Manual 9

THINK BRICK AUSTRALIA

Detailing of Clay Masonry

This publication updates and supersedes the publication of the same name published by the Clay Brick and Paver Institute and in May 2000.

Cover: The School of Health Sciences at the University of Notre Dame Australia is the first new building on a campus that has helped revitalise the West End of Fremantle. The building's "contemporary warehouse" appearance helps link it with adjacent historic brick buildings that have been repurposed. Designed by Marcus Collins Architects, built by W Fairweather & Son. Photograph by Gary Peters, courtesy Austral Bricks.

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1. Introduction

This manual provides guidance for the detailing of clay masonry in buildings. The guidance is of a general nature, representing industry recommendations for good practice. It should always be recognised that alternative methods exist, and might be preferred in some situations for architectural, geographical or other reasons.

In conjunction with this manual, appropriate reference should be made to the Building Code of Australia (BCA)[1] and the various relevant Australian standards, including Masonry Structures (AS 3700)[2] with its Commentary[3], and Residential Slabs and Footings (AS 2870)[4] with its Commentary[5].

Where specific dimensions are given on details in this manual, they should be regarded as indicative only. The use of terms such as low wind, high wind or earthquake loading should be interpreted as necessarily vague – specific dimensions for roof tie-downs, anchorages for earthquake resistance and so on should be designed by a structural engineer to suit the particular circumstances, the local loading and soil conditions, and the requirements of the local authorities. The diagrams should not be taken as a substitute for engineering detail drawings.

Durability considerations are not covered in this manual and are included in TBA Manual 7: Design of Clay Masonry for Serviceability[6].

2. Roof Anchorage

Roof anchorages are required to resist not only uplift from wind forces, but also lateral shear from wind and earthquake forces. Requirements vary widely for different regions, depending on the level of wind and earthquake risk. Where the term high wind is used, it should not be taken to include cyclonic wind conditions, but only a comparatively higher level of wind than that referred to as low wind. Some typical arrangements are indicated for cavity walls, veneer walls and single-skin walls.

2.1 Cavity walls

For cavity walls, three common details are shown. The detail in Figure 1 is suitable for low wind loads and uses a galvanised steel strap to tie the top plate to the masonry wall. The roof structure must also be adequately connected to the top plate at every truss or rafter. Resistance against the uplift force is provided by the weight of the masonry and to mobilise this sufficiently the strap must be embedded at least 600 mm down in the wall. It is usually assumed that the weight of a section of the masonry wall acts against the force in the tie-down strap, with a low level of bond strength in the masonry providing further resistance.

For higher wind loads, a detail such as that shown in Figure 2 can be used. In this detail the tie-down strap is attached directly to the rafter or truss and uses a steel bar embedded in both leaves of masonry to mobilise a greater weight of the wall. For very high wind loads such as in cyclonic regions a continuous tie-down rod carried through to the footing would be required. Such a detail is not shown here.

Where resistance to significant earthquake forces is also required, a detail such as that shown in Figure 3 can be used. This detail mobilises both leaves of masonry for resistance to uplift forces and includes positive tying of the roof structure and the top plate to the top of the wall so that resistance to horizontal shear forces is provided.

Figure 1. Roof – cavity wall (low wind)

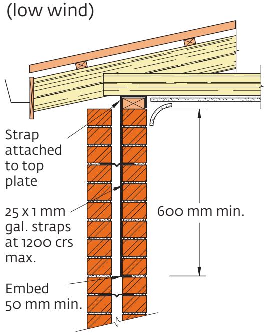


Figure 2. Roof – cavity wall (high wind)

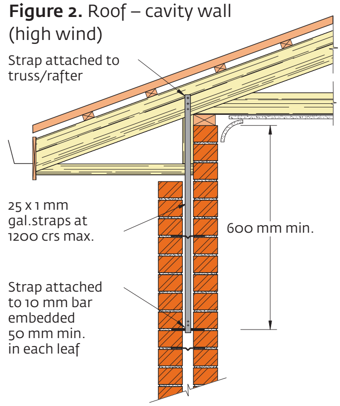
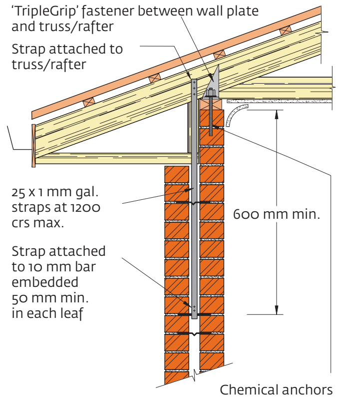


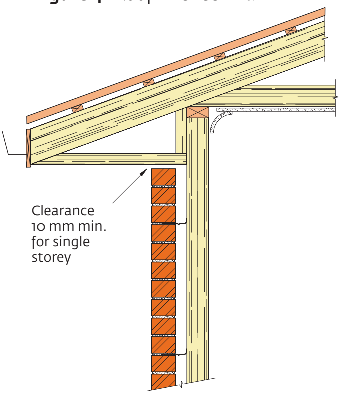
Figure 3. Roof – cavity wall (high wind and earthquake)



2.2 Veneer walls

For veneer walls in housing, the building frame is assumed to support the load of the roof structure (including any uplift force). Where the frame is of timber, the only requirement for the masonry is that a sufficient gap should be left between the top of the wall and the underside of the overhanging eaves to accommodate shrinkage of the frame. For softwood framing this gap should be at least 10 mm for a single-storey building and 20 mm for a two-storey building (with timber floors). A typical detail is shown in Figure 4.

Figure 4. Roof – veneer wall



2.3 Single-skin walls

For single-skin (clay block) walls, three common details are shown. The detail in Figure 5 is suitable for low wind areas and uses a reinforced bond beam at the top of the wall to provide tying for the roof structure. A galvanised steel truss plate is hooked to the reinforcement in the bond beam. Alternatives might use a threaded rod or a section of steel angle anchored into the bond beam.

For higher wind loads a detail such as that shown in Figure 6 might be used. In this detail the truss plate is attached to the roof structure with a galvanised strap passing over the truss or rafter. The longitudinal bond beam reinforcement is tied to the footing with a reinforcing bar. Either the whole wall or only the cores housing tie-down rods might be grouted.

Where earthquake resistance is also required, the detail shown in Figure 7 might be suitable. Here the roof structure and the top plate are positively tied to the bond beam, which is tied in turn to the footing. This arrangement ensures that horizontal shear forces arising from earthquakes can be resisted. In this particular example the grouting fills the bond beam, but not the whole wall and the tie-down rod would require corrosion protection because it is not embedded in grout. Such an arrangement might not be suited to areas subject to cyclonic wind.

Figure 5. Roof – single-skin wall (low wind)

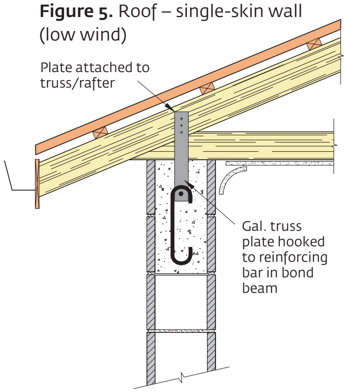


Figure 6. Roof – single-skin wall (high wind)

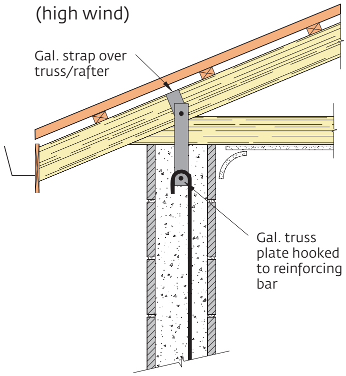
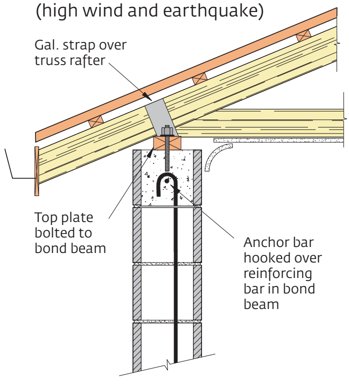


Figure 7. Roof – single-skin wall (high wind and earthquake)



3. Wall Supports

There are many different types of supports for walls, including footings, slabs and shelf angles. Requirements for residential slabs and footings are covered by AS 2870. Typical details are shown here for cavity walls, veneer walls, single-skin walls, internal walls, support of walls on slabs and supports for the tops of internal walls. Some details for the support of walls on nibs and shelf angles are shown in Section 6.

Weepholes (see Section 4.6) should be provided above all flashings. Termite protection measures might also be required but are omitted here for clarity.

3.1 Cavity walls

The detail shown in Figure 8 is for supporting a cavity masonry wall on a raft slab. The step down at the edge of the slab can be any convenient height but must be at least one course of brickwork to ensure adequate draining of the cavity. Usually, 86 mm is the most convenient height. The water-proofing membrane beneath the slab must extend above the finished ground level. Mortar should be packed behind the flashing to minimise the risk of it being punctured.

Figure 8. Base of a cavity wall on a raft slab

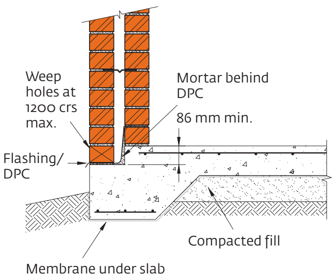
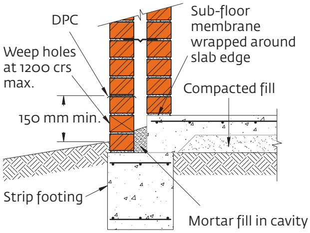


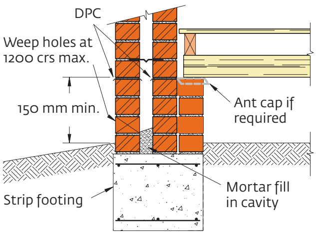
Figure 9 shows an alternative detail for a cavity wall, supported on a strip footing with a floor slab founded on compacted fill. In this case the flashing does not extend across the cavity; proper drainage is ensured by an outward-sloping fill of mortar at the base of the cavity. The damp-proof course in the outer leaf should be at least 150 mm above the finished ground level (if not paved) and the sub-floor membrane should extend around the front of the slab and be embedded beneath the inner leaf.

