TECHNICAL note

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Articulated Walling

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PREFACE

In 1984 the Cement & Concrete Association of Australia (now Cement Concrete & Aggregates Australia) published Construction Note 9 *Articulated Walling* (CN9). It was replaced in 1991 by Technical Note 61 (TN61) under the same title. This first edition of TN61 was a referenced document in AS 2870.1 – 1988 *Residential Slabs and Footings – Part 1: Construction.*

A second edition of TN61 published in 1998 took into account the provisions of a replacement Standard, ie AS 2870 – 1996 *Residential Slabs and Footings – Construction.* It remains a referenced document in that Standard. It is also a referenced document in the Building Code of Australia (BCA), Volume 2 *Housing Provisions.*

This third edition of TN61 also takes into account the requirements of all relevant Australian standards including the draft of the yet-to-be-published AS 4773 *Construction Practices for Masonry in Small Buildings.* The definition of articulation joints used in this Standard has been adopted, ie as a subset of 'Control Joints' they deal only with angular distortions in walls due to the response of a footing system to ground deformations. Other movements in masonry walls are deemed to be accommodated by other types of control joints. This document nevertheless recognises that it is often appropriate for articulation joints to be multi-purpose, ie to function as expansion and/or contraction joints in addition to their primary function.

1 SCOPE

This Technical Note deals with the articulation of masonry walls, both internal and external, built on a concrete slab-on-ground or strip footing. The details included also provide guidance for the articulation of masonry walls with other footing systems on reactive soils, eg pier-and-beam footings.

The joint spacings and details given are intended for masonry (brick and block) walls constructed of materials such as clay, concrete, calcium silicate or stone. Autoclaved aerated concrete (AAC) masonry walls are not covered in this document. While the principles still apply, the joint spacing will need to be appropriate for the increased stiffness of the AAC wall system.

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Likewise, the principles apply in mine subsidence areas (particularly in areas where long-wall mining methods are used) as the ground movements are similar to those encountered on reactive clay soils. However, items such as the required joint width and spacing will need to be calculated to confirm that the details contained herein are appropriate for the expected ground movement.

While articulation joints normally apply to masonry walls, framed walls (referred to as clad frame in AS 2870[1]) which are more flexible than masonry walls may also benefit from articulation. The location and spacing of articulation joints for clad frame walls are similar to those recommended for masonry walls.

While every individual situation where an articulation joint is required can not be covered because of the variety of wall and window/door opening combinations, this document provides guidelines for the location and detailing of articulation joints.

2 INTRODUCTION

Masonry walls – whether built of bricks or blocks, made of fired clay, concrete or sand/lime – are rigid and brittle. They can thus tolerate only minor footing movement without cracking and/or causing windows and doors to become jammed.

Unpainted masonry walls incorporating cement/lime mortar are the most tolerant of movement, and any cracking in the mortar joints tends to be inconspicuous. In rendered and/or painted walls, cracking may be visually unacceptable, even though structural performance is unimpaired.

The solution is to provide footings that are rigid enough or to articulate the walls; the latter will usually be the more economical solution as more flexible footings can be used. Articulation involves dividing the walls into panels separated by vertical joints that allow movement and thus reduce the risk of cracking.

Footing movement is typically caused by swelling and shrinking of the foundation material. Thus the risk of movement depends on the extent to which the foundation soil reacts to changes in moisture content. AS 2870 classifies sites in accordance with the soil's reactivity in a range from Class A (stable) to Class E (extremely reactive). The Building Code of Australia (BCA)[2] requires that houses on all sites other than Class A and Class S (slightly reactive) incorporate articulated walls.

It is important to note that articulation of the walls of a building does not replace the need to adopt other measures which are essential when building on reactive-soil sites to further reduce the risk of cracking to masonry walls from foundation movement. Measures intended to provide more consistent foundation conditions include:

- Draining surface water away from the building to prevent ponding adjacent to footings.
- Providing 'apron' paths around perimeter walls to better control and provide more consistent moisture levels within the soil adjacent to the footings.
- Avoiding large trees or thick shrubbery nearby that locally draw moisture from the soil and cause uneven and often large soil movements.
- Providing flexible drainage connections to prevent water leakage near footings.

These and other practical measures are outlined in *Foundation Maintenance and Footing Performance: A Homeowner's Guide*[3].

3 FOUNDATION AND BUILDING MOVEMENT

The foundation is the ground that supports the building and the footing is the construction (concrete slab, strip, pad or piers) which transfers the load from the building to the foundation.

Footings may be designed to either restrict or accommodate movements that occur in the foundation soil. For small buildings constructed on soils that shrink or swell (reactive sites) it is usually uneconomical to attempt to design a rigid footing system to avoid transmission of any significant movement to the superstructure. It is better to design the footing system to allow a limited amount of movement, and a superstructure that can tolerate that movement.

Generally, the more reactive the soil is the more rigid the footings need to be in order to ensure the acceptable performance of the structure above. If brittle elements such as masonry walls which are susceptible to cracking due to movement are articulated, the risk of cracking will be minimised, and less-rigid footings than those needed for non-articulated buildings will be adequate.

Deemed-to-comply or standard footing systems for soils of varying reactivity are detailed in AS 2870. Apart from full masonry on Class H sites, for which articulation is mandatory, options are given for either articulated or non-articulated masonry construction for various site classes. On stable sites (Class A) and slightly reactive sites (Class S) no concession in footing size is allowed for articulated masonry veneer walling. On Class S sites there is a concession for articulated full masonry. Note that the acceptable construction provisions of the BCA require articulation on all site classes other than Class A and S.

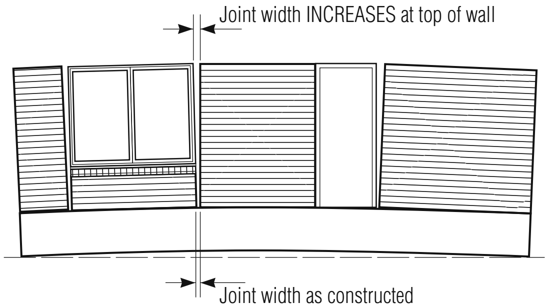
More flexible wall types such as clad frame walls with timber or metal studs will also benefit from articulation to reduce the risk of surface distress and window and door jamming due to foundation movement.

The construction of a building on a reactive soil site typically causes changes in the moisture content of the soil under the building relative to the surrounding soil. After the construction of slab-on-ground footings the soil beneath the slab will generally have a higher moisture content than the surrounding soil, causing reactive soils to swell and form a mound. Strip footings with suspended flooring systems, which provide ventilation under the floor, generally cause the soil beneath the floor to dry causing reactive soils to shrink and form a dish. Seasonal weather changes (ie dry and wet periods) will cause reactive soils around the exposed edges of the building to also either swell or shrink. This may increase the mounding (dry periods) or even cause dishing of slab-on-ground footings if the moisture increase around the edges is more than that under the slab (wet periods) **Figure 1**.

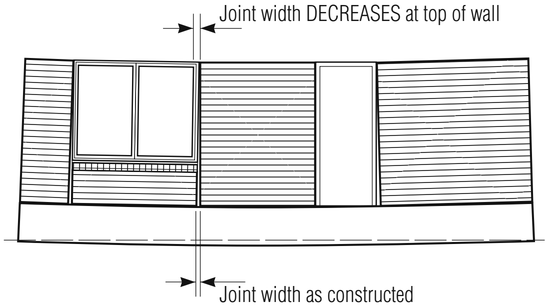
The differences in the soil movement cause the greatest problems. Doming and dishing of the foundation soil and footings – although it may be only a few millimetres – causes distortion in the walls. Articulation is designed to accommodate such movement by dividing walls into smaller panels that can move independently of each other, thereby minimising the risk of cracking in the walls.

