate from the floor. This system is described in AS 2870 Clause 3.2.5.

The design must also make provision for the control of termite attack. AS 3660 provides deemed-to-comply slab, footing and masonry details that are resistant to termites (**Figure 1.16**).

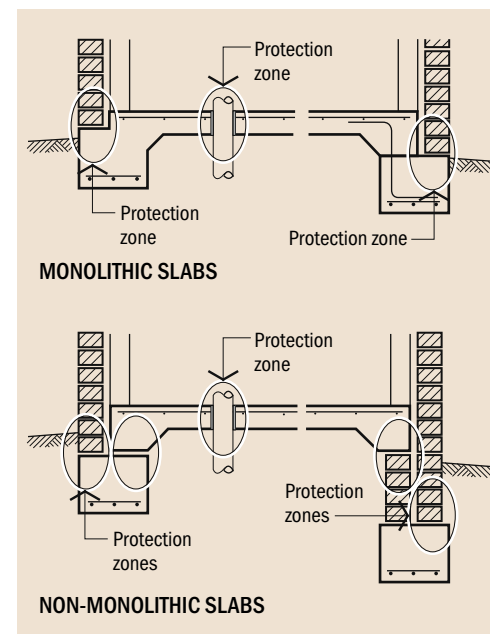


Figure 1.16 Termite Protection Zones Requiring Supplementary Protection by One of the Methods Listed in AS 3660

Set out below is a general glossary of concrete masonry terms. Where appropriate, the definitions have been expanded to give more information. These terms are hyperlinked from the Chapters in which they are first used.

1.11.1 GENERAL MASONRY TERMS

Hollow concrete block

Concrete masonry unit complying with AS/NZS 4455 that consists of concrete face shells and webs between cores.

Face shells

The two vertical faces of a hollow concrete block that are visible in a completed wall. Typically the minimum face-shell thickness of 140 mm wide blocks is 25 mm and for 190 mm or 290 mm wide blocks is 30 mm. In all cases the face shells are tapered to facilitate easy removal of the blocks from the moulds during manufacture although, in some blocks intended for reinforced use, the taper is kept to a minimum.

Webs

The transverse parts of a hollow concrete block that join the face shells. Webs may be full height (the same height as the face shells), rebated (shorter than the face shells) by up to 50 mm to allow horizontal steel to pass through) or knock out (with planes of weakness which enable them to be partially removed during construction). Some blocks, such as lintel blocks, are U-shaped without vertical webs.

Water thickener

A methyl cellulose additive for mortar to hold the moisture in suspension thus

permitting the proper hydration of the cement and reducing the tendency to dry out. A water thickener may also include an agent which assists workability of the mortar.

Bed-joint reinforcement

Small-diameter steel reinforcement placed in the mortar joints of masonry walls. Bed-joint reinforcement consisting of two 3 mm diameter galvanized wires held in position by smaller cross wires will assist in the control of cracking of finished masonry.

Main reinforcement

The steel reinforcement grouted into the masonry to resist the principal loads resulting from wind, earthquake, gravity or soil movement.

Secondary reinforcement

The reinforcement used to distribute concentrated loads and resist shrinkage or thermal movement. Secondary reinforcement may consist of steel bars grouted into the masonry, or may be bed-joint reinforcement.

Unreinforced masonry

Elements of masonry that do not contain main reinforcement. Unreinforced masonry may incorporate steel bed-joint reinforcement if required.

Vertically-reinforced core

A masonry element consisting of main reinforcement grouted vertically into the cores of hollow blockwork. Due to cover limitations in thin blocks, the most common hollow concrete blocks used with vertical reinforcement are 140 mm, 190 mm or 290 mm wide.

Bond beam

An element of reinforced masonry consisting of main reinforcement grouted horizontally into hollow blockwork. Due to cover limitations in thin blocks, the most common hollow concrete blocks used in bond beams are 140 mm, 190 mm or 290 mm wide. The blockwork may consist of lintel blocks (U-shaped), H blocks, Double-U blocks, hollow blocks with knock-out webs or hollow blocks with rebated webs.

Mixed construction

Masonry walls consisting of a combination of unreinforced masonry and reinforced masonry (reinforced cores and/or bond beams) where the spacing of the reinforced elements is greater than the spacing permitted for reinforced masonry (ie spacing greater than 2.0 metres for out-of-plane bending and a horizontal spacing greater than 2.0 metres for vertically-reinforced cores, or a vertical spacing greater than 3.0 metres for horizontal bond beams for in-plane shear.)