Figure 9. Base of a cavity wall on a strip footing with slab on fill



The detail shown in Figure 10 is for a cavity wall on a strip footing with a suspended timber floor. The important elements are similar to the previous detail. The ant cap, when required, can be combined with the damp-proof course. Ventilation required for the sub-floor area is not shown.

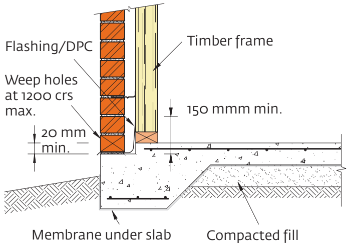
Figure 10. Base of a cavity wall with suspended floor



3.2 Veneer walls

For a veneer wall on a raft slab, as shown in Figure 11, the step down can be any convenient dimension of at least 20 mm, but the flashing must extend up at least 150 mm above the base and be attached to the timber framing. The flashing also acts as a damp-proof course for the masonry. The waterproofing membrane for the slab must extend above the finished ground level.

Figure 11. Base of a veneer wall on a raft slab



3.3 Single-skin walls

Figure 12 shows a single-skin (clay block) wall with tie-down reinforcing rods for high wind resistance seated on a raft slab. For this type of wall there is usually no stepdown in the slab and water-proofing is provided by an external coating on the wall, which should extend down below the level of the top slab surface. The slab waterproofing membrane should be wrapped around and exposed above the finished ground level.

An alternative detail for single-skin walls is shown in Figure 13. In this case the wall is seated on a strip footing. It is usual to pour the slab and grout the lower courses of the wall in one operation. Other points are the same as for the previous detail.

Engineer's details should be obtained for single-skin walls that utilise high wind tie-down rods.

Figure 12. Base of a single-skin wall on a raft slab

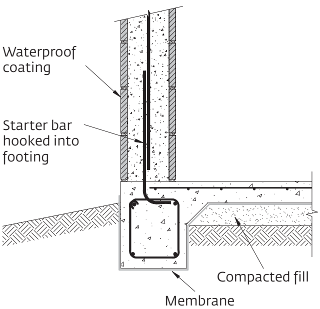
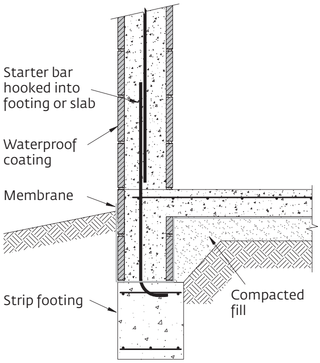


Figure 13. Base of a single-skin wall on a strip footing with slab on fill



3.4 Internal walls – raft slab

For the support of internal walls, a raft slab must be stiffened or at least strengthened. Two typical details are shown in Figure 14 and Figure 15. With single-storey walls this can usually be achieved within the slab thickness but for two-storey construction the slab will require additional thickening. Engineer's details should be obtained for the slab.

Figure 14. Internal wall support – single storey

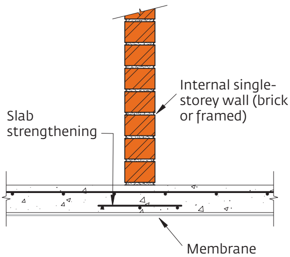
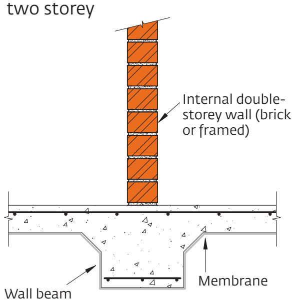


Figure 15. Internal wall support – two storey



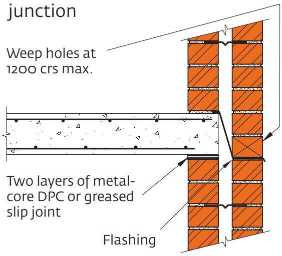
3.5 Nibs and shelf angles

When non-loadbearing masonry cladding is supported on nibs and shelf-angles it is essential to allow for sufficient movement to accommodate long-term expansion and to provide adequate flashing to exclude water. The arrangements for flashing of these supports are shown in Section 6, where other aspects are discussed.

3.6 Wall-slab junctions

A typical detail for the junction of a slab with a cavity wall is shown in Figure 16. As for other flashing details, weepholes must be provided at least every 1200 mm to drain the flashing. A slip joint beneath the slab edge is essential to accommodate differential movement.

Figure 16. Typical wall-slab junction



3.7 Tops of internal walls

The tops of internal walls should always be supported so that the wall has sufficient robustness and resistance to incidental loads caused by pressure differences within the building. In earthquake-prone regions, there is also a requirement for resistance to lateral forces generated by earthquakes. The details for providing this support vary depending on the level of loading and local construction practices. Typical details for low earthquake risk areas, providing support against nominal wind loads, are shown in Figure 17 and Figure 18. The most important requirement for these details is provision for movement between the different materials at the wall-ceiling junction.

Figure 19 and Figure 20 show details for earthquake-prone areas that should be regarded only as typical arrangements. These details provide enhanced resistance to lateral shear forces between the roof structure and the wall. For adequate attachment, the chemical anchors should penetrate at least 70 mm into the top of the masonry wall. Engineer's details should be obtained for each particular situation.

Figure 17. Internal wall supported by a cornice

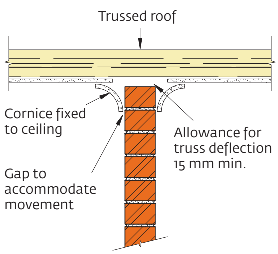


Figure 18. Internal wall supported by a top plate

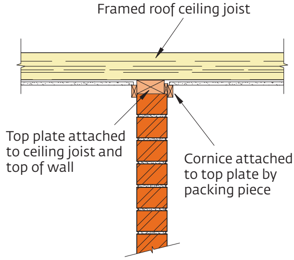


Figure 19. Typical detail for internal wall in earthquake areas – perpendicular joist

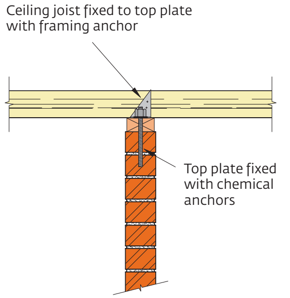
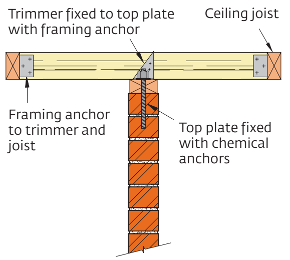


Figure 20. Typical detail for internal wall in earthquake areas – parallel joist



4. Prevention of Dampness

Problems relating to water penetration into masonry buildings happen all too often, but they can be prevented. Construction methods exist which, if carefully followed, will ensure a durable and watertight building.

Where dampness or deterioration due to water occurs in walls, it is common to find that the cause of failure is a poor architectural detail, unsuitable materials, bad workmanship or a combination of them all. Any of these causes might arise from a lack of understanding of the properties of the materials involved, although carelessness or building down to a price will sometimes be the cause of bad workmanship.

The BCA (Housing Provisions) includes various details of construction practice for flashings and damp-proof courses that are deemed to be acceptable and should be read in conjunction with this manual.

4.1 Prevention of water penetration through walls

Bricks and mortar both contain fine pores or capillaries of irregular shape and size extending for various distances and directions. Water lodging on one surface of a wall made of these materials will be drawn into the pores by capillary force and, if sufficient water is present over a long enough time, it may eventually penetrate through the full thickness of the wall to appear as dampness on the inside. This is a possible cause of dampness in walls with no cavity, but capillary action will not result in water running down the inside face of such a wall. Most free water found in this location enters through gaps in the joints due to bed furrowing, tip jointing or other poor bricklaying practices. Defects in flashings can also be a cause.

Cavity wall construction, which operates on the principle that the cavity provides a break between a wet outside leaf and a dry inside leaf, is usually an effective barrier to penetration of rainwater falling on the face of the wall unless large gaps allow water to enter and either blow or splash across the cavity. The effectiveness of the cavity will be greatly reduced if it is bridged by mortar droppings or poorly designed or installed wall ties. Free drainage of the cavity must occur if water transmission to the inner leaf is to be avoided.

The porous nature of both bricks and mortar makes a major contribution to the water tightness of a wall. Their blotting paper action of soaking up free water considerably reduces the load on flashings and other waterproofing elements and the water-holding capacity of brickwork is seldom exceeded by the volume of water delivered to it during a period of rain.

4.2 Damp-proof courses

The correct locations for ground and floor-level damp-proof courses (DPCs) are shown in Section 3. In some regions in the past, it has been the practice to provide two DPCs below timber floor level, but a single membrane is now often recommended. The combination of a DPC and a termite shield in this location will be necessary in many regions. Where there is any risk that surrounding ground may be waterlogged and the brick to be used below the floor level DPC is not of a type known to be highly resistant to salt attack, the provision of an additional DPC close to ground level is recommended.

Membrane-type DPCs must be laid across the full width of the wall or leaf and should be visible on either side when the brickwork is completed to show that the operation of tooling the joint has not provided a bridge of mortar across the membrane. If the membrane is carried across the cavity to form a flashing, it should incorporate a step-up of two courses from the outside to the inside leaf (see Section 3).