Doming and dishing of the footings means that articulated wall panels need to be able to move in their own plane, with the articulation joints opening and closing in response to the foundation movement. The articulation joint width and details (eg sliding or vertical expansion joint ties) should allow for this movement. Note that the foundation movement associated with reactive soils generally occurs over long periods (say 12 to 18 months) due to the relative impermeability of the clay materials that typically cause the swelling and shrinkage movements. Thus joints will tend to open or close seasonally with prolonged wet or dry conditions, rather than over short periods.

It should also be noted that the greatest opening or closing occurs at the top of an articulation joint, with little or no movement at the bottom (ie at the top of the footing). For this reason, provided that some hairline cracks in the wall just above the footing is acceptable (usually concealed within the mortar joints), articulation joints may start above the level of the damp-proof course **Figure 2**. This has the advantage of providing less interference to the installation of damp-proof courses and termite



DOMING CAUSED BY SWELLING OF REACTIVE SOILS



DISHING CAUSED BY SHRINKAGE OF REACTIVE SOILS

Figure 1 Effect of ground movement on footings and articulated walls

Figure 2 Articulation joint above damp-proof course

barrier systems within the masonry walling or cavity. For situations where the damp-proof course is more than say 400 mm above the footing or the risk of cracking in this area must be minimised, it is recommended that the articulation joint should extend down to the footing and allowance be made for movement in any built-in components such as termite barriers.

Ideally, the wall layout for the building should follow a basically straight grid pattern so the beams of a raft slab can follow the wall pattern economically and simplify the division of the wall into independent panels by articulation joints.

The roof construction (framed, trussed or beam-and-rafter) should include adequate bracing to prevent spreading of the roof framing and hence the tops of walls being pushed out which could cause cracking of internal walls that are located adjacent to the eaves.

4 FOOTINGS FOR ARTICULATED WALLS

One of the benefits of articulated walling is the reduction in the size and ultimate cost of footings required for a building with masonry walls on reactive soils. Because an articulated structure has sufficient flexibility to move in harmony with the footings without developing unacceptable cracks, the footing can be designed to be less rigid than would be required for a non-articulated masonry superstructure.

Regarding the 'acceptability' of cracking, AS 2870 includes guidance on this by classifying the damage that may occur to walls. Adoption of the deemed-to-comply or standard footing designs in AS 2870 should ensure that the majority of damage to walls falls into damage category 0 (either no cracking or hairline cracks less than about 0.1 mm in width), some may fall into category 1 (fine cracks less than about 1 mm in width which do not need repair) and a few may fall into category 2 (noticeable cracks less than about 5 mm in width that can be easily filled). Damage categories 3 and 4 include cracking from 5 mm to 15 mm and 15 to 25 mm respectively with doors and windows jamming and, in the worst cases, possibly distorting. Damage within these categories seldom occurs, and when it does, is usually the result of some specific site problem. The range of categories acknowledges that standard footing designs on typical sites of a particular soil classification (Class A, S, M and H) will generally perform satisfactorily, but that soil conditions are variable. Thus, in some instances the soil and therefore footing movements will be greater.

The *Guide to Standards and Tolerances*[4] produced by various State Government Authorities, refers to a category 2 crack as being a defect requiring minor repair work such as repointing. Note that these fine cracks usually occur in the mortar joints where they often go unnoticed. Damage in categories 3 and 4 will generally require more substantial repairs.

Thus while articulation allows a more flexible and therefore economical footing system for a particular walling type and soil reactivity, the expected performance levels of the standard designs having articulated walling follows the same philosophy outlined above regarding acceptable crack widths, ie the majority of articulated walls on footing systems complying with AS 2870 will perform satisfactorily, some will display fine cracks and a few will have noticeable cracking.

Articulation may therefore be used in two ways for any given walling type: it may be used to reduce the required footing size, or, by maintaining the footing size required for the non-articulated case, to further reduce the risk of walls cracking and windows and doors jamming. The latter approach is recommended for walls containing arches, and for buildings with rendered or painted finishes where any cracking that may occur is more noticeable.

If one of the standard footing designs in AS 2870 (which ensure compatibility between footing design and tolerable movement for the type of walling system) is not used, the designer should consider the following points when determining the allowable deflection of the footings:

- Materials and construction of internal and external walls
- Surface finish of internal and external walls
- The number of articulation joints and their location
- Length and plan arrangement of walls
- The inclusion of damage-prone elements such as masonry arches.

Suggested maximum limits for the deflection for the design of footings and rafts for various types of construction given in AS 2870 are reproduced in **Table 1**. The limit adopted for a particular design will depend on the form of construction and take account of factors such as the distance between articulation joints, number of storeys, first-floor construction materials, wall surface finish, and whether or not the masonry is reinforced. The design limit for deflection should be nominated by an experienced engineer. Note that for non-articulated, full-masonry construction, a deflection of the footing of around 5 mm over a 10-m span may cause cracking.

Should more than one form of construction be used in a building, it is possible to design footings with different limits of deflection in separate parts

Figure 3 Control joints less than 2 m from the corner do not function as articulation joints

of the building. AS 2870 simplifies this issue by equating different external and internal wall types to an 'equivalent' type of construction which may then be used for the entire footing system, thus allowing standard details to be used throughout.

5 SPACING OF ARTICULATION JOINTS

If footings appropriate for articulated masonry have been selected from the standard designs within AS 2870, then the recommended maximum spacing of articulation joints in straight, continuous masonry walls having no openings should be in accordance with **Table 2**. If walls have openings larger than 900 x 900 mm, the maximum joint spacing should be 5.0 m.

The spacing from corners or ends of walls should be in the range of 2 m to 4.5 m for all finishes and masonry wall types. Control joints less than 2 m from the corner or end of a wall may be necessary for other reasons. However, they should not be regarded as effective articulation joints **Figure 3**. For single-storey construction, if there are windows present near corners or ends of walls then the articulation joint should generally be located near or at the furthest side of the window from the corner or end of wall **Figure 4**.

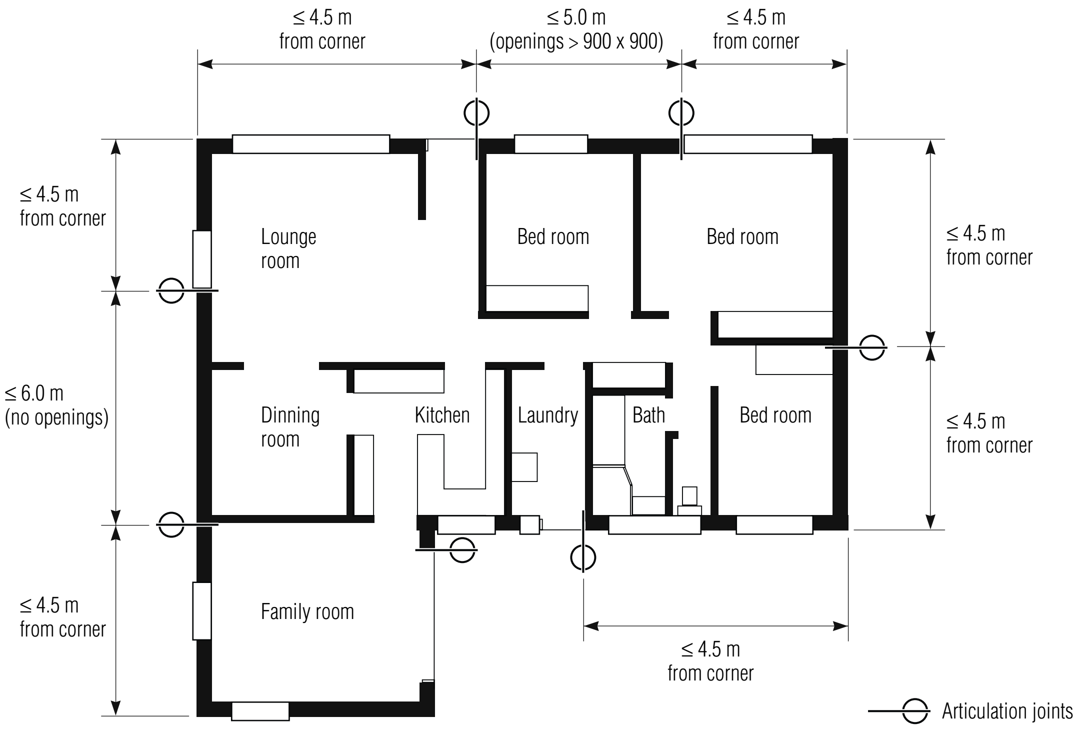


Figure 4 Typical location of articulation joints for brick veneer building on Class M site with face finished masonry