Reinforced masonry

Masonry walls into which specified quantities of main reinforcement are incorporated at centres not exceeding specified limits as follows:

For out-of-plane bending, if either horizontal or vertical main reinforcement is incorporated at centres not exceeding 2.0 metres, the masonry is considered to be "wide-spaced reinforced masonry". The reinforcement requirements specified in AS 3700 Clause 8.6 are:

The main reinforcement in the direction of bending shall:

- (a) be spaced at centres not exceeding 2000 mm
- (b) include an area of at least 100 mm^2 within 300 mm of the edges of the member; and
- (c) be such that $M_d \geq 1.2$ bending capacity of the unreinforced maximum.

For in-plane shear, if horizontal main reinforcement is incorporated at centres not exceeding 3.0 metres together with vertical main reinforcement at centres not exceeding 2.0 metres, the masonry is considered to be "wide-spaced reinforced masonry". The reinforcement requirements specified in AS 3700 Clause 8.7 are:

The reinforcement shall comply with the following:

- (i) *The reinforcement shall be located symmetrically in the cross section.*
- (ii) *Vertical reinforcement shall be spaced at centres not exceeding $0.75 H$ and in any case not greater than 2000 mm horizontally. Horizontal reinforcement shall be spaced at centres not exceeding $0.75 L$ and in any case, not greater than 3000 mm vertically.*
- (iii) *The vertical reinforcement shall be such that $A_s \geq 0.0013 A_d$ and the horizontal reinforcement is such that $A_s \geq 0.0007 A_d$. If the reinforcement does not meet these requirements then the wall shall be designed in accordance with Clause 7.5.3.*
- (iv) *Reinforcement with an area of at least 100 mm^2 shall be included within 300 mm of edges parallel to the main reinforcement. It shall be permissible to omit the reinforcement at an edge of the wall, provided the member is anchored to an abutting reinforced concrete member.*



Note: Qualification as reinforced masonry rather than mixed construction affects robustness limits and the design loads for earthquake

Anchorage by the provision of starter bars of an area equal to or exceeding the area of the main reinforcement lapped with the main reinforcement and anchored to the concrete member in accordance with the requirements of AS 3600, shall be deemed to satisfy this requirement.

Close-spaced reinforced masonry

A system of reinforced masonry that is fully-grouted and contains reinforcement at a maximum spacing of 800 mm both horizontally and vertically. The minimum area of horizontal and vertical reinforcement shall be 0.0013 A_g .

Wide-spaced reinforced masonry

A system of reinforced masonry, satisfying the criteria for reinforced masonry for the particular action being considered, but not satisfying the requirements for close-spaced reinforced masonry.

1.11.2 ACOUSTIC TERMS

Sound

Sound is created by vibrating bodies. It is carried from the source to the receiver, usually the ear, by a compression and decompression wave. The ear is an extremely sensitive frequency and pressure measuring device, capable of responding to minute variations in both phenomena. It perceives sound as a combination of frequency spectra as a series of pressure variations. Sound audible to humans is generally in the frequency range from 125 Hz (low pitch) to 5 kHz (high pitch).

Noise

Noise may be defined as unwanted sound or sound pollution. With ever-increasing sources of noise and a trend towards higher population densities, noise control has become an important environmental issue.

Decibel

The decibel scale is a scale of sound intensity ratios. Its unit, the decibel (dB), approximates the smallest change of sound detectable by the human ear. A change of 10 dB (1 bel), at any base sound intensity, corresponds to a ten-fold change in sound intensity, 20 dB to a one-hundred-fold change, 30 dB to a one-thousand-fold change and so on. It is a relative, not an absolute scale.

To define an absolute scale of sound intensity level, the average threshold of hearing was adopted as the zero point. This corresponds to an intensity of 10–12 W/m² and an RMS pressure of 2×10^{-5} Pa. The human ear can tolerate a maximum intensity of approximately 120 dB based on this scale, corresponding to 1 W/m² and an RMS pressure of 20 Pa.

Weighted Sound Level

For convenience in defining a measured or design sound level by a single figure without having to define it in terms of a sound spectrum over a number of frequency bands, and to permit single-figure measurements to be made with sound-level meters, “weighted” sound level measurements are often used. Three weighting networks, referred to as “A”, “B” and

“C”, are used for comparison purposes.