4.3 Cavity flashings

In order to be effective, a wall cavity must act as an uninterrupted gap between a wet external leaf and a dry internal leaf. Whenever it is bridged or interrupted by other parts of the building, for example by frames in openings or structural elements such as columns, beams, shelf angles or haunches, special precautions are required to prevent the transfer of moisture across the cavity. The flashing details given in Section 3 and Section 6.4 (for nibs and shelf angles) set out the general principles applicable to waterproofing of interruptions to the cavity.

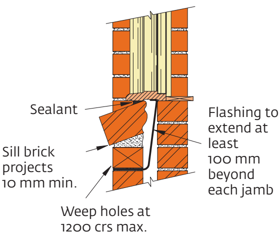
Weep-holes are necessary to drain any water that may be collected by the cavity flashings to the outside of the wall. Particular precautions are required in walls exposed to high winds, because air pressure on the external face can prevent the water from escaping through the weep holes. When there is such a risk, the step across the cavity should be increased.

Squaring-up the flashing to follow the horizontal and vertical surfaces is preferred to the common practice of carrying the flashing across the cavity in a straight diagonal slope. It is most important that all joints in the flashing are adequately lapped and sealed, particularly at corners.

4.4 Window flashings

Flashing under window sills should extend across the cavity and be embedded across the full width of the window into the bed joint one course below the sill brick. The flashing can be embedded through the full width of the outer leaf if this will not affect the structural sufficiency, otherwise it may be embedded 25 mm into the outer leaf. Alternative details, such as draping the flashing in the cavity, are not recommended. The flashing should extend into the cavity by 100 mm to 200 mm beyond each window jamb.

Figure 21. Window sill flashing – timber window in a cavity wall



Windows installed into lower-storey brick veneer walls of houses (using softwood framing) must have at least 5 mm clearance between the underside of the sill and the top of the sill brick to allow for shrinkage of the timber frame. For second-storey windows the clearance should be at least 10 mm. This gap should be sealed with a flexible sealant.

Typical sill flashing details are shown in Figure 21 and Figure 22 for timber-frame windows and Figure 23 and Figure 24 for metal-frame windows.

Figure 22. Window sill flashing – timber window in a veneer wall

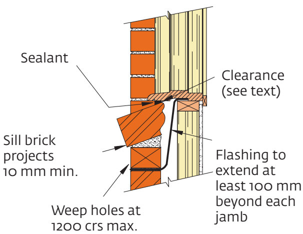


Figure 23. Window sill flashing – metal window in a cavity wall

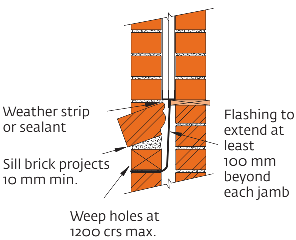
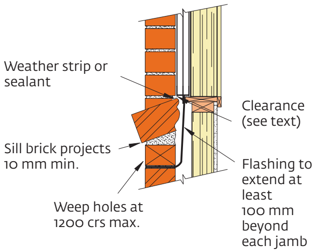


Figure 24. Window sill flashing – metal window in a veneer wall



4.5 Parapet flashing

The recommended uses of DPCs in parapets are shown in Figure 25 and Figure 26. Because parapets, free-standing walls and the like are so exposed to the weather, they are particularly prone to damage from water penetration and need protection by high shear strength DPCs at both top and bottom. Particular attention must be paid to the stability of parapets and free-standing walls because a lack of restraint makes them prone to sliding or overturning where the bond is broken at the DPC.

The requirements for the DPC result from two factors: the membrane must be sufficiently robust to allow it to be placed in the wall without risk of perforation from angular particles intruding into the bed and it must not extrude from the joint under load from above. The application of a skim of mortar to flush up the bed before placing the membrane is advisable to reduce the risk that it will become perforated.

Closing the cavity and extending the parapet up in solid work saves the need for a purpose-made coping (see Figure 25). On the other hand, a full-height cavity (see Figure 26) eliminates the weakness of the solid external wall between DPCs and may be suitable in many locations.

In order to be certain that efflorescence will not occur in the brickwork beneath copings, the provision of a continuous DPC membrane under copings is strongly recommended. When this is inserted above a cavity wall, a small piece of fibre-cement sheeting can be used to support the DPC across the cavity.

Figure 25. Parapet flashing – solid wall

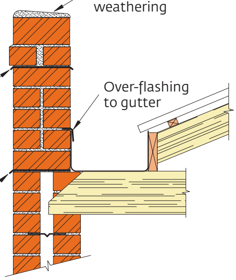
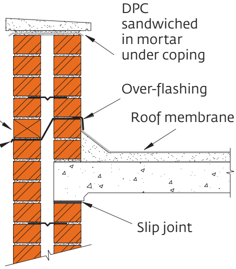


Figure 26. Parapet flashing – cavity wall



4.6 Weepholes

A weephole is simply a drain hole through a wall, but its functions can be described as:

(a) To discharge the slurry of mortar droppings and water resulting from the cleaning of cavities during bricklaying.

(b) To drain moisture that penetrates the outer leaf of brickwork or the sill.

(c) To give some degree of cavity ventilation.

(d) To discharge ground water through retaining walls.

Weepholes are generally required at 1200 mm maximum centres, at the head and sill flashings of windows over 1200 mm wide. However, it is acceptable to omit weepholes above and below small windows, and at windows protected by eaves, where the amount of moisture does not justify their placement.

Figure 27 shows four alternative weephole configurations, which are described below.

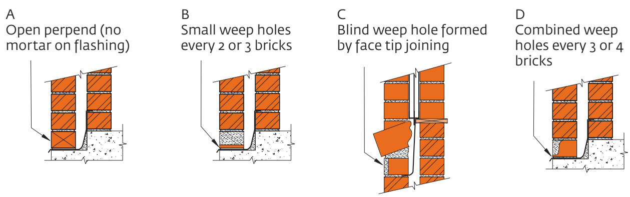
The simplest and most common weephole is the open perpend (A). However, its large size – a brick height plus the lower mortar bed joint – creates an attractive nest for spiders and can be visually unsatisfactory, especially with light-coloured mortar. There should be no mortar on the flashing at the base of the weephole. Smaller, more closely spaced weepholes are preferable.

Alternatively, the bricklayer can form small weepholes at the time of laying the bed mortar, using a 10 mm rod or a square stick (B). They should be spaced every two or three bricks, that is, at 480 or 720 mm centres. These weepholes are particularly recommended for wind-exposed brickwork.

Blind weepholes can be used to drain window head or sill flashings without being visible (C). The bricklayer simply face tips the course of bricks on the window flashing so that instead of a fully-filled perpend joint, only 15 to 20 mm of the face of the mortar joint is formed. Care should be taken to ensure the bed joint mortar on the flashing is also only face-filled at the perpend joint.

The combined weephole is a practical combination of the preceding designs (D). The bricklayer simply face tips the perpend joint and then uses a 10 mm rod or dowel to form a small slot or hole. Slots should be 20 to 30 mm high and spaced every three or four bricks (720 to 960 mm centres).

Figure 27. Alternative weephole configurations



5. Lintels

5.1 General

Lintels are necessary to support brickwork over door and window openings in walls. There are many types of lintels and no one type is best in all circumstances. Questions of performance, economy, appearance and durability must be considered when specifying lintels. This section gives structural requirements that can be used to specify any type of commercially made lintel. The requirements are given in tabular form for situations where clay brickwork is to be supported over openings up to 4.2 m in span and the brickwork is either non-loadbearing or supports domestic floor or roof loads. The design assumptions and methods of calculation are described.

A full examination of the structural behaviour of brickwork supported by lintels is beyond the scope of this manual and a number of conservative assumptions have therefore been used. Lintel manufacturers usually provide load tables for their products, some of which assume composite action between the lintel and the masonry. This is a very efficient structural action, which uses the brickwork and the lintel together as a beam to resist the loads. This action cannot be achieved for all materials and has not been assumed in the tables presented here. When using manufacturers' tables it is essential to check that the underlying assumptions are compatible with the circumstances of the particular building being designed.

While the methods of design used in this note do not utilise the moment capacity of brickwork, the ability of brickwork to form an arch over openings has been allowed for. The function of the lintel is to provide support for the triangle of brickwork above the opening, which does not form part of the arch, and it must be strong and stiff enough to prevent separation of the triangle from the adjoining brickwork. When the height of brickwork over the opening is too small to form an arch of adequate strength, the lintel must be able to carry all of the loads acting above the opening.

There is no need to create a high shear capacity in the brickwork because all the forces acting through the brickwork are resolved into compressive stresses. Any brick and mortar combination that is suitable for the conditions can be used.

5.2 Definitions

A number of terms used throughout this section have been given specific meanings to simplify the determination and selection of lintels. For the purposes of this section the terms have the following meanings:

Stiffness (EI) – the stiffness of a lintel is expressed in terms of the Modulus of Elasticity (E) and the Moment of Inertia (I) for which the unit is MN.mm^2.

Strength (M) – the strength of a lintel is expressed in terms of bending moment capacity for which the unit is kN.m.

5.3 Using the design tables

The design tables in Section 5.4 can be used for openings in internal, external and gable walls. Reference need not be made to Section 5.6 (Design by Calculation) unless verification of the determined lintel size is required. This manual considers the support of single leaf walls only; cavity walls should be treated as two single-leaf walls, each requiring support.

Point loads are not covered in the design tables. For the design of lintels to carry point loads, reference should be made to Section 5.6. It is also possible in some circumstances where wind loads are high and, for example, a light metal roof is used, that net uplift forces will occur on a lintel. Such cases are not provided for in the tables.

The two most significant factors affecting the choice of lintels are strength and stiffness. A lintel must have both adequate strength and stiffness and the factor that imposes the more severe requirement controls the choice of lintel size. Usually the stiffness requirement is the more severe.

To determine the required strength and stiffness of a lintel the following data must be known –

(i) the clear span of the opening (L);

(ii) the height of the brickwork above the lintel (h); and,

(iii) the type and magnitude of the loads acting upon the lintel.

The procedure is as follows:

(i) Select the appropriate tables based on the load type.