TABLE 1 Maximum design differential movement, Δ, for design of footings and rafts *(from AS 2870)*

Type of construction	Absolute maximum deflection, Δ as a function of span, L (mm)	Absolute maximum deflection, Δ (mm)
Clad frame	L/300	40
Articulated masonry veneer	L/400	30
Masonry veneer	L/600	20
Articulated full masonry	L/800	15
Full masonry	L/2000	10

Notes: 'L' is the footing or slab length in the design direction.
'Special provisions for the Design of Residential Slabs and Footings for South Australian Conditions' [5] *relates the maximum deflection to joint spacing.*

TABLE 2 Maximum spacing of articulation joints for unreinforced masonry walls *(after AS 4773 Parts 1 and 2[6])*

Site class[1]	Masonry wall construction and surface finish	Joint spacing (m) for wall height/joint widths		
		Up to 4 m high for 10-mm joints	4 m to 8.5 m high	
			For 10-mm joints	15-mm joints
A and S		Articulation not required[2]		
M, M–D	External face finish masonry	6.0	4.2	6.0
	External rendered and/or painted masonry	5.5	3.9	5.5
	Internal face finish or sheeted masonry	6.0	4.2	6.0
	Internal rendered and/or painted masonry	5.5	3.9	5.5
H, H–D[3]	External face finish masonry	5.0–5.5	3.5–3.9	5.0–5.5
	External rendered and/or painted masonry	4.5–5.0	3.2–3.5	4.5–5.0
	Internal face finish or sheeted masonry	5.0–5.5	3.5–3.9	5.0–5.5
	Internal rendered and/or painted masonry	4.5–5.0	3.2–3.5	4.5–5.0
E	Refer *Note 4*			

Notes:
1 As defined in AS 2870
2 Use maximum spacing for expansion or contraction joints.
3 For H–D sites use the shorter spacing within the range.
4 The location of articulation joints for Class E sites should be determined from engineering principles.

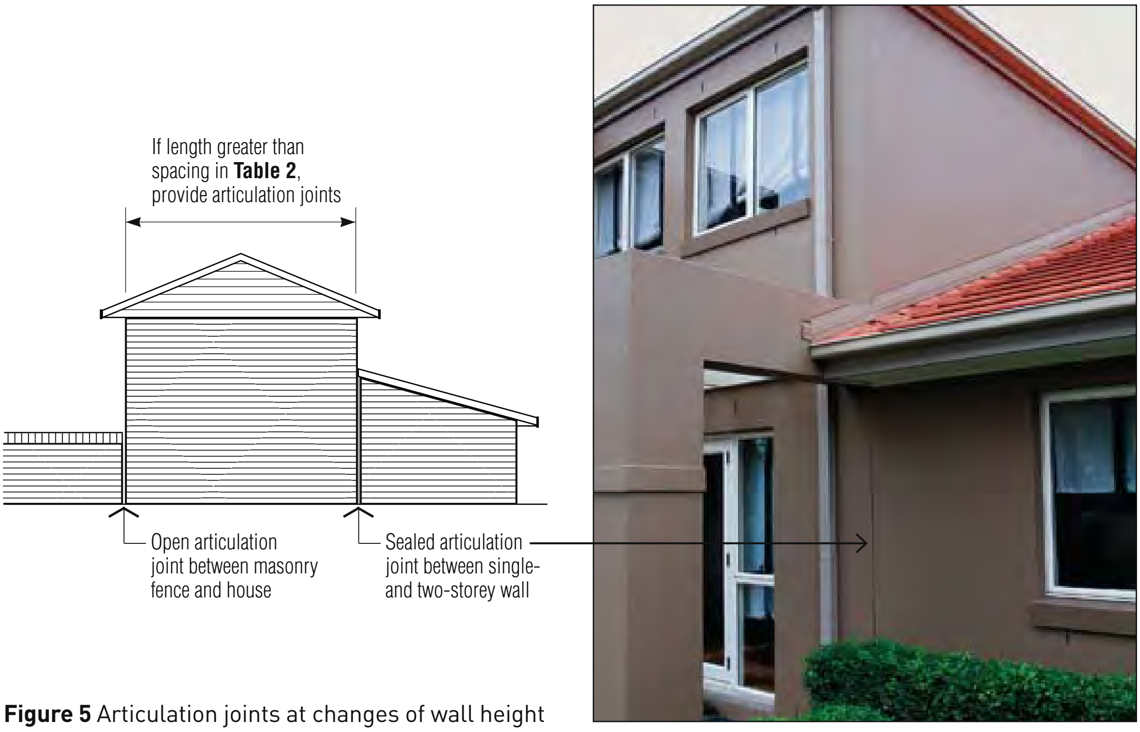


Figure 5 Articulation joints at changes of wall height

For footings designed by an engineer, the maximum spacing of joints will depend on the maximum deflection adopted in the design. If the joint spacing exceeds four times the average wall height or 12 m, the walls should be considered as non-articulated and the maximum deflection for this case should be selected on the basis of non-articulated masonry construction[5]. Also, 'sections of walls without openings may be considered as fully articulated if the distance between joints is not more than twice the average height, nor 6 m.' This is in agreement with the maximum 6-m spacing adopted in **Table 2**.

For Class E (extremely reactive) sites, the footings should be designed in accordance with engineering principles, with the joint spacing depending on the maximum deflection adopted. Note that deemed-to-comply or standard footing designs are not provided for Class E sites in AS 2870.

6 LOCATION OF ARTICULATION JOINTS

In addition to locations determined by the maximum spacing, articulation joints should also be located at positions where concentrations or variations in the potential development of stress may occur, for example:

- Where the height of the wall changes abruptly by more than 20% of its lesser height eg changes of storey height **Figure 5**.
- Control or construction joints in slab-on-ground or strip footings.
- Window and door openings **Figures 6 to 9**. For two-storey buildings, positioning openings to allow easier location of articulation joints is desirable **Figure 8**. Note that most lintel design methods assume arching of the masonry over the opening thereby reducing the loads that the lintel must support. If the articulation joint is in line with the edge of the opening (**Figure 8 (b)** and **Figure12**), lintel sizes selected from standard design tables should be checked for adequacy as masonry can no longer be assumed to arch over the opening.
- Changes in wall thickness **Figure 14**. Note that engaged piers are not considered to be a change in thickness.
- Junctions of walls built of different masonry materials (clay, concrete, calcium silicate or stone) **Figure 14**;
- Joints between masonry walls and structural reinforced concrete or steel elements;
- Deep chases or rebates for service pipes **Figure 15**. Note that chases deeper than 25% of the leaf thickness should be regarded as a change in thickness.
- At offsets in walls. Note that the internal corner is an inconspicuous location for a joint **Figure 16**.
- At changes in plan geometry where differences in movement may occur, eg where the family room shown in **Figure 4** is connected to the remainder (and basic rectangular shape) of the house.

For other than brick veneer walls (which are attached to a structural/supporting framework), articulation joints should be located either at or within 300 mm of wall junctions or engaged piers that serve as lateral supports. Note that their positioning should not interfere with the required lateral support **Figure 17**.