The “A” weighting network is designed to simulate as far as possible the response of the human ear to complex sounds of different frequencies. Sound measurements using the “A” network are expressed as dBA.

The “B” weighting network provides an intermediate degree of low frequency sound attenuation. Sound measurements using the “B” network are expressed as dBB.

The “C” weighting network provides the closest practical approach to equal response to sounds of all audible frequencies within the meter’s range. Sound measurements using the “C” network are expressed as dBC.

Sound Level Meter

A sound level meter in its simplest form is a microphone and amplifier capable of measuring the intensity of a complete sound, either as a whole or at each of a number of frequency bands or ranges in the audible frequency spectrum, or its intensity in a “weighted” scale. The meter is fitted with electronic filters to permit the exclusion of frequency ranges other than that being measured and a calibrated measuring device. Other filter networks are built into the electronic circuits to enable weighted sound level measurements to be made over the full audible frequency range as an alternative to measurements at each frequency band.

Airborne Sound

Airborne sound results from a source which is remote from the receiver and which is

transmitted to the receiver through the air as pressure waves.

Impact Sound

Impact sound in a structure such as a wall results from a body striking the structure and causing sound to be transmitted as vibrations directly through the structure.

Noise Reduction Coefficient

The sound absorbing properties of materials are compared by measuring absorption coefficients at frequencies of 250, 500, 1000 and 2000 Hz. The averaged value over the spectrum, as a proportion of the notional absorption of an open window (which is assumed to be 1.0 i.e. 100% absorption) is termed the Noise Reduction Coefficient (NRC) for the material. Such coefficients range from 0.02 (2% absorption) for hard plaster to around 0.8 (80% absorption) for special acoustic materials.

Weighted Sound Index, R_w

There is considerable advantage in expressing a wall’s ability to resist the transmission of airborne sound as a single number. The sound transmission loss equals the incident sound at each audible frequency less the transmitted sound at the same frequency. The mean of the sound transmission losses over the audible range of frequencies gives a good indication of sound attenuation for concrete masonry and similar massive walls, although it is not reliable for many lightweight materials at critical speech-privacy frequencies. Therefore, it is more useful to calculate a “weighted mean”, rather than a “mean”, of the sound transmission loss.



The Weighted Sound Index (R_w) for laboratory measurements is defined in AS/NZS 1276.1 (based on ISO 717-1) and ISO 140.3. In summary, R_w is determined by comparing the set of laboratory test sample transmission losses against a set of reference data obtained from ISO 717-1 for the sixteen one-third octave bands between 100 Hz and 3150 Hz. The reference data is amplitude shifted in steps of 1 dB by the same amount until the sum of unfavourable readings determined at each frequency is as large as possible, but not more than 32 Hz. R_w is equal to the 500 Hz value of the reference data less the number of decibels that the reference data was shifted.

Previously in Australia, Sound Transmission Class (STC), based on an ASTM test procedure, has been used to define a wall's ability to resist the transmission of airborne sound. However, the Building Code of Australia now defines its performance requirements in terms of the ISO based Weighted Sound Index (R_w). In practical terms, there is little difference between the two for concrete masonry, and the test results included in this manual are expressed as STC values, rather than R_w . AS/NZS 1276.1 Appendix ZA provides a comparison of STC and R_w .

Spectrum Adaptation Terms, C and C_{tr}

Notwithstanding the fact that a weighted index (eg R_w) can provide an improved indication of acoustic attenuation of audible frequencies, there are some sources of sound, such as urban traffic noise, that are not well accommodated. The Spectrum

Adaptation Term (C_{tr}) has been introduced to further describe the performance of a wall when subjected to sound likely to originate from A-weighted urban traffic noise. A similar Spectrum Adaptation Term (C) may also be used to describe the response to A-weighted "pink" noise. The Spectrum Adaptation Terms (C and C_{tr}) are defined in AS/NZS 1276.1 (based on ISO 717-1).

Both C and C_{tr} have negative values, such that when they are added to the R_w , they diminish the combined value. Therefore relatively small values for C and C_{tr} indicate good overall performance whilst large values indicate a deterioration of performance at low frequencies. Typically, concrete masonry will have a values in the following ranges:

C -1 to -2
 C_{tr} -3 to -10.