(ii) Select the appropriate row based on the height of brickwork above the lintel and the load width for roof and floor loads.

(iii) Select the appropriate column based on the clear span of the opening.

(iv) Find the required moment and stiffness.

(v) Select a lintel with the required properties.

5.4 Design tables

The tables provide the strength and stiffness requirements for lintels in four structural situations (see Figure 28):

A. Non-loadbearing walls – Table 1 and Table 2.
To be used where lintels carry only the brickwork above openings, such as in the case of brick veneer walls and the non loadbearing outer leaves of cavity walls.

B. Walls Supporting Tiled Roofs – Table 3 and Table 4.
To be used where lintels carry both the brickwork and the loads due to domestic tiled roofs and ceilings above openings.

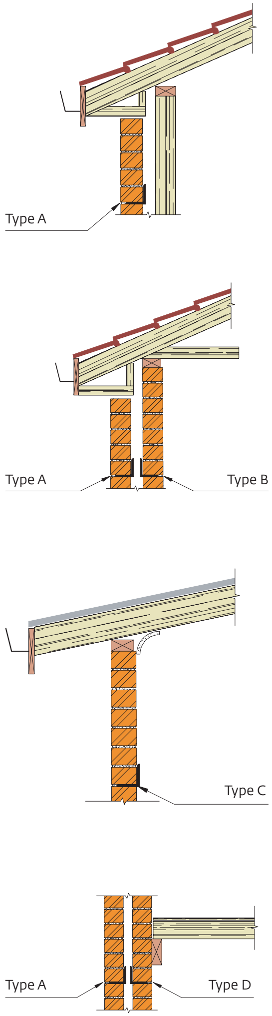
C. Walls Supporting Sheet Steel Roofs – Table 5 and Table 6.
To be used where lintels carry both the brickwork and the loads due to domestic sheet steel roofs and ceilings above openings.

D. Walls Supporting Timber Floors – Table 7 and Table 8.
To be used where lintels carry both the brickwork and the dead and live loads of suspended timber floors above openings.

All tables have been prepared for limit states design using load factors from AS 1170.0[7]. The self-weight of the lintel is not included. The tables apply for 110 mm leaves of brickwork and are conservative for 90 mm thick leaves. Other cases can be designed by calculation but this should be carried out by a qualified structural engineer.

The roof and ceiling dead loads are based on a tiled roof at 22.5° slope and a steel sheet roof at 12.5° slope, with a plasterboard ceiling, giving total loads of 0.9 kPa for the tiled roof and 0.4 kPa for the sheet roof. The roof live load was taken as 0.25 kPa. The total floor dead load was taken as 0.5 kPa and the floor live load as 1.5 kPa. The load width is the horizontal distance, perpendicular to the supporting lintel, from the centre of the ceiling span between points of support. Any eaves overhang from the centre line of the loadbearing lintel must be included. For lintels in internal walls supporting roof loads, the load width is taken as half the sum of ceiling spans on both sides of the lintel.

Figure 28. Lintel load cases



Note: Ties are omitted for clarity.

Table 1. Moment requirements for lintels supporting non-loadbearing walls

(Unit is kN.m)

Height of brickwork above lintel, h (mm)	Clear span of opening, L (m)											
	0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
300	0.06	0.12	0.20	0.29	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6
600	0.08	0.18	0.33	0.52	0.7	1.0	1.3	1.6	2.0	2.3	2.8	3.2
900	0.08	0.18	0.35	0.61	0.9	1.3	1.8	2.2	2.8	3.4	4.0	4.7
1200	0.08	0.18	0.35	0.61	1.0	1.4	2.0	2.7	3.4	4.2	5.0	5.9
1500	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.7	4.7	5.7	6.9
1800	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.1	7.5
2100 or more	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7

Table 2. Stiffness requirements (EI) for lintels supporting non-loadbearing walls

(Multiply by 10^3 to give unit of $MN.mm^2$)

Height of brickwork above lintel, h (mm)	Clear span of opening, L (m)											
	0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
300	1.9	4.7	9.4	16.6	26.6	40	57	78	105	136	188	252
600	2.1	6.5	16.0	29.7	49.1	75	109	151	203	265	367	496
900	2.1	6.5	15.9	32.9	63.7	101	150	212	289	381	530	720
1200	2.1	6.5	15.9	32.9	61.0	104	177	256	355	475	670	917
1500	2.1	6.5	15.9	32.9	61.0	104	167	254	397	543	777	1076
1800	2.1	6.5	15.9	32.9	61.0	104	167	254	372	527	844	1188
2100 or more	2.1	6.5	15.9	32.9	61.0	104	167	254	372	527	786	1138

Table 3. Moment requirements for lintels supporting walls and tiled roofs

(Unit is kN.m)

Height of brickwork above lintel, h (mm)	Load width (m)	Clear span of opening, L (m)											
		0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
300	1.8	0.18	0.44	0.79	1.24	1.8	2.4	3.1	4.0	4.9	5.9	7.0	8.2
	3.0	0.26	0.65	1.18	1.86	2.7	3.7	4.8	6.1	7.5	9.1	10.8	12.6
	4.2	0.34	0.86	1.58	2.49	3.6	4.9	6.4	8.2	10.1	12.2	14.5	17.0
	5.4	0.42	1.07	1.97	3.12	4.5	6.2	8.1	10.3	12.7	15.3	18.3	21.4
	6.6	0.50	1.28	2.36	3.75	5.4	7.4	9.7	12.4	15.3	18.5	22.0	25.8
600	1.8	0.08	0.18	0.53	0.99	1.6	2.3	3.0	4.0	5.0	6.1	7.4	8.7
	3.0	0.08	0.18	0.66	1.30	2.1	3.1	4.2	5.5	7.0	8.6	10.4	12.4
	4.2	0.08	0.18	0.79	1.62	2.7	3.9	5.4	7.1	9.0	11.1	13.5	16.1
	5.4	0.08	0.18	0.92	1.93	3.2	4.8	6.6	8.7	11.0	13.7	16.6	19.7
	6.6	0.08	0.18	1.05	2.25	3.8	5.6	7.8	10.2	13.0	16.2	19.6	23.4
900	1.8	0.08	0.18	0.35	0.61	1.2	1.9	2.8	3.8	4.9	6.2	7.6	9.1
	3.0	0.08	0.18	0.35	0.61	1.4	2.4	3.5	4.9	6.4	8.1	9.9	12.0
	4.2	0.08	0.18	0.35	0.61	1.6	2.8	4.2	5.9	7.8	10.0	12.3	14.9
	5.4	0.08	0.18	0.35	0.61	1.8	3.2	4.9	6.9	9.2	11.8	14.7	17.9
	6.6	0.08	0.18	0.35	0.61	1.9	3.6	5.6	8.0	10.7	13.7	17.1	20.8
1200	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.4	3.4	4.7	6.0	7.6	9.2
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.6	4.0	5.5	7.3	9.3	11.4
	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.8	4.5	6.4	8.6	11.0	13.6
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	3.1	5.0	7.3	9.8	12.7	15.8
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	3.3	5.5	8.1	11.1	14.4	18.0
1500	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.1	5.6	7.3	9.1
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.4	6.3	8.3	10.6
	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.7	6.9	9.3	12.0
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	5.0	7.5	10.3	13.5
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	5.3	8.1	11.4	14.9
1800	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.7	8.6
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	7.0	9.3
	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	7.3	10.1
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	7.7	10.8
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	8.0	11.5
2100 or more	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7

Table 4. Stiffness requirements (EI) for lintels supporting walls and tiled roofs

(Multiply by 10^3 to give unit of $MN.mm^2$)

Height of brickwork above lintel (mm)	Load width (m)	Clear span of opening, L (m)											
		0.9	1.2	1.5	1.8	2.1	2.4	2.7	3	3.3	3.6	3.9	4.2
300	1.8	4.7	15	33	62	103	160	235	329	446	587	819	1112
	3.0	6.6	21	49	92	155	240	353	496	673	888	1239	1686
	4.2	8.4	28	64	122	206	321	472	663	901	1189	1660	2259
	5.4	10.3	35	80	152	257	401	590	831	1128	1490	2081	2832
	6.6	12.2	41	96	182	308	481	709	998	1356	1791	2502	3406
600	1.8	2.1	6.5	24	52	95	155	236	339	468	626	883	1212
	3.0	2.1	6.5	29	67	126	209	320	464	645	867	1228	1690
	4.2	2.1	6.5	34	82	157	262	405	590	822	1108	1572	2168
	5.4	2.1	6.5	40	97	187	316	490	715	999	1348	1916	2646
	6.6	2.1	6.5	45	112	218	369	574	841	1176	1589	2261	3123
900	1.8	2.1	6.5	15.9	33	79	141	227	338	478	651	932	1293
	3.0	2.1	6.5	15.9	33	89	168	277	421	605	832	1200	1676
	4.2	2.1	6.5	15.9	33	99	195	328	505	731	1012	1468	2058
	5.4	2.1	6.5	15.9	33	110	222	379	588	857	1193	1735	2440
	6.6	2.1	6.5	15.9	33	120	248	430	672	984	1373	2003	2822
1200	1.8	2.1	6.5	15.9	33	61	104	202	319	469	656	957	1347
	3.0	2.1	6.5	15.9	33	61	104	219	361	545	776	1148	1633
	4.2	2.1	6.5	15.9	33	61	104	236	403	621	897	1339	1920
	5.4	2.1	6.5	15.9	33	61	104	253	445	697	1017	1530	2207
	6.6	2.1	6.5	15.9	33	61	104	270	486	773	1137	1722	2493
1500	1.8	2.1	6.5	15.9	33	61	104	167	254	435	633	949	1362
	3.0	2.1	6.5	15.9	33	61	104	167	254	460	693	1064	1554
	4.2	2.1	6.5	15.9	33	61	104	167	254	486	753	1178	1745
	5.4	2.1	6.5	15.9	33	61	104	167	254	511	814	1293	1936
	6.6	2.1	6.5	15.9	33	61	104	167	254	536	874	1408	2127
1800	1.8	2.1	6.5	15.9	33	61	104	167	254	372	527	901	1332
	3.0	2.1	6.5	15.9	33	61	104	167	254	372	527	939	1427
	4.2	2.1	6.5	15.9	33	61	104	167	254	372	527	977	1523
	5.4	2.1	6.5	15.9	33	61	104	167	254	372	527	1016	1618
	6.6	2.1	6.5	15.9	33	61	104	167	254	372	527	1054	1714
2100 or more	1.8	2.1	6.5	15.9	33	61	104	167	254	372	527	786	1138
	3.0	2.1	6.5	15.9	33	61	104	167	254	372	527	786	1138
	4.2	2.1	6.5	15.9	33	61	104	167	254	372	527	786	1138
	5.4	2.1	6.5	15.9	33	61	104	167	254	372	527	786	1138
	6.6	2.1	6.5	15.9	33	61	104	167	254	372	527	786	1138