Figure 6 Articulation joints at window/door openings
(**a**) Maximum spacing
(**b**) Face-finished wall with sealant to match mortar colour
(**c**) Face-finished wall with sealant to match brick colour

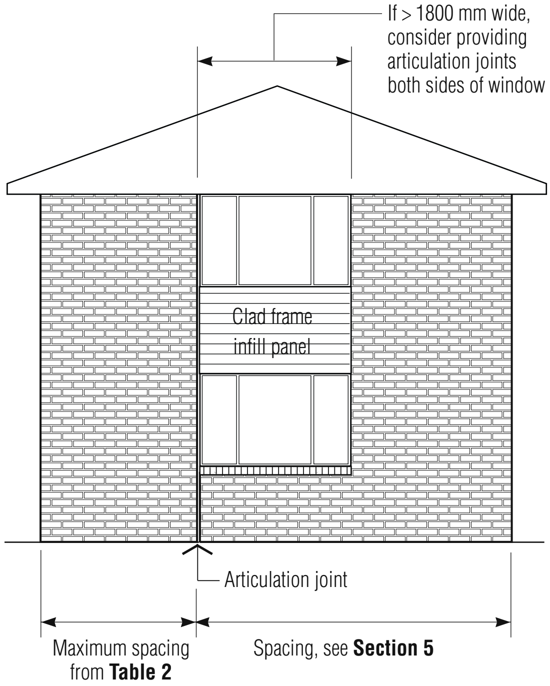


Figure 7 Articulation joints at window openings with infill panel between

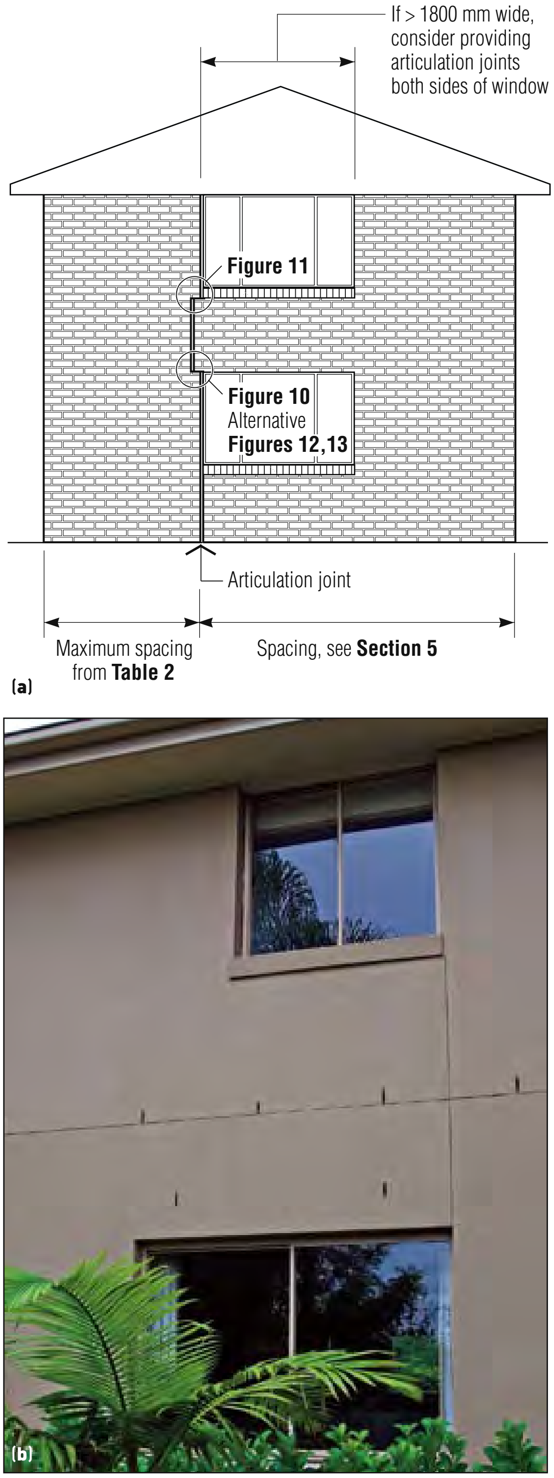


Figure 8 Articulation joint at window openings with masonry between

(**a**) Offsetting joint may simplify detail at lintel

(**b**) Positioning of openings to line up may simplify location of joints and reduce visual impact

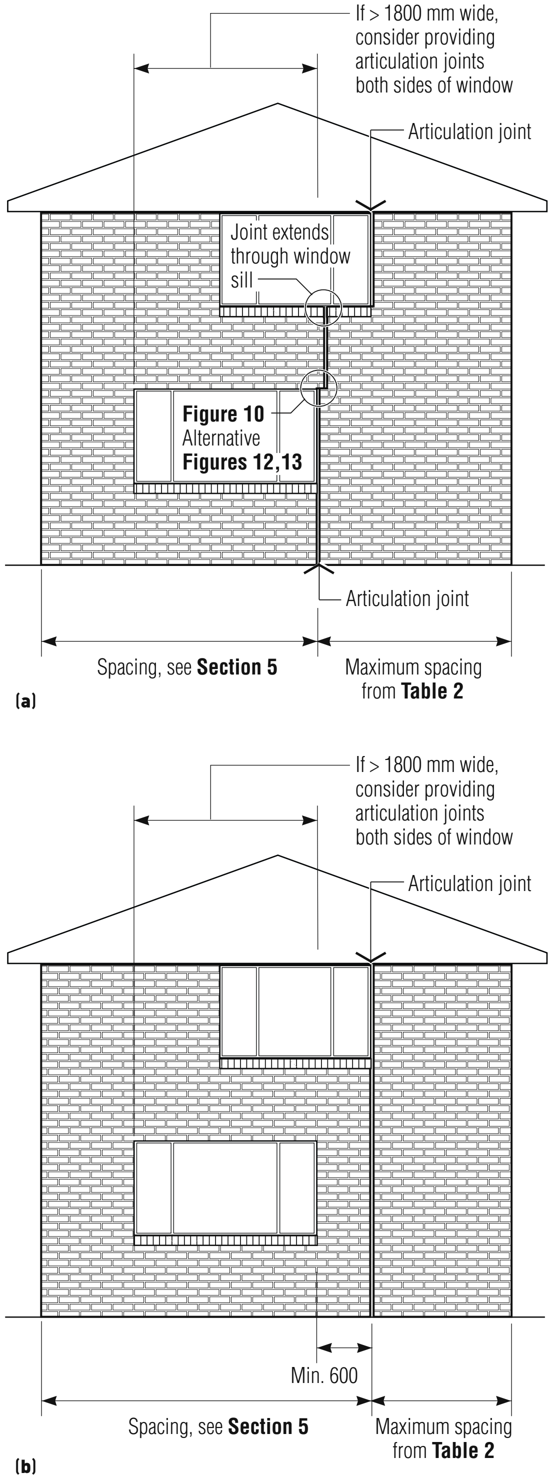


Figure 9 Articulation joints at window openings that are offset

(**a**) Joint adjacent to lower opening

(**b**) Joint adjacent to higher opening

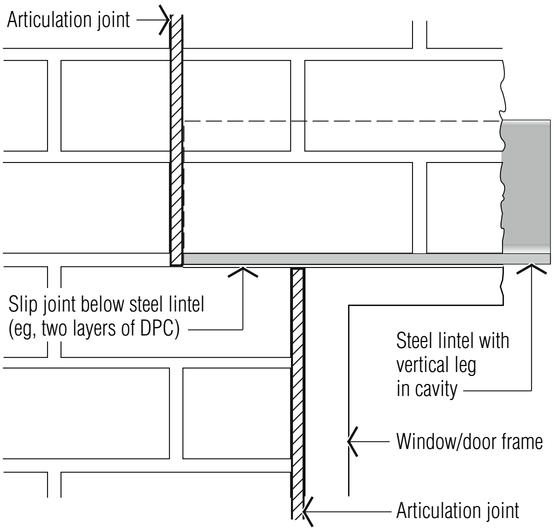


Figure 10 Articulation joint offset to end of steel (or other) lintel over opening (this detail is recommended where possible to ensure arching of masonry over opening)