Weighted Standardised Level Difference, $D_{nT,w}$

The Weighted Standardised Level Difference ($D_{nT,w}$), for field measurements is defined in AS/NZS 1276.1 (based on ISO 717-1) and ISO 140-4 in a manner similar to that used for Weighted Sound Index (R_w).

Previously in Australia, Field Sound Transmission Class (FSTC), based on an ASTM test procedure, has been used to define a wall's ability to resist the transmission of airborne sound in the constructed building. However, the Building Code of Australia now defines its performance requirements in terms of the ISO based Weighted Standardised Level Difference ($D_{nT,w}$).

1.11.3 ROBUSTNESS TERMS

Isolated pier

An isolated pier is a masonry member where neither the thickness nor the length exceeds one fifth of its height. For example, a member which is 2.4 metres high will be considered as an isolated pier if its length is less than 480 mm. If it is greater than 480 mm, it is considered to be a wall.

Length, L_r

The length used for robustness calculations measured between vertical supports, or, if an opening is incorporated, from a vertical support to the edge of the opening.

1.11.4 FIRE TERMS

Basalt

During many years of fire testing, the term 'basalt' has been loosely applied to various basic rocks including Basalt, Dolerite, Gabbro and Trachyte that contain less than 10% quartz. Masonry units containing them have been shown to have enhanced structural adequacy. From tests using basalt aggregates this enhancement was analyzed and values for units with basalt aggregate content at least 45% were evaluated on the basis of at least 45% of the total aggregate (coarse and fine) being basaltic.

Fire Resistance Level (FRL)

The grading periods for structural adequacy (stability against collapse), integrity (resistance against excessive cracking and the passage of flame and hot gasses) and insulation (resistance to the passage of heat). FRLs are expressed in minutes in the sequence of structural adequacy, integrity and insulation, eg 90/60/30.

Material Thickness

Also commonly referred to as the Equivalent Thickness, this is a measure of the amount of actual material in a hollow unit. It is calculated by dividing the net volume of the unit (gross volume less volume of cores) by the face area of the unit. Even though hollow blockwork is commonly laid on face-shell mortar bedding, the material thickness of a wall is assumed to be the same as that of the masonry units used in its construction. If concrete grout or equivalent is placed in all cores of a wall of hollow units, the material thickness will be equal to the total thickness. If some cores are left ungrouted, the material thickness of the wall will be regarded as equal to the material thickness of ungrouted units.



1.11.5 VERTICAL LOAD TERMS

Concentrated load

A concrete slab bearing on the top of a wall will usually distribute concentrated loads to the wall as a relatively uniform load

Loadbearing wall

Any wall that supports loads in addition to its own self-weight.

Non-loadbearing wall

Any wall that supports only its own self-weight.

1.11.6 HORIZONTAL LOAD TERMS

Ductility

The ability of the structure or element to undergo repeated and reversing inelastic deflections beyond the point of first yield while maintaining a substantial proportion of its initial load-carrying capacity.

Ductile structures

It is assumed in this manual that ductile structures include:

- buildings with reinforced concrete floors and reinforced masonry loadbearing walls, and
- buildings with reinforced concrete floors, beams and columns and reinforced masonry shear walls.

Concrete floors, beams and columns must comply with AS 3600.

Reinforced concrete masonry loadbearing walls and shear walls must comply with AS 3700 and consist of 190 mm or 140 mm hollow concrete blockwork with close-spaced reinforcement (horizontal and vertical steel reinforcing bars, N12 or larger, grouted into the blockwork at up to 800 mm centres) in concrete of characteristic compressive strength at least 20 MPa.

Nonductile structures

It is assumed in this manual that nonductile structures include:

- buildings with loadbearing walls or shear walls consisting of unreinforced masonry, and
- buildings with reinforced concrete masonry consisting of wide-spaced reinforcement (greater than 800 mm centres either horizontally or vertically).

0.1g

0.1g is the force equal to 0.1 times the gravitational force exerted by a particular element. A typical 190 mm hollow concrete, reinforced blockwork wall (consisting of grouted elements and ungrouted elements) would have an average wall density of approximately 220 kg/m² and a gravitational force of approximately 2.2 kN/m². This would correspond to a lateral working pressure at 0.1g of 0.22 kPa.