Table 5. Moment requirements for lintels supporting walls and sheet roofs

(Unit is kN.m)

Height of brickwork above lintel, h (mm)	Load width (m)	Clear span of opening, L (m)											
		0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
	1.8	0.13	0.30	0.54	0.83	1.2	1.6	2.1	2.6	3.2	3.9	4.6	5.4
	3.0	0.18	0.42	0.76	1.19	1.7	2.3	3.0	3.8	4.7	5.7	6.8	7.9
300	4.2	0.22	0.54	0.98	1.55	2.2	3.0	4.0	5.0	6.2	7.5	8.9	10.4
	5.4	0.27	0.66	1.21	1.91	2.8	3.8	4.9	6.2	7.7	9.3	11.0	12.9
	6.6	0.31	0.78	1.43	2.27	3.3	4.5	5.9	7.4	9.1	11.1	13.2	15.5
	1.8	0.08	0.18	0.44	0.79	1.2	1.7	2.3	2.9	3.7	4.5	5.4	6.4
	3.0	0.08	0.18	0.52	0.97	1.5	2.2	3.0	3.8	4.8	5.9	7.1	8.5
600	4.2	0.08	0.18	0.59	1.15	1.8	2.7	3.6	4.7	6.0	7.4	8.9	10.5
	5.4	0.08	0.18	0.67	1.33	2.2	3.1	4.3	5.6	7.1	8.8	10.6	12.6
	6.6	0.08	0.18	0.74	1.51	2.5	3.6	5.0	6.5	8.3	10.2	12.4	14.7
	1.8	0.08	0.18	0.35	0.61	1.1	1.7	2.4	3.1	4.0	5.0	6.0	7.2
	3.0	0.08	0.18	0.35	0.61	1.2	1.9	2.8	3.7	4.8	6.0	7.4	8.9
900	4.2	0.08	0.18	0.35	0.61	1.3	2.2	3.2	4.3	5.6	7.1	8.7	10.5
	5.4	0.08	0.18	0.35	0.61	1.4	2.4	3.6	4.9	6.5	8.2	10.1	12.2
	6.6	0.08	0.18	0.35	0.61	1.5	2.6	4.0	5.5	7.3	9.3	11.5	13.9
	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.2	3.1	4.1	5.2	6.5	7.8
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.4	3.4	4.6	5.9	7.4	9.1
1200	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.5	3.7	5.1	6.7	8.4	10.3
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.6	4.0	5.6	7.4	9.4	11.6
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.8	4.3	6.1	8.1	10.3	12.8
	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.0	5.2	6.6	8.1
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.1	5.6	7.2	9.0
1500	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.3	5.9	7.8	9.8
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.4	6.3	8.4	10.6
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	4.6	6.7	8.9	11.5
	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.4	8.1
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.6	8.6
1800	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.8	9.0
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	7.0	9.4
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	7.2	9.8
	1.8	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	3.0	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
2100 or more	4.2	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	5.4	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7
	6.6	0.08	0.18	0.35	0.61	1.0	1.4	2.1	2.8	3.8	4.9	6.2	7.7

Table 6. Stiffness requirements (EI) for lintels supporting walls and sheet roofs

(Multiply by 10^3 to give unit of $MN.mm^2$)

Height of brickwork above lintel (mm)	Load width (m)	Clear span of opening, L (m)											
		0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
300	1.8	3.3	9.9	21.6	39.8	66	102	149	208	281	369	513	696
	3.0	4.3	13.3	29.6	55.3	93	143	210	294	398	524	730	991
	4.2	5.2	16.8	37.7	70.9	119	185	271	380	515	679	947	1287
	5.4	6.2	20.2	45.8	86.4	145	226	332	466	632	834	1164	1583
	6.6	7.2	23.7	53.9	101.9	172	267	393	552	750	989	1381	1878
600	1.8	2.1	6.5	20.1	41.3	73	117	174	248	340	451	633	865
	3.0	2.1	6.5	22.8	49.1	89	144	218	313	431	575	811	1111
	4.2	2.1	6.5	25.5	56.9	105	172	262	377	522	699	988	1358
	5.4	2.1	6.5	28.1	64.6	120	199	305	442	613	824	1166	1604
	6.6	2.1	6.5	30.8	72.4	136	227	349	507	705	948	1343	1850
900	1.8	2.1	6.5	15.9	32.9	72	122	190	277	386	520	737	1016
	3.0	2.1	6.5	15.9	32.9	77	136	216	320	452	613	876	1213
	4.2	2.1	6.5	15.9	32.9	82	150	242	363	517	706	1014	1410
	5.4	2.1	6.5	15.9	32.9	87	163	268	406	582	799	1152	1607
	6.6	2.1	6.5	15.9	32.9	93	177	294	449	647	892	1290	1804
1200	1.8	2.1	6.5	15.9	32.9	61	104	190	289	414	568	818	1138
	3.0	2.1	6.5	15.9	32.9	61	104	198	310	453	630	916	1286
	4.2	2.1	6.5	15.9	32.9	61	104	207	332	492	693	1015	1434
	5.4	2.1	6.5	15.9	32.9	61	104	216	353	531	755	1113	1582
	6.6	2.1	6.5	15.9	32.9	61	104	225	375	571	817	1212	1729
1500	1.8	2.1	6.5	15.9	32.9	61	104	167	254	417	589	865	1224
	3.0	2.1	6.5	15.9	32.9	61	104	167	254	430	620	925	1322
	4.2	2.1	6.5	15.9	32.9	61	104	167	254	443	651	984	1421
	5.4	2.1	6.5	15.9	32.9	61	104	167	254	456	682	1043	1519
	6.6	2.1	6.5	15.9	32.9	61	104	167	254	469	713	1102	1618
1800	1.8	2.1	6.5	15.9	32.9	61	104	167	254	372	527	873	1262
	3.0	2.1	6.5	15.9	32.9	61	104	167	254	372	527	893	1311
	4.2	2.1	6.5	15.9	32.9	61	104	167	254	372	527	913	1361
	5.4	2.1	6.5	15.9	32.9	61	104	167	254	372	527	932	1410
	6.6	2.1	6.5	15.9	32.9	61	104	167	254	372	527	952	1459
2100 or more	1.8	2.1	6.5	15.9	32.9	61	104	167	254	372	527	786	1138
	3.0	2.1	6.5	15.9	32.9	61	104	167	254	372	527	786	1138
	4.2	2.1	6.5	15.9	32.9	61	104	167	254	372	527	786	1138
	5.4	2.1	6.5	15.9	32.9	61	104	167	254	372	527	786	1138
	6.6	2.1	6.5	15.9	32.9	61	104	167	254	372	527	786	1138

Table 7. Moment requirements for lintels supporting walls and timber floors

(Unit is kN.m)

Load width (m)	Clear span of opening, L (m)											
	0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
1.8	0.8	1.4	2.3	3.4	4.7	6.4	8.3	10	13	16	19	23
3.0	1.2	2.2	3.6	5.2	7.2	9.6	12.4	16	19	23	28	33
4.2	1.7	3.0	4.8	7.1	9.7	12.9	16.6	21	25	31	36	43
5.4	2.1	3.9	6.1	8.9	12.2	16.2	20.7	26	32	38	45	53
6.6	2.6	4.7	7.4	10.7	14.8	19.5	24.8	31	38	45	54	63

Table 8. Stiffness requirements (EI) for lintels supporting walls and timber floors

(Multiply by 10^3 to give unit of $MN.mm^2$)

Load width (m)	Clear span of opening, L (m)											
	0.9	**1.2**	**1.5**	**1.8**	**2.1**	**2.4**	**2.7**	**3**	**3.3**	**3.6**	**3.9**	**4.2**
1.8	14.2	35.3	72	130	215	334	495	704	971	1304	1857	2579
3.0	22.3	54.5	110	195	318	488	713	1004	1370	1823	2571	3540
4.2	30.4	73.7	147	260	421	642	932	1304	1770	2341	3285	4500
5.4	38.5	92.9	185	325	524	795	1151	1604	2169	2860	4000	5461
6.6	46.6	112.1	222	389	627	949	1370	1904	2568	3378	4714	6422

5.5 Construction details

5.5.1 General

Arch bars and angle lintels are vulnerable to corrosion, which may cause cracking of the brickwork and unsightly staining. It is recommended that all steel lintels be either stainless steel or hot dip galvanised after fabrication, or receive equivalent protection before installation. AS 3700 specifies requirements for corrosion protection of accessories, including lintels, depending on the exposure conditions (see also TBA Manual 7: Design of Clay Masonry for Serviceability).

There should be at least three courses of masonry over any lintel. Lintels should be built into the masonry at each end for a distance of not less than 100 mm for spans up to 1000 mm and 150 mm for larger spans, for the loads described in the tables above. For larger loads the masonry should be assessed to ensure that it is not locally overloaded. The masonry supporting the lintels should be constructed in a mortar not weaker than 1 cement: 2 lime: 9 sand by volume. The heads of all openings in cavity brickwork must be properly flashed.