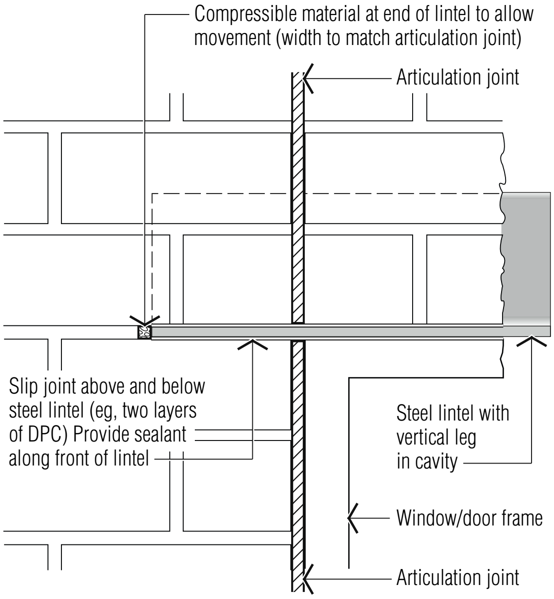


Figure 12 Alternative if articulation joint can not be offset to end of steel lintel

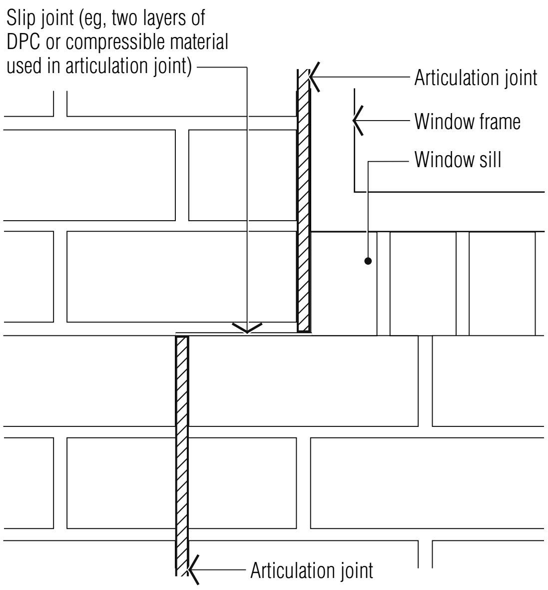


Figure 11 Articulation joint offset at window sill

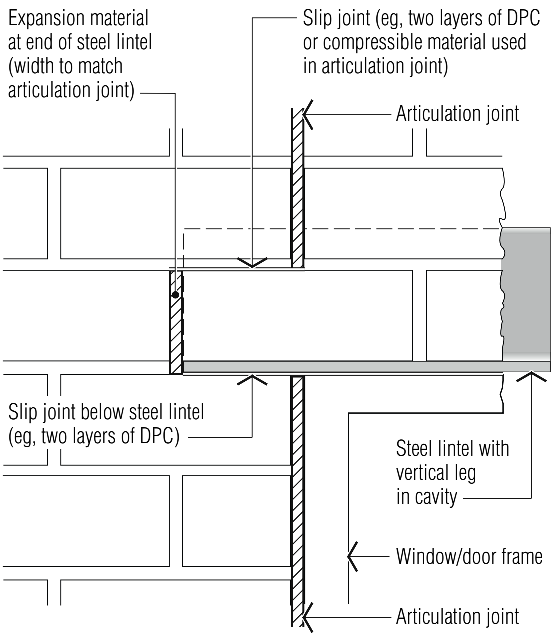


Figure 13 Alternative if articulation joint can not be offset to end of steel lintel (similar detail is appropriate for prestressed concrete or clay lintels)

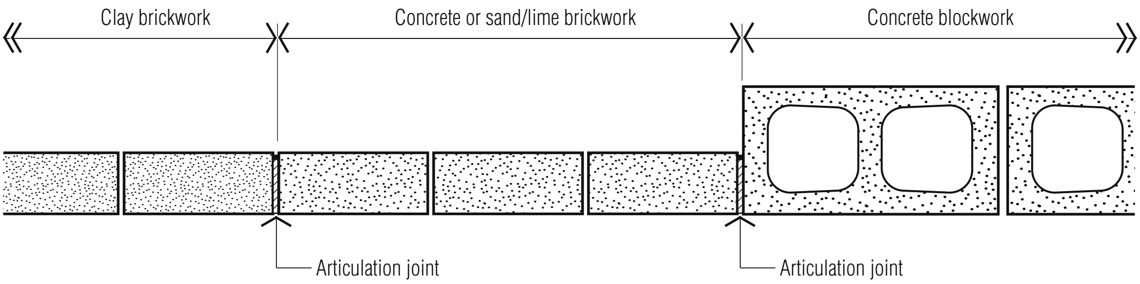


Figure 14 Articulation joints at changes of wall thickness/material

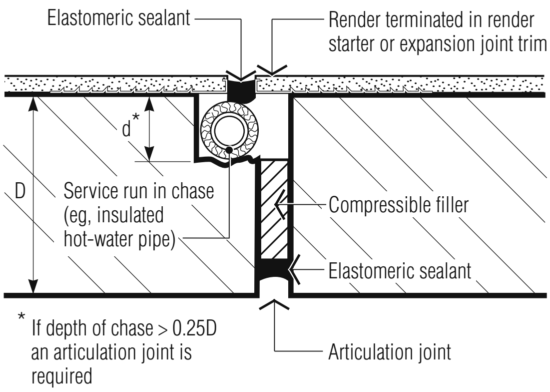


Figure 15 Articulation joints at deep chases

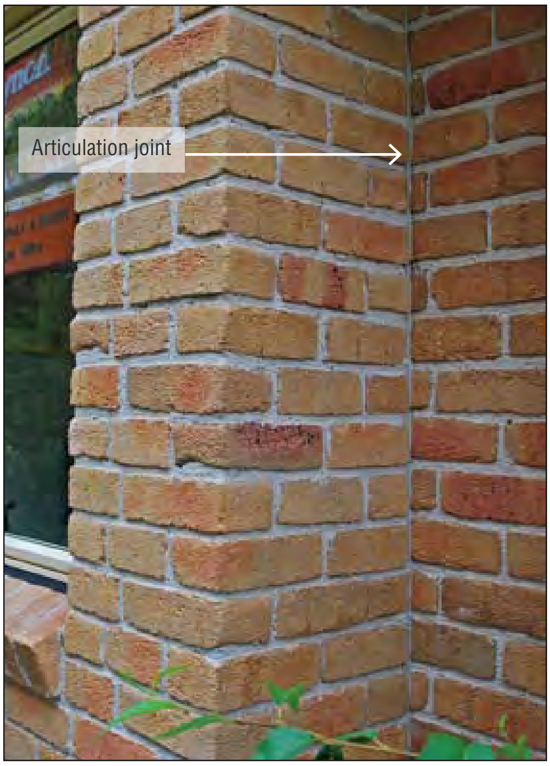


Figure 16 Articulation joint at offset in wall

7 DETAILING OF ARTICULATION JOINTS

7.1 External Walls

To maintain the bonding pattern at vertical articulation joints (recommended), half-length bricks or blocks should be used at joint locations in masonry walls. The option of toothing masonry at joints is generally not recommended because of the difficulty of ensuring the required gap is achieved. (Note that AS 3700 does not allow toothing unless it is specifically considered in the design). Further, as most sealants perform better in tension and compression (at the vertical joint) than in shear (at the horizontal part of a toothed joint), suitable joint details must be specified if toothing is being considered.

If the walls are rendered or coated, the same movement capacity available in the articulation joint should be provided in these finishes. Render can be stopped either side of the joint by using a starter trim or possibly an expansion-joint trim. Simply forming a groove in the render at the joint location is not recommended **Figure 18 (a)**. Bagged finishes and other types of thin coatings should also be kept flush with the edges of the joint. The painting of these types of finishes (including the sealant) will make joints less conspicuous **Figure 18 (b)**.