Out-of-plane horizontal load

A pressure or point load which acts perpendicular to the plane of the wall. This includes earthquake loads, wind pressures or suctions on a building wall.

In-plane horizontal load

A force that acts in the direction of the plane of the wall. This includes:

- vertical compression resulting from gravity, or overturning forces and horizontal shear forces in shear walls intended to convey lateral earthquake loads, or
- wind loads from the top of the structure to the base.

1.11.7 MOVEMENT TERMS

Contraction joints

Opening joints to cater for shrinkage of the wall. They usually incorporate a flexible sealant at the surface.

Expansion joints

Closing joints that incorporate a compressible material of sufficient thickness to cater for the expansion in the walls adjacent to the joint.

Articulation joints

Both opening and closing joints to cater for movement of the footings or supports.

1.11.8 DURABILITY TERMS

Protected Grade

Masonry units that would suffer substantial and early failure when subjected to the test method in AS/NZS 4456.10.

General Purpose Grade

Masonry units that, in the supplier's experience, can be demonstrated to have

a history of surviving under environmental conditions similar to the site considered. Products that fit this category are not expected to meet the mass-loss criterion for "exposure category" when tested in accordance with AS/NZS 4456.10.

Exposure Grade

Masonry units that, in the supplier's experience, can be demonstrated to have a history of surviving in saline environments.

1.11.9 THERMAL PERFORMANCE TERMS

Thermal Conduction

The heat transfer mechanism whereby heat energy travels through matter. Heat moves in the direction of decreasing temperature.

Thermal Convection

Heat transfer by fluid flow in liquids and gases resulting from density gradients caused by temperature variations. In this context, convection in gases is significant where air can move through openings in structures.

Thermal Radiation

A form of electro-magnetic radiation which does not depend on the presence of matter to transfer heat energy. It can operate just as effectively in a total vacuum. Opaque materials interposed between a heat radiation source and its object prevent heat transfer by radiation. Glass and other translucent materials offer little resistance to radiated heat from the sun, its major source.



Thermal Conductivity (k)

The thermal conductivity of a material is defined as the thermal energy transmitted in unit time through unit area of a slab of a homogeneous material of unit thickness when unit temperature difference is maintained between its surfaces. The unit of thermal conductivity is watts per metre per kelvin ($W/[m.K]$).

Temperature (K)

In thermal conductivity calculations, the temperature unit adopted is the kelvin. The kelvin scale is known as the thermodynamic temperature scale. Its zero point is $-273.15^{\circ}C$, absolute zero temperature. The freezing point of water, $0^{\circ}C$, is equivalent to 273.15 K and a temperature change of 1 K is the same as $1^{\circ}C$. The conversion equation is $K = ^{\circ}C + 273.15$.

Thermal Conductance (C)

The thermal conductance of a structural component or a structure is defined as the thermal energy transmitted in unit time through unit area of a uniform structural component or structure of particular thickness, per unit temperature difference between surfaces. The unit of thermal conductance is watts per square metre per kelvin ($W/[m^2K]$).

Film or Surface Conductance (f_i and f_o)

Film or surface conductance is the conductance of the air film at the inner (f_i) or outer (f_o) surface of a wall or barrier. Its unit of measurement is $W/(m^2K)$. Film conductance values thus apply to inner and outer wall surfaces.

Air Space Conductance (a)

Air space conductance is the conductance of an enclosed air space such as wall cavity or ceiling space.

Thermal Resistivity (1/k)

Thermal resistivity is the reciprocal of thermal conductivity. It is resistance to heat flow per unit temperature difference and thickness. The unit of measurement is metres kelvin per watt ($[m.K]/W$). Thermal properties of actual components may be calculated from these figures by multiplying them by their thickness.

Thermal Resistance (R)

Thermal resistance is the reciprocal of thermal conductance and is designated R . It is a measure of the resistance to heat flow per unit temperature difference of the full thickness of the heat barrier. The unit of resistance is metres² kelvin per watt ($[m^2K]/W$).

Thermal Transmittance (U)

Thermal transmittance is the heat energy transmitted in unit time through unit area of a given composite structure (eg a wall consisting of concrete masonry blocks, air films, cavities, etc) per unit temperature difference between the air films on the two sides of the structure. The unit of thermal transmittance is the same as the unit of thermal conductance ($W/[m^2K]$). It is an overall measure of heat transfer from the air film on the warmer side of a wall or other structure to the air film on the cooler side. Thermal conductance on the other hand is a measure only of heat transfer through

an individual homogeneous element of the structure, from surface to surface, not taking into account the effect of air films or cavities. The property is commonly referred to as the 'U'-factor of a construction.