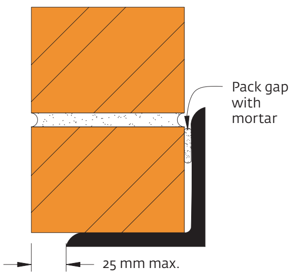
To allow the full arching action to develop in the masonry, lintels should be propped during construction until the masonry has hardened.

5.5.2 Angle lintels

Because angles tend to twist when loaded, they should be carefully built-in and mortar should be packed between the vertical leg and the masonry (see Figure 29). No angle with a bottom leg less than 70% of the width of the brick it supports should be used and the overhang should not exceed 25 mm.

Angles and arch-bars with a flange thickness of 10 mm are difficult to build into a standard bed joint thickness and therefore it is desirable to select members not greater than 8 mm in thickness.

Figure 29. Packing of mortar behind angle lintel to prevent twisting



5.5.3 Reinforced brickwork lintels

Lintels that act compositely with the brickwork they support, for example reinforced brickwork lintels, are recommended for a number of reasons. With most steel and concrete lintels, the brickwork sits on top of and is separate from the lintel. The greater the height of the brickwork the larger the load on the lintel and hence the larger and more expensive the lintel must become.

With reinforced brickwork lintels, the brickwork is part of an integrated structural system in which the brickwork becomes the lintel beam. A small quantity of steel is placed near the tensile face and the brickwork carries the compressive forces. The greater the height of the brickwork, the larger is the bending strength of the brickwork lintel.

The structural advantages make reinforced brickwork lintels particularly suited to large spans or where large loads must be supported. In addition, the steel components in reinforced lintels are not visible when installed.

The use of any brickwork reinforcing system should be based on the manufacturer's literature.

5.5.4 Other types of lintels

A number of proprietary lintels are made for brickwork in addition to the common steel lintels. They include lightweight box-section metal lintels, reinforced concrete lintels, prestressed concrete lintels, prestressed fired clay lintels and brickwork reinforcement systems. A full discussion of these products is beyond the scope of this manual; use of these lintels should be based on the manufacturers' literature.

5.6 Lintel design by calculation

5.6.1 Notation

The notation used in this section is as follows:

Symbol Meaning

Symbol	Meaning
a, b	The distance from the face of an abutment to a position vertically below a point load acting upon a lintel
E	Modulus of elasticity of a material (Young's Modulus)
EI	E x I, a measure of the stiffness of a lintel
h	The height of brickwork to its highest point above a supporting lintel
h_1	The height above a lintel to the application of a superimposed load
G	The brickwork gravity (dead) load per unit thickness
I	The Moment of Inertia of a lintel (Second Moment of Area)
L	The clear span of a lintel
M	The required or actual bending moment capacity of a lintel
s	A subscript used for superimposed loads
t_w	The actual thickness of a wall
w	Load per unit length or area
W	The total load acting upon a lintel
γ	Load factor from the SAA Loading Code (AS 1170.1)
Δ	Deflection of a lintel under load

Consistent units should be used for all calculations.

5.6.2 Design assumptions

The design methods used in this manual are based upon the following assumptions:

(i) Brickwork forms a natural arch, which can transfer load to the abutments of the openings. The brickwork that is supported by the lintel forms either a triangle or a trapezium in which the lintel is the base and the sides rise inwards at an angle of 45°.

(ii) Where L is less than 2h (the span of the opening is less than twice the height of the brickwork above the opening) all loads uniformly applied to the brickwork above a height of L/2 will be carried by arching action in the brickwork.

(iii) Where L is greater than 2h (the span of the opening is more than twice the height of the brickwork above the opening) all loads uniformly applied to the central section of the brickwork for a length of L - 2h will be uniformly distributed into the lintel and the remainder of such loads above the opening will be carried by arching action in the brickwork.

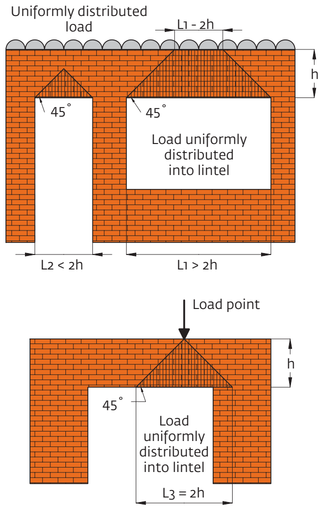
(iv) Point loads applied to the brickwork are uniformly distributed downwards through an angle of 45° on either side of the vertical.

(v) The total strength and stiffness requirements are the sum of the requirements for the individual load components.

(vi) Deflection of the lintel should not be greater than L/360 or 10 mm, whichever is the lesser.

The load distribution assumptions are illustrated in Figure 30.

Figure 30. Assessment of loads on lintels



5.6.3 Strength calculations for lintels supporting non-loadbearing walls

Where L is greater than 2h, the mass of the brickwork acting upon the lintel can be estimated using the expression:

$$W = h(L - h)\, G t_w$$

The maximum bending moment acting upon the lintel, factored in accordance with limit states design, can be estimated by the expression:

$$M_{max} \cong \frac{\gamma\, WL\left(1 + \frac{h}{L}\right)}{8}$$

Where L is equal to or less than 2h, the mass of the brickwork acting upon the lintel can be estimated using the expression:

$$W = \frac{L^2 G t_w}{4}$$

The maximum bending moment acting upon the lintel can be estimated by the expression:

$$M_{\max} = \frac{W L}{6}$$

5.6.4 Stiffness calculations for lintels supporting non-loadbearing walls

Where L is greater than 2h the deflection of lintels supporting non loadbearing brickwork can be estimated using the expression:

$$\Delta_1 \cong \frac{W L^3}{384EI\left(1-\frac{h}{L}\right)}\left[5-6\left(\frac{h}{L}\right)^2\right]$$

Where L is equal to or less than 2h the deflection can be estimated using the expression:

$$\Delta_2 = \frac{W L^3}{60EI}$$

Transposing the equation and introducing a deflection value leads to the required EI for the lintel. In the tables of this manual the limiting deflection value used is L/360 or 10 mm, whichever is the lesser.

5.6.5 Strength calculations for lintels lupporting loads additional to the brickwork

Where L is greater than 2h the strength requirements additional to that caused by the mass of the brickwork can, for uniformly distributed loads, be estimated using the expression:

$$M_{\max} = \frac{W_s L}{8}$$

For nearly uniformly distributed loads such as timber joists bearing directly onto brickwork at 450 mm centres, the resulting applied bending moment can be estimated using the expression:

$$M_{\max} \cong \frac{W_s L}{6}$$

The total uniformly distributed superimposed load can be approximated using the expression:

$$W_s \cong w(L-2h_1)$$

For superimposed loads h_1 is the height above the lintel of the point of application of the load. This may be less than the full height of the brickwork supported by the lintel such as in the case of the first floor of a building.

Point loads can be considered in one of two ways. The load applied to brickwork at a point can be taken to be uniformly distributed downwards through an angle of 45° from the vertical until it meets the lintel, or alternatively the moment induced in the lintel can be estimated using the expression:

$$M \cong \frac{W_s ab}{L}$$

5.6.6 Stiffness calculations for lintels supporting loads additional to the brickwork

Where L is greater than 2h the deflection of the lintel caused by superimposed loads, additional to the deflection caused by the brickwork, can be estimated using the expression:
(For uniformly distributed loads)

$$\Delta_1 \cong \frac{5\, W_s L^3}{384\, EI}$$

and –

(For nearly uniformly distributed loads)

$$\Delta_2 \cong \frac{W_s L^3}{60\, EI}$$

A simple and conservative expression for determining the deflection of lintels caused by point loads is:

$$\Delta \cong \frac{W_s a^2 b^2}{3\, EI\, L}$$

5.6.7 End condition of lintels

It has been assumed in the calculations in Sections 5.6.3 to 5.6.6 that lintels are simply supported. Some benefit is in fact derived from the end restraint provided by building the lintel into the brickwork, but with a relatively strong lintel, the influence of a small amount of end restraint is minor. In the case of arch bars, which are relatively weak and elastic, the effect of end restraint can be significant. The values for the strength and stiffness properties of arch bars could be adjusted according to the height of brickwork above the lintel and hence the degree of end restraint possible, provided that the bar is built into the brickwork for a distance of at least 100 mm.

6. Movement Gaps

All building materials change size as their temperature varies, or as they are loaded or unloaded. Some materials (such as concrete and cement products) shrink as they dry out after being placed in position in a building and shrink further as they cure. Clay bricks expand slowly over a long period of time. When different materials are used together, their different responses to changing loads, temperatures and moisture contents will lead to size differences between them. The resulting differential movements must be taken into account if damage to the structure is to be avoided and this is done by the provision of movement gaps between parts of the structure.

6.1 Dimensional changes in clay masonry units

There are a number of potential sources of dimensional change in clay masonry. All except long-term expansion are cyclic, reversible changes.

6.1.1 Thermal

The thermal expansion of clay bricks varies slightly depending upon their colour and the method of manufacture, but the value is unlikely to be greater than 0.008 mm/m/ºC. Thermal expansion can be taken into account in calculating the spacings of movement gaps in external brickwork (see later) but no particular account need be taken of thermal expansion in most internal brickwork.

6.1.2 Short term wetting and drying

All masonry units expand on wetting and contract on drying, but these changes are usually not sufficient to require consideration in clay brickwork.

6.1.3 Long term permanent expansion

Expansion of fired clay units begins as soon as they have cooled after firing and takes place in all three directions. This expansion is due to reaction with moisture and is sometimes referred to as 'permanent moisture expansion'. All fired clay products, including bricks, are subject to chemical reactions between water and certain of their constituent minerals that cause them to expand. The reactions begin when bricks in the kiln cool below about 400ºC, they are not hastened by wetting and, for practical purposes, are irreversible.