Articulation joints must be free of mortar and may be packed with a compressible filler such as polystyrene or a closed-cell polyethylene foam to ensure a continuous gap and provide a backing for an elastomeric sealant to be gunned into the joint **Figure 19**. Note that semi-rigid foams, bitumen-impregnated fibre board (eg jointex) or cork are not suitable as permanent joint fillers because of their limited compressibility. Alternatively, a temporary filler may be used to keep the joint clean and true; when removed, a permanent backer rod is forced into the joint to provide a backing for the sealant **Figure 20**. Note that the joint must be clean and free of any materials (eg mortar) that would prevent or restrict closing of the joint.

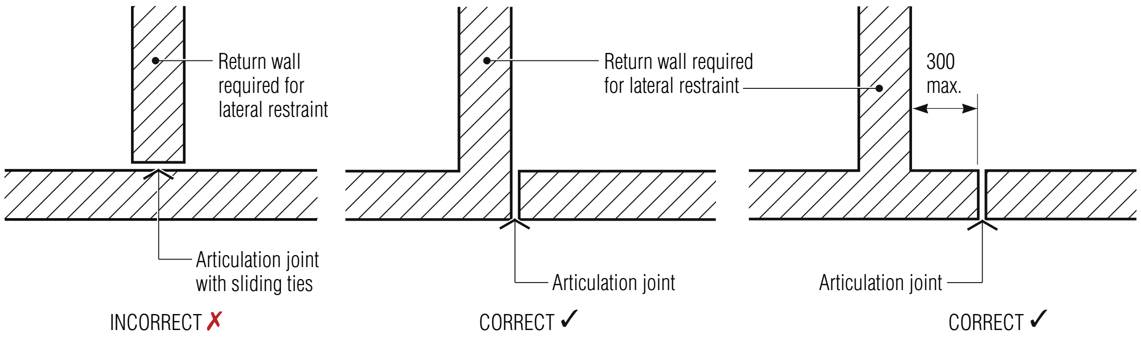


Figure 17 Location of articulation joints to maintain stability

7.1.1 Minimum Width

The minimum width of articulation joints should take into consideration the height of the wall and the expected movement, especially if the joint is to serve the dual function of articulation and expansion or contraction. **Table 2** gives suitable joint spacings for both 10- and 15-mm-wide joints for walls up to 8.5 m high.

The joint widths in **Table 2** will also accommodate some expansion or contraction of the masonry wall panels. Designers and builders should, however, consider whether there is potential for greater movement than can be accommodated by a 10- or 15-mm joint width, eg in mine subsidence areas. Where the control joint functions both as an articulation joint and an expansion joint, either the overall width of the joint should be increased to 0.7 times the sum of the required widths for each separate function, or the joint spacing should be reduced for the 10- or 15-mm-wide joints.

7.1.2 Joint Sealants

Sealant materials typically include silicones and polyurethanes. For painted finishes, either a specialist silicone sealant that can be painted, or more commonly, a polyurethane sealant should be used. Polysulphide materials (able to be painted) are also available but as they are two-component products, they are not commonly used. Sealants should have a minimum extensibility of 50% (ie ±25%) and be suitable for the clay or concrete masonry walling material used. Some sealants may require priming of the joint to promote bonding to the substrate. Sealants are gunned into the joint and are available in a variety of colours, either to match the masonry or mortar colour to assist in reducing the visual impact of the joint. It is also possible to dust the surface of freshly applied sealant with crushed mortar, thereby giving it a texture and colour that closely matches the mortar joints in the surrounding brickwork. Note that sealants and/or filler materials should be recessed back from the outside face to prevent the sealant being squeezed out of the joint if the maximum expected compression of the joint occurs **Figure 21**.

Sealants should be applied towards the end of the construction after any initial movement has occurred.

For clay bricks which tend to grow, sealants must allow for long-term, permanent compression; for concrete or calcium silicate bricks and blocks which tend to shrink, the sealants must allow for long-term tension.

The geometry of the sealant is important to ensure that the material is able to comply with the stated performance. If the depth of the sealant is too great it will act more like a rigid 'block' than a thin elastic member and will not be able to extend/contract properly. Generally, the depth of sealant should not be more than the joint width for joints up to 12 mm in width, and no more than half the joint width for wider joints. The joint filler or a backer rod, are typically used to provide the correct joint geometry. The manufacturer's recommendations should be followed for each specific material. Note that sealants may need to be replaced every 10 to 15 years (depending on type and exposure condition) as part of building maintenance.

Where articulation joints occur at the ends of lintels (ie at the sides of window/door openings) and movement of the lintel along the bed joint is expected, this joint may also be sealed as the movement will typically cause cracking and loss of the mortar from the joint **Figure 22**.

If the wall of a Class 1 building (house) is located closer than 900 mm to a property boundary (other than a boundary adjoining a road or other public space), the BCA requires a fire resistance level (FRL) of not less than 60/60/60. However, the BCA states that small openings in the masonry such as sub-floor vents, weepholes and control joints (including articulation joints) do not need to be fire rated. For fire separating walls of attached Class 1 buildings and other building types, the use of a fire-rated sealant in articulation joints should be provided. For such buildings, the sealant may also need to provide acoustic performance.

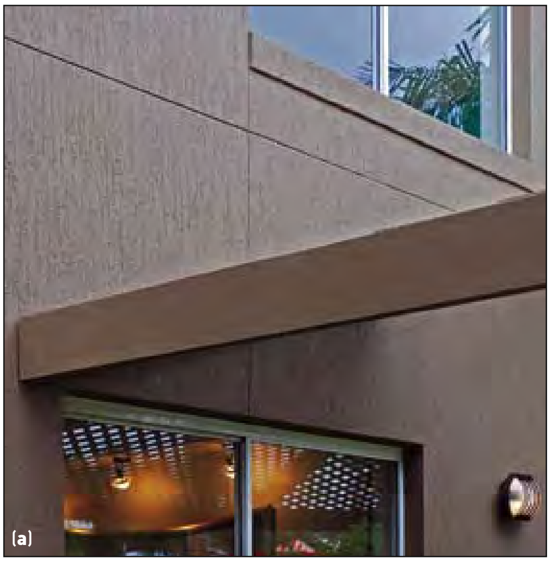


Figure 18 Joints should be continuous through applied finishes

(a) Joints should be continuous through applied finishes such as render, not just scored in the surface as shown

(b) Joints/sealants may be painted to reduce their visual impact

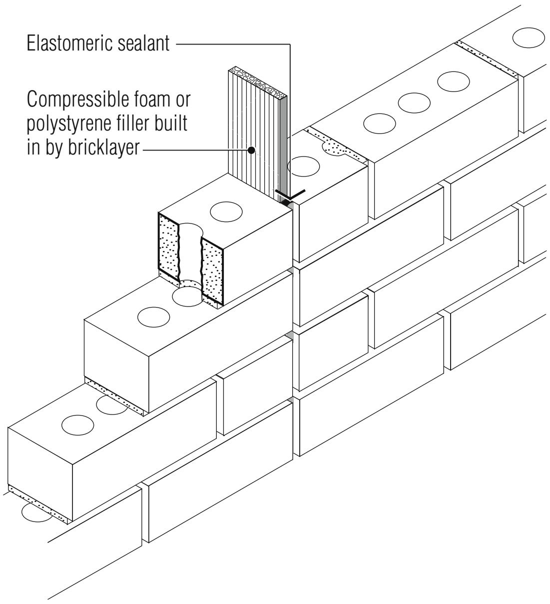


Figure 19 Typical articulation joint detail for external masonry wall

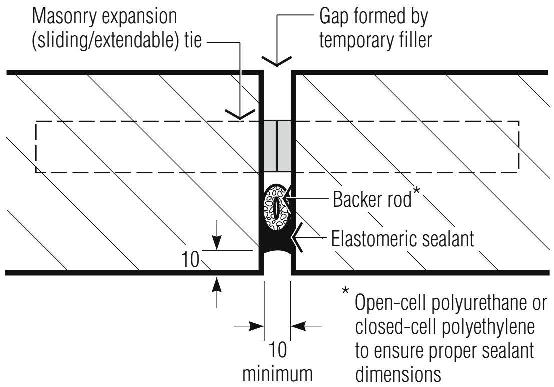


Figure 20 Alternative articulation joint detail for external masonry wall

Figure 21 Joint filler/sealant squeezed out of joint as a result of not having been recessed

Figure 22 Bed joint along lintel may also require sealing at articulation joints

7.1.3 Wall Ties

To provide support for wall panels at articulation joints, the BCA requires wall ties to be provided on each side of the joint and spaced horizontally no more than 300 mm from the joint. The vertical spacing of wall ties at articulation joints must also be halved, effectively doubling the number of ties at these locations. In order to suit brick or block courses, the vertical spacing could vary from 200 to 400 mm but should average the required 300-mm spacing (ie half of the normal 600-mm vertical spacing).