Thermal Mass

Thermal mass (also known as thermal inertia or thermal capacitance) is a measure of a material's ability to retain its current level of heat energy when subjected to an external temperature differential.

1.11.10 FOOTING TERMS**Foundation**

The ground that supports the building.

Footing

The construction that transfers the loads from the building to the foundation. The footings referred to in this handbook are:

- reinforced strip footings (independent of wall and slab);
- reinforced concrete slabs stiffened with beams;
- reinforced concrete strip footings or slabs and beams connected monolithically with reinforced hollow concrete blockwork walls.

Articulation

Construction in which masonry walls are divided into discrete panels to permit wall movement to take place without the formation of cracks.

Structurally Independent Wall/Footing System

Concrete footings and masonry walls that are structurally independent of each other. As the soil moves, the footings cantilever (or span), resisting forces imposed by the structurally independent walls above. Unable to tolerate any appreciable movement, the walls may crack. The design approach is to limit the footing deflection and limit the deflection ratio so that any cracks that form in the walls remain at an acceptable width. Articulation of the walls may assist in confining movement to areas within the wall where it is less noticeable.

Structurally Integrated Footing/Wall Deep Beam System

Concrete footings structurally connected to reinforced hollow concrete blockwork walls to form a deep beam system. As the soil moves, the footing/wall deep beams cantilever (or span), resisting the forces imposed by their own self weight, permanent and imposed loads from floors and roofs. The design approach is to provide sufficient strength and stiffness in the footing/wall deep beams to ensure that they do not crack when required to cantilever (or span). In large buildings, articulation of the walls may assist in confining movement to areas within the walls where it is least noticeable. Care must be taken to ensure that articulation does not diminish the strength of the footing/wall deep beams in those areas where it is required.



Movement Joint

An intentional plane of weakness built into the structure to permit one element to move relative to another without diminishing the structural integrity or the aesthetics of the structure.

Crack

An unintentional plane of weakness in the structure which opens when subjected to the stresses caused by thermal or soil movement, shrinkage, permanent, imposed, fire or earthquake loads. In some circumstances cracks may lead to unacceptable loss of structural integrity and/or appearance.

1.12

STANDARD DESIGN CHARTS

Most chapters in Part B of this manual include design charts for common loadings and applications. The general procedure for their use is as follows:

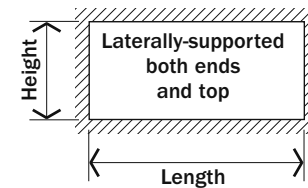
- Select the required wall thickness (and, if appropriate, the reinforcement arrangement)
- Select the appropriate support conditions, eg supported on four sides.
- Project the length of the wall between vertical supports and the height of wall between horizontal supports to determine the design point. In the case of reinforced masonry, a reinforced core or bond beam is considered to be a support. Treat control joints as unsupported free ends.
- Select a curve that is above or to the right of the design point. Read off the load capacity corresponding to the selected curve. If necessary, interpolate between the curves.
- Check that the masonry wall is adequate for other loadings, design requirements and construction requirements.

The design charts may be used for the rapid checking of masonry walls shown on drawings by the following procedure:

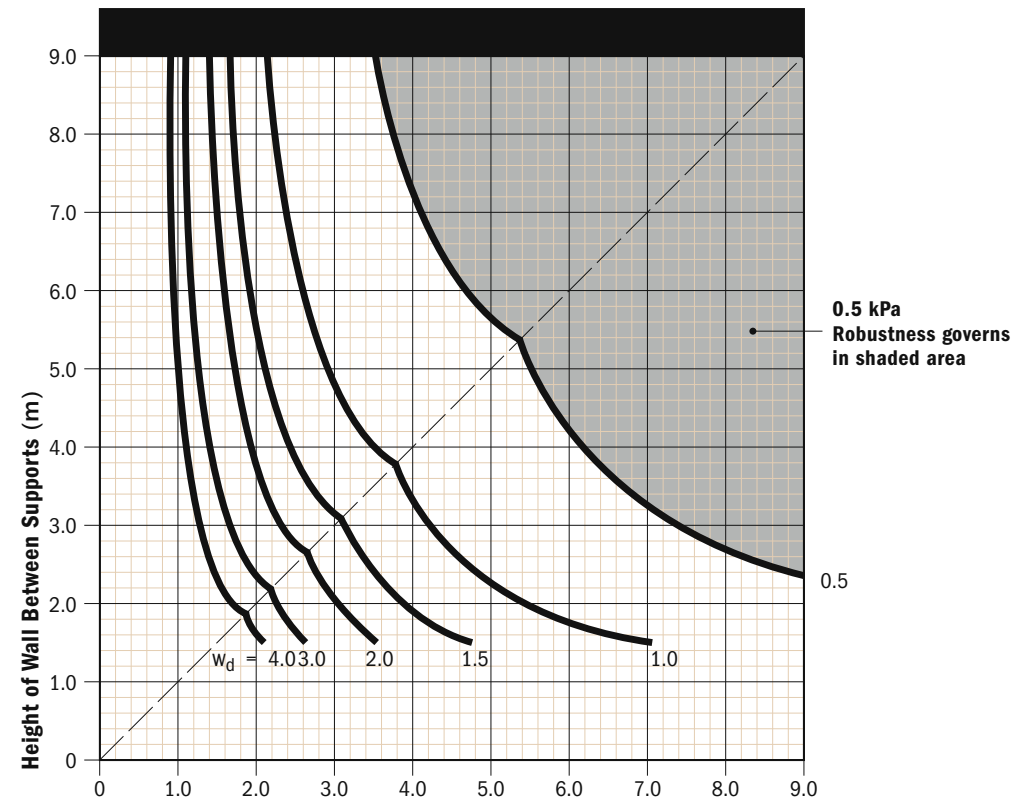
- Print the appropriate design chart onto an overhead transparency material.
 - Move the transparency over 1:100 scale elevations of the walls to be checked ensuring that they fall within the envelope described by the axes and the curve representing the design load.
- OR
- Draw a horizontal line on the transparency at the required height of the walls, from the vertical axis to the curve representing the design load. The length of this line is the permissible length of wall between supports. The plan view at 1:100 scale of each wall may be rapidly checked using the transparency.

UNREINFORCED MASONRY – without openings

1 of 4



Design pressure, w_d (kPa)



Typical Design Chart

1.13.1 AUSTRALIAN STANDARDS**Structural Masonry Standards**

- AS 3700 *Masonry structures*
- AS 4773.1 *Residential Masonry Part 1: Design*
- AS 4773.2 *Residential Masonry Part 2: Construction*

Materials Standards

- AS/NZS 4455.1 *Masonry units, pavers, flags and segmental retaining wall units Part 1: Masonry units*
- AS/NZS 4456 *Masonry units and segmental pavers – Methods of test*
- AS/NZS 4671 *Steel reinforcing materials*
- AS 3972 *Portland and blended cements*
- AS 1316 *Masonry composite cement*
- AS 1672.1 *Limes for building*
- AS 2758.1 *Concrete aggregates*
- AS/NZS 2699.1 *Built-in components for masonry construction - Wall ties*
- AS/NZS 2699.2 *Built-in components for masonry construction - Connectors and accessories*
- AS/NZS 2699.3 *Built-in components for masonry construction - Lintels and shelf angles (durability requirements)*
- AS 2904 *Damp proof courses and flashings*

Associated Standards

- AS 3700 Supplement 1 *Masonry structures – Commentary*
- AS 1684 *National Timber Framing Code*
- AS 3600 *Concrete structures*
- AS 2870 *Residential slabs and footings – Construction*
- AS 3660.1 *Termite management – New Building work*
- AS 3660.2 *Termite management – In and around existing buildings and structures - Guidelines*

Loading Standards

- AS/NZS 1170.0 *Structural design actions – General principles*
- AS/NZS 1170.1 *Structural design actions – Permanent, imposed and other actions*
- AS/NZS 1170.2 *Structural design actions – Wind actions*
- AS/NZS 1170.3 *Structural design actions – Snow and ice actions*
- AS 1170.4 *Structural design actions – Earthquake actions in Australia*
- AS 4055 *Wind loads for housing*
- AS 1530.4 *Fire resistance tests of elements of building construction*

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