Any atmosphere in which people can live and breathe contains sufficient water to cause clay brick expansion and neither the magnitude nor the rate of expansion is measurably changed when bricks are used internally rather than externally. However, total movement is made appreciably less by the absence of significant temperature changes and, consequently, gaps to accommodate movements are often not required in internal walls.

The magnitude of long-term permanent change in the dimensions of clay bricks (growth) depends upon the material from which they are made. It is now generally accepted that the rate of expansion diminishes with time and can be accurately represented by a linear relationship with the logarithm of time.

Experience shows that if control gaps are provided, with widths calculated on the basis of the coefficient of expansion of the particular brick used in the structure, stresses due to the restraint of further growth are unlikely to cause distress during the remaining practical life of the building.

6.1.4 Coefficient of expansion

The coefficient of expansion is an estimate of the amount bricks will grow in the first fifteen years after they are made. Values are generally lower than they were in the past because of a better understanding of the factors influencing expansion and better control over the manufacturing processes, particularly the firing temperature. When it is required, the coefficient of expansion for particular units can be obtained from the manufacturer.

Coefficient of expansion is now given the symbol e_m, but it was often formerly referred to simply as the 'e' value. The value is determined by subjecting a brick fresh from the kiln to saturated steam at atmospheric pressure. This expansion has been shown to correlate well with natural expansion over a longer period. The test procedure is given in the standard test procedures for clay masonry units (AS 4456.11)[8].

Coefficients of expansion can be classified as:

(a) Low up to 0.8 mm/m

(b) Medium exceeding 0.8 up to 1.6 mm/m

(c) High exceeding 1.6 up to 2.4 mm/m

However, it must be remembered that:

- There is no pattern in the coefficients of expansion based on brick colour or manufacturing method that enables general figures to be produced.

- Within a single brick type the coefficient of expansion can vary considerably at different production times. In some instances, a halving or doubling of e_m values has been observed from bricks sold under the same name but manufactured six months apart.

For these reasons designers should obtain current expansion data for the particular brick they propose to use.

6.2 Design of control gaps

6.2.1 General

The common use of reinforced concrete frames in buildings, together with the availability of a wider range of bricks, have contributed to making the control of movements more complex than before. Locations and widths of control gaps to accommodate long-term moisture expansion can be determined based on the characteristic expansion of the units. In many instances these gaps will be in the same locations as those needed to accommodate differential movements between various parts of the structure, arising from seasonal and diurnal thermal movements plus those associated with foundation and footing movements.

The Masonry Structures Code (AS 3700) includes overall limits on joint width and movement but does not specify a method of design for gap spacings. Such a method is outlined in this section.

6.2.2 Sources of movement

Masonry units
Details on how to obtain data on the magnitude of growth (coefficient of expansion) have been given in Section 6.1.4. It must be remembered that expansion takes place in the height and width as well as the length of the units.

Foundation and footing movements
Uniform movements of the footings of a building should not affect masonry walls. However, differential movements due to uneven settlement or moisture change in the foundation can lead to cracking of masonry. Where these movements are expected to be significant, the structure can be designed as articulated masonry. In general, the control joints incorporated by a prudent designer to articulate brickwork against damage from footing movement can normally also act as gaps to control movements associated with expansion of the units. Design of articulated masonry is covered in TBA Manual 7.

Frame movements
In all instances where masonry is hung as a curtain-wall to enclose a framed structure it is necessary to give consideration to the movements in the frame that might affect the cladding.

(a) Temperature movements
The building frame will usually be internal and will remain comparatively unchanged in its temperature. An allowance of 0.35 mm/m for temperature movements due to heating and cooling of the masonry cladding is recommended, to provide for temperature differences of up to 40ºC between the frame and its cladding.

(b) Frame shortening
Modern framed structures usually have a frame of reinforced concrete, with high creep and shrinkage characteristics, and the masonry cladding is a two-leaf wall with one leaf within the frame. The outer leaf is connected to it only by wire ties across a cavity and is carried at floor level by a concrete nib or steel shelf-angle. In these circumstances it is imperative that proper provision be made to accommodate the differences between the movement of the frame and the cladding, even if the frame is of steel where frame shortening is small.

For reinforced concrete frames it is possible to use techniques such as those suggested by Fintel and Khan[9] to calculate column shortening for the particular building and to use that figure in determining gap widths. Alternatively, it is recommended that the conservative value of 1.2 mm/m be adopted as the allowance for shortening of a reinforced concrete frame. If the frame is of steel, or if a loadbearing masonry wall supports the outer leaf, the appropriate conservative value is 0.5 mm/m.

(c) Horizontal concrete shrinkage
The horizontal shrinkage of concrete beams and slabs will act in the opposite direction to the expansion of the clay brickwork and the difference between them has a potential to cause damage. This aspect is usually adequately dealt with by providing slip joints between the concrete and the masonry.

6.2.3 Gaps for internal walls

Experience shows that where bricks with medium to low coefficients of expansion (e_m below about 1.2 mm/m) are used in internal walls with full-height door openings, no expansion gaps need be provided. Otherwise, the formula derived below should be used (after it has been modified to eliminate the thermal expansion component) to determine the gap spacings needed to protect the continuous masonry above the openings.

Similarly, experience suggests that the internal leaves of external walls can be built without a control gap at the top provided the leaf of masonry is fully supported within the frame and any clay bricks used for this purpose have an e_m value below about 1.2 mm/m.

Where masonry is used to partition a framed structure, it is often considered desirable to provide a control gap at the top of such partitions to ensure that they do not become loadbearing. In such an instance, the partition can be stabilised by using a connection that allows relative vertical movement between the partition and the concrete slab above. Proprietary connectors are available for this purpose and the advice of the manufacturer should be sought.

6.2.4 Gaps for external walls

Control of the movements that have been described is best achieved by providing vertical gaps to accommodate horizontal movement and horizontal gaps to accommodate vertical movement. These are described below.

Horizontal movement

Growth of the masonry units themselves is all that needs to be considered in designing for horizontal movement. In most walls, there are restraints that reduce the actual expansion of the masonry to about half the e_m value of the bricks. In parapets, however, such restraint does not exist or is so reduced that the full amount of expansion must be assumed to occur. On the other hand, in base brickwork that is not more than about 600 mm high between ground level and a sheet damp-proof course, experience shows that the risk of damage is slight if expansion gaps are omitted.

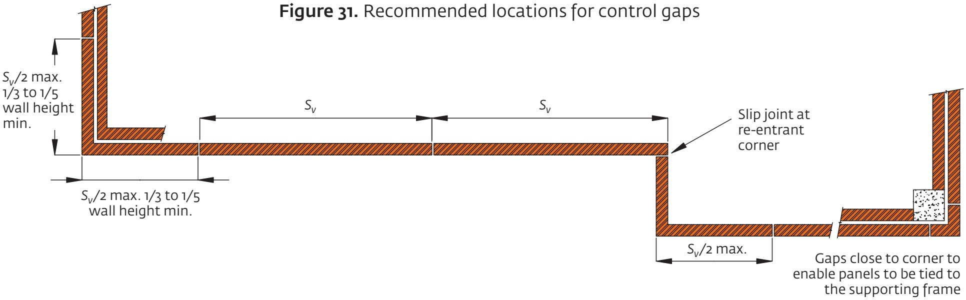
A wall with unrestrained ends will expand in both directions from the centreline. Therefore, movement into a control gap from both sides must be allowed for. So that disruption to other elements in the wall is avoided, it is generally recommended that the maximum movement at each gap be limited to 7 to 8 mm from the wall section on each side of the gap, that is a total movement at the gap of 15 mm and a total gap width (as constructed) of about 20 to 25 mm. AS 3700 requires the total calculated closing movement to be not greater than 15 mm and the final width of the gap to be not less than 5 mm. AS 3700 also requires any joint to be treated as a structural end, and the wall supports must be designed accordingly.

Corners and offsets are the places most vulnerable to damage and it is advisable to locate the first gap as close to the corner as possible. It should never be further from the corner than half the calculated gap spacing. In a framed building, it will usually be desirable to locate corner gaps very close to the corner. If this is done, the masonry on either side of the gap can be separately tied to the column to provide stability to both panels. Where the masonry is self-supporting and not tied to a frame, it relies on the stability provided by the bonded corners. In these circumstances, it is advisable that the first gap is located at least 0.3 times, but preferably 0.5 times the height of the wall from the corner.

Any wall or section of wall that is more than half the gap spacing in length between corners, offsets or ends should be protected by the inclusion of a vertical control gap.

Guidelines for positioning of control gaps are illustrated in Figure 31.

Figure 31. Recommended locations for control gaps



Consideration should also be given to providing control joints at wall openings and at changes in wall thickness (other than for piers, buttresses or other members that provide support).

In developing a method for calculating the spacing of vertical gaps, the following notation is used:

S_v = Maximum spacing of vertical gaps in walls (in metres).

S_{vp} = Maximum spacing of vertical gaps in parapets (in metres).

e_m = The coefficient of expansion of the clay unit used in the construction (mm/m).

It has been recommended practice for many years to design spacings of vertical control gaps in walls based on half the 5-year expansion value. It is known that expansion varies with the logarithm of time[10] and the 5-year expansion is about 70% of the 15-year expansion (e_m). The design movement for walls is therefore;

$$0.5 \times 0.7 \times e_m = 0.35 e_m$$

Double this amount is used for parapets.

If the spacing of vertical gaps is S_v, the total closure at each gap would be:

$$\text{Closure} = S_v (0.35 e_m + 0.35) \text{mm}$$

where 0.35 mm/m is the allowance for thermal movement in the wall.