For cavity and unreinforced single-leaf masonry walls, lateral support across the joint (to carry horizontal loads and to maintain alignment) should be provided. To achieve this, and also to allow the joint to open and close, masonry expansion (sliding/extendable) ties are used **Figure 23**. The strength, number and spacing of ties should be sufficient to transfer the calculated loads across the joint. As a

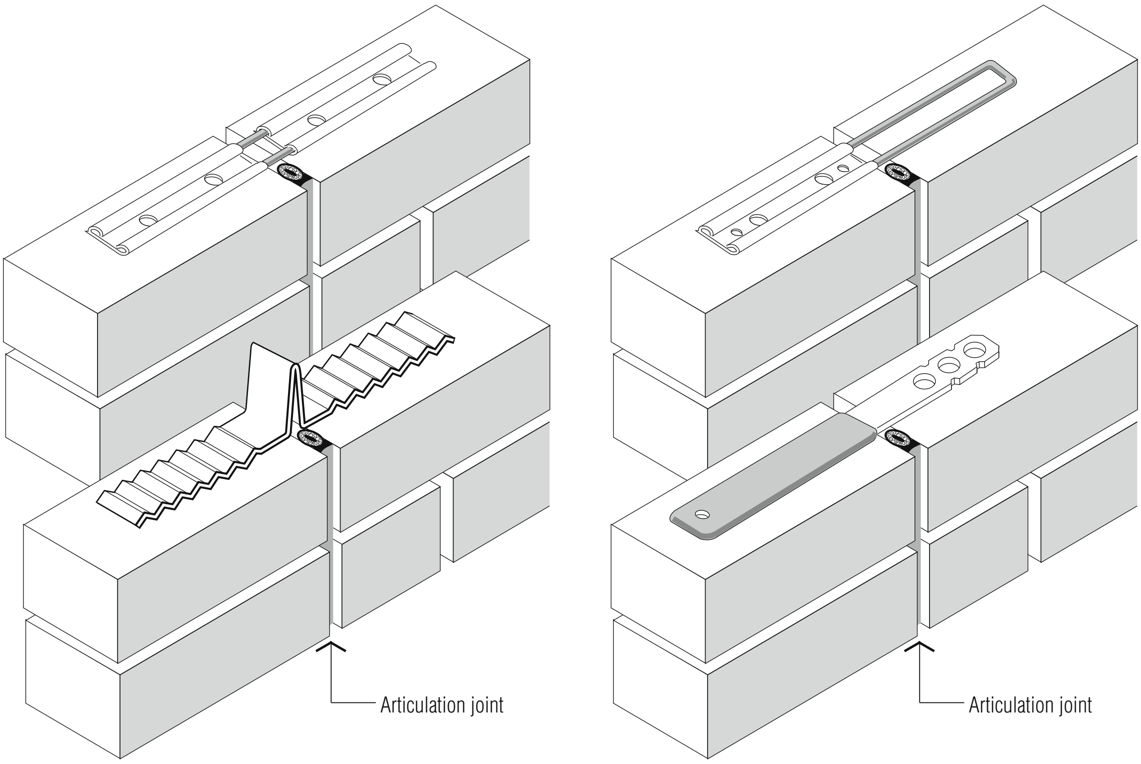


Figure 23 Examples of masonry expansion (sliding/extendable) ties

guide, for brick masonry, ties should be provided every fourth course and for block masonry, every second course, ie at 400-mm centres. If a filler strip is used it should extend around the sliding ties. For masonry having hollow cores, adequate embedment of the ties will generally require the grouting of any cores containing the larger sliding ties.

For masonry veneer (brick or block) and reinforced single-leaf (block) masonry walls, sliding ties may also be provided, but are generally not required as the masonry on either side of the joint is held in place by either a structural frame (typically timber) or reinforced and grouted cores which provide the required support to the masonry.

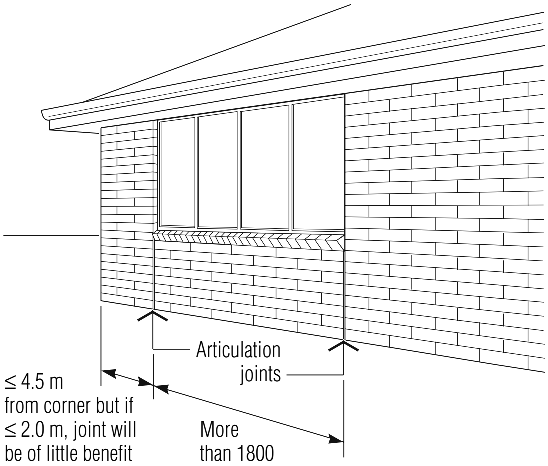


Figure 24 Articulation joints should be considered at both sides of wide window/door openings

7.1.4 Termite Barriers

Articulation joints do not prevent the installation of effective termite barrier systems within the masonry wall or cavity since each barrier system has specific details for this situation. Note that any termite barriers that cross articulation joints must be able to accommodate the expected movement.

7.2 Windows and External Doors

In residential buildings articulation joints should be combined with window or external door openings wherever possible, as these typically form points of weakness within the masonry wall, at which the risk of cracking is increased. The continuous vertical articulation joint, running from footing (or damp-proof course) to roof, can be provided on the line of the window or door jamb. These locations also assist to reduce the visual impact of the joint as it is possible to conceal much of the joint behind architraves and cover mouldings, particularly with full-height windows and doors.

For windows or doors up to 1.8 m wide, and with the maximum joint spacings from Section 5, an articulation joint is generally required on only one side of the window or door. For larger windows and doors, articulation joints at both sides of the opening should be considered **Figure 24**. Note that if one side is less than 2 m from a corner, an articulation joint on the side closest to the corner will be of little benefit **Figure 3**.

It is essential that a gap is left between the window or door frame and masonry to ensure that movement is possible. One method of achieving this in cavity/solid masonry while still providing secure fixing of the frame to the walling, is to use column expansion ties fixed to the widow or door frame

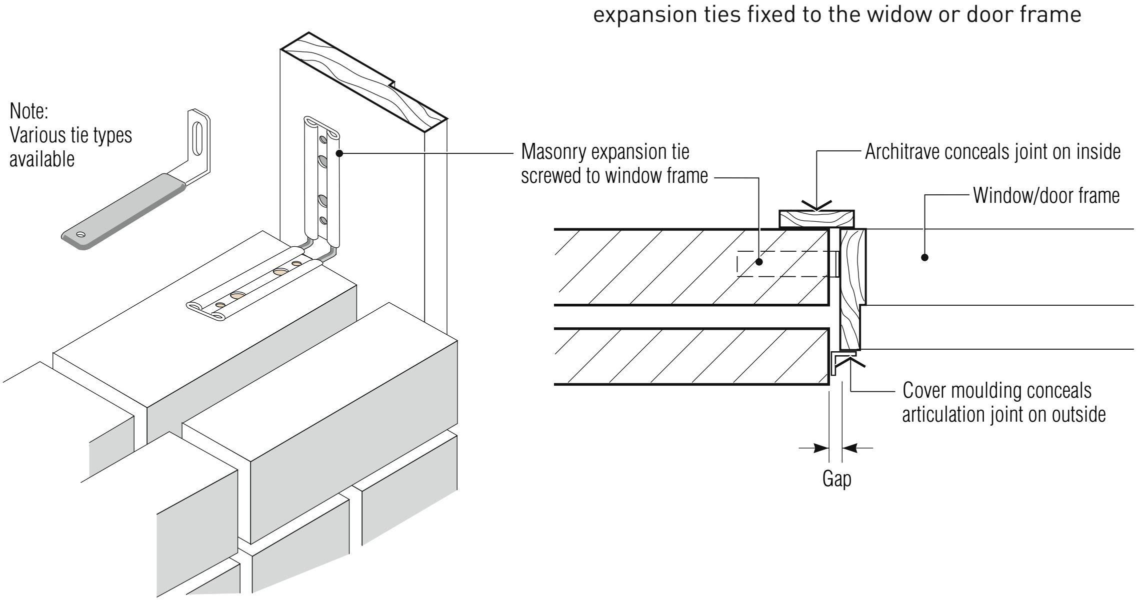


Figure 25 Fixing of window/door frames at articulation joints

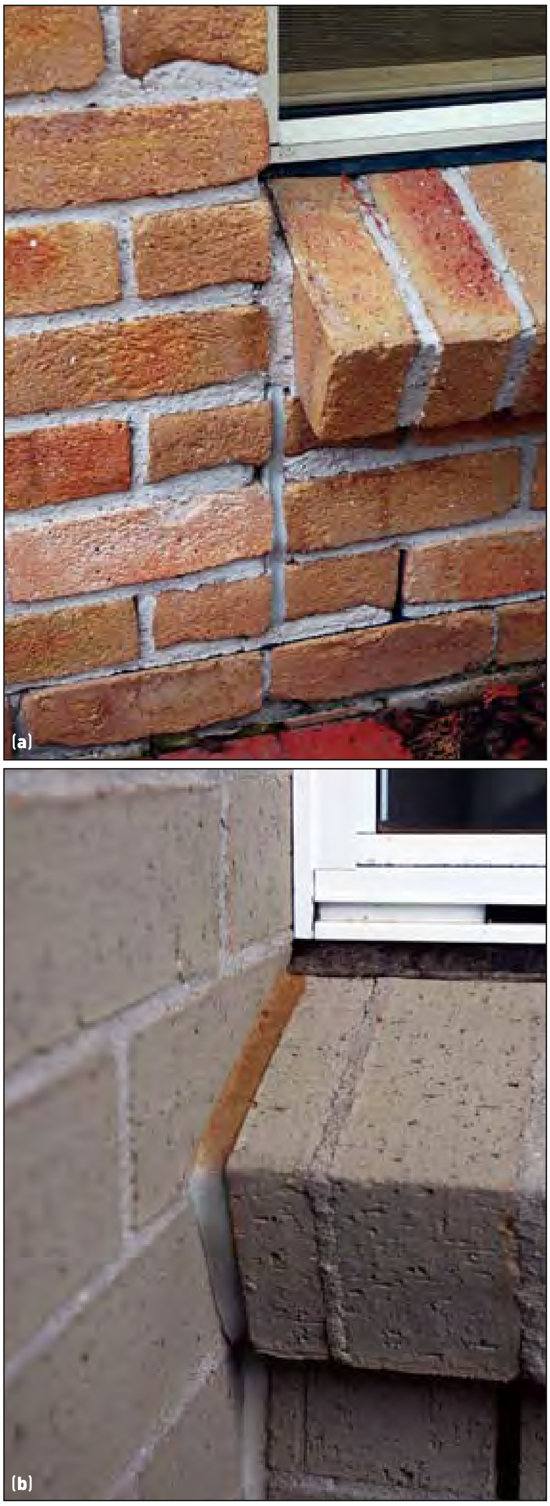


Figure 26 Articulation joints should be continuous
(**a**) Joint should be continuous alongside window sill
(**b**) Joint is continuous alongside window sill but required gap between masonry and window frame has not been provided

Figure 27 Articulation joint between openings

and built into the masonry wall **Figure 25**. The practice of building masonry (including sills) hard against window or door frames at the location of an articulation joint is not recommended **Figure 26**.

Full-height windows, or windows with infill panels below the sill, eliminate the need to form an articulation joint in the masonry. Instead the architrave and external cover strip conceals the full-height gap of the articulation joint between the window or door and wall **Figure 25**.

Masonry is not recommended above window or door heads when building on reactive soil sites. For this reason the openings shown in **Figure 24** and **Figure 27** extend to the top wall plate or eaves lining. If the window or door itself cannot be taken to this height, then an infill panel should be provided. Beams over windows or doors supporting a top plate and spanning between articulated wall panels should be free to move on the masonry walls on both sides. Where masonry can not be avoided above openings, and for two-storey walls, refer to Section 6 for joint and lintel details that allow movement at joint locations.

Articulation joints should not be located in narrow masonry panels between two window or door openings as zig-zag cracking at the sill level may develop. A sufficiently wide panel of masonry should be provided between openings to reduce the risk of cracking **Figure 27** (1200 mm minimum is recommended by the Brick Industry Association, USA[8]).

7.3 Wall/Eaves Junctions

The amount of movement, which must be accommodated in articulation joints under doming action, increases from zero at the bottom of the joint to a maximum at the top. It is therefore advantageous to keep wall heights as low as possible. For this reason, the use of boxed or soffit-lined eaves is recommended for buildings having articulation joints. Eaves may be finished by resting the eaves lining on top of the external masonry walls. At window and door openings a simple framing of timbers hung from the roof structure supports the eaves lining **Figure 28**.

Where the external leaf of a masonry wall is used to support the roof structure, or where a single-leaf masonry wall is used, then raked or flush eaves provide a good detail for an articulated building. There are two methods of detailing raked eaves – with exposed rafters, or by lining under the rafters. Either way, the cover moulding between eaves and the wall should be attached to the top plate or rafters, thereby allowing the masonry to move independently and articulation joints to function properly **Figure 29**.

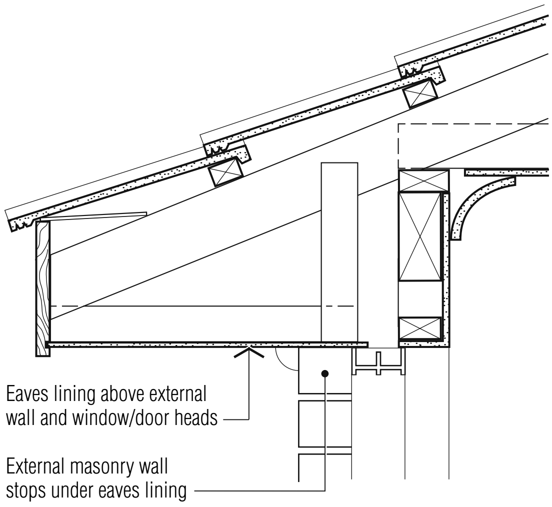


Figure 28 Boxed or (horizontal) soffit-lined eaves

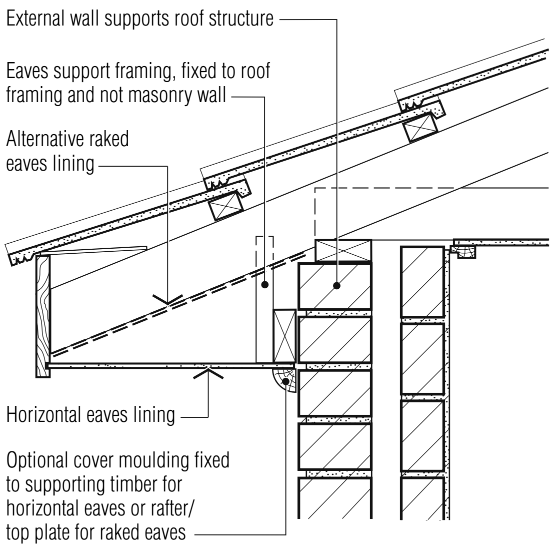


Figure 29 Eaves detail – roof supported on external leaf of masonry wall