If the closure is to be limited to 15 mm, then:

$$\text{Max } S_v = \frac{15}{0.35 e_m + 0.35} \text{ metres}$$

$$= \frac{43}{e_m + 1} \text{ metres}$$

A similar approach to parapets gives:

$$\text{Max } S_{vp} = \frac{21.5}{e_m + 0.5} \text{ metres}$$

For example, consider a clay brick where e_m = 1.6 mm/m.

Then, $S_v = \frac{43}{2.6} = 16.5 \text{ m}$

and $S_{vp} = \frac{21.5}{2.1} = 10.2 \text{ m}$

The first gap in the main wall should be no more than 8 m from the corner and, in the parapet, 5 m from the corner. However, it is probably best to put the first gap close to the corner and run it through both the wall and parapet. Then, for this example, full-height gaps in the run of wall and parapet would be at around 16.5 m centres, with an extra gap in the parapet half way between each of the full-height gaps.

In many instances, it may be convenient to locate gaps at some line or lines occurring on the facade, for example behind downpipes. Wider spacing than that calculated might be adopted with more safety on south and east-facing walls where the movement from temperature changes will be less.

A nearly invisible joint can be provided at a re-entrant angle by the provision of a straight joint that permits the long wall to slide behind the shorter return (see Figure 31).

Vertical movement

Horizontal gaps to control vertical movement are required only in buildings where the external leaf of masonry is non-loadbearing and is supported by a frame or floor slabs. In these situations, provision is required for the shortening of the supporting frame or walls, for the growth of the clay bricks and for movements associated with temperature differences between the internal supporting structure and the external brick cladding.

In order to avoid disruption or loss of effectiveness to wall ties and other elements in the wall, the gap closing movement should be limited to 10 mm. A total gap width of 15 mm is appropriate for such a movement.

In calculating the maximum spacing of horizontal control gaps, the full amount of the expansion of the units is assumed to occur. This is a conservative approach because it ignores the possibility of shortening due to creep in new mortar.

Where a non-loadbearing outer leaf of clay brickwork covers a loadbearing masonry structure, the value of e_m used in calculating the gap width under the support for the outer leaf should be taken as the difference in the coefficient of expansion between the masonry units in the inner and outer leaves.

In developing a method for calculating the maximum spacing of horizontal gaps or the amount of vertical movement to be accommodated, the following additional notation is used:

S_h = spacing of horizontal gaps in walls (in metres).

Δ_h = closing movement in a horizontal gap included in a wall (mm).

For a reinforced concrete frame building:

$$\begin{aligned}\Delta_h &= S_h(0.7e_m + 0.35 + 1.2)\text{mm}\\ &= \mathrm{S_h}(0.7e_m + 1.55)\text{mm}\end{aligned}$$

Where 0.35 mm/m is the allowance for thermal movement and 1.2 mm/m is the allowance for frame shortening.

If Δ_h is restricted to 10 mm it follows that S_h must not be greater than:

$$\begin{aligned}\text{Max } S_h &= \frac{10}{0.7e_m + 1.55}\text{ metres}\\ &= \frac{14.3}{e_m + 2.2}\text{ metres}\end{aligned}$$

For a steel framed or a loadbearing-masonry building –

$$\begin{aligned}\Delta_h &= S_h(0.7e_m + 0.35 + 0.5)\text{mm}\\ &= \mathrm{S_h}(0.7e_m + 0.85)\text{mm}\end{aligned}$$

Where 0.5 mm/m is the allowance for frame or loadbearing wall shortening.

If Δ_h is limited to 10 mm, S_h must not be greater than:

$$\text{Max } S_h = \frac{14.3}{e_m + 1.2}\text{ metres}$$

For example, consider a reinforced concrete framed building with a floor height of 3.6 m to be clad with a clay brick having a high coefficient of expansion (e_m) of 2.0 mm/m. It has been decided to restrict the differential movement between the frame and the cladding to a maximum of 10 mm.

$$\text{Max } S_h = \frac{14.3}{2.0 + 2.2} = 3.4\text{ metres}$$

This distance is less than the floor-to-floor centre distance (3.6 m) and hence this brick (e_m = 2.0 mm/m) cannot be conveniently used in this building. For the gaps to be located at floor levels (S_h = 3.6 m) a brick is required with an e_m value not exceeding 1.77 mm/m.

If the frame were changed to steel –

$$\text{Max } S_h = \frac{14.3}{2.0 + 1.2} = 4.5\text{ metres}$$

In this case, the brick can be conveniently used. By making S_h = 3.6 m to suit the storey height it can be shown that a brick having an e_m value as high as 2.77 mm/m would be acceptable for the steel-framed building.

6.3 Recommended maximum gap spacings

AS 3700 does not prescribe limits on gap spacings, relying on designers to specify appropriate locations for each situation. Table 9 and Table 10 give limits that are recommended as reasonable general maxima, based on closures of 10 mm or 15 mm in vertical gaps and 10 mm in horizontal gaps.

Table 9. Maximum spacings for vertical control gaps in clay masonry (m)

		Vertical gaps for 15 mm closure		Vertical gaps for 10 mm closure	
Coefficient of expansion e_m (mm/m)		**Walls (S_v)**	**Parapets (S_p)**	**Walls (S_v)**	**Parapets (S_p)**
Low	up to 0.4	30	23	20	16
	0.41 to 0.8	23	16	16	11
Medium	0.81 to 1.2	19	12	13	8
	1.21 to 1.6	16	10	11	6
High	1.61 to 2.0	14	8	9	5
	2.01 to 2.4	12	7	8	4

Table 10. Maximum spacings for horizontal control gaps in clay masonry (m)

		Horizontal gaps for 10 mm closure	
Coefficient of expansion e_m (mm/m)		**Reinforced concrete frames**	**Steel frames and loadbearing masonry**
Low	up to 0.4	5.5	8.9
	0.41 to 0.8	4.8	7.2
Medium	0.81 to 1.2	4.2	6.0
	1.21 to 1.6	3.8	5.1
High	1.61 to 2.0	3.4	4.5
	2.01 to 2.4	3.1	4.0

6.4 Construction details

6.4.1 Vertical gaps

Vertical gaps should be straight joints. Toothed gaps are nearly impossible to construct in a manner that enables them to function properly.

In forming a vertical joint, a neat parallel-sided gap, free from mortar droppings, will be most easily created if a rigid board of suitable dimensions is built-in. Any material that is rigid enough to perform this function will be too incompressible to act as a filler or as a backing for a caulking compound seal and must be removed before the gap is sealed. Failure to remove this temporary filler will result in major problems. Sealing should be done using one of the methods illustrated in Section 6.4.3.

6.4.2 Horizontal gaps

Any element that supports masonry cladding should have a movement control gap beneath it. Typical details of gaps and suitable methods of providing support for the cladding are given in Figure 32 and Figure 33.

Figure 32. Brickwork supported by a nib on the slab

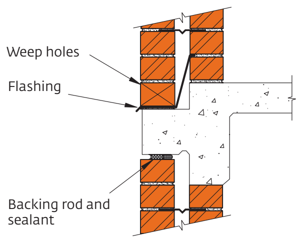
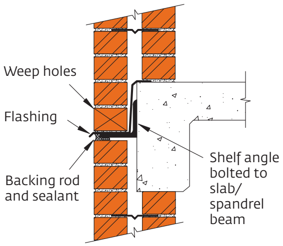


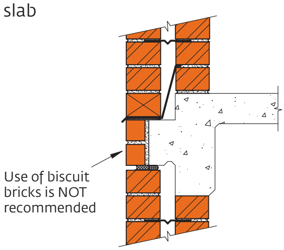
Figure 33. Brickwork supported by a shelf angle



Concrete nibs should be used only where they are to be carried completely through the wall. If this is not aesthetically acceptable, the outer leaf should be carried on a shelf angle. Many troubles arising from differential vertical movement are traceable to the use of nibs that project only partly into the brickwork and are faced with biscuit bricks. This type of detail is not recommended (see Figure 34).

If shelf angles are adopted, construction must be carefully detailed and even more carefully supervised to ensure that they provide the maximum possible support and that the required gaps have been provided. Shelf angles and their fixings should be of stainless steel or they should be hot-dip galvanised after fabrication.

Figure 34. Unacceptable detail for brickwork support by a nib on the slab



6.4.3 Gap sealing

Before sealing an expansion gap, it is essential that the gap be cleaned so that no hard materials such as mortar droppings are left in it to prevent its proper functioning. Failure to ensure that gaps are clean before sealing is the most common cause of brick expansion problems. Figure 35 shows typical methods of sealing control gaps.

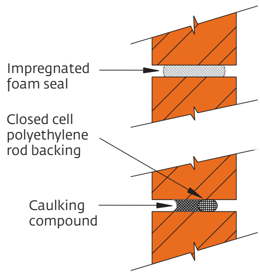
An expansion gap in clay brickwork gets narrower with time, and therefore the gap sealer does not have to stick to the sides of the gap, as would be the case with an opening gap. In these circumstances, a comparatively simple caulking material, such as butyl-mastic, is usually quite adequate. It is of paramount importance to ensure that only highly compressible material is placed in the gap so that potentially damaging forces are not transferred across it.

Materials such as pulp-board, cork or even semi-rigid foams are not suitable as gap fillers for a closing joint. If such materials are used to form the joint, they should be removed before the gap is sealed because most have compressive strengths high enough to transfer damaging forces across the joint. The use of joint fillers that are too rigid is the second most common cause of brick expansion problems.

A simple means of sealing gaps is first to clean them out and then to insert either a bitumen impregnated plastic-foam strip as the complete seal or a closed-cell polyethylene foam circular rod as a backing for a gun-applied butyl caulking compound. In either case the finished seal should be kept well back (approximately 25 mm) from the face of the wall to avoid an unsightly squeezing out of the compressed seal brought about the closing of the gap (see Figure 35).

For horizontal gaps under shelf angles or haunches, the seal will usually have to be located close to the face to reduce the risk of water penetration into the brickwork below (see Figure 33).

Figure 35. Methods of sealing vertical control gaps



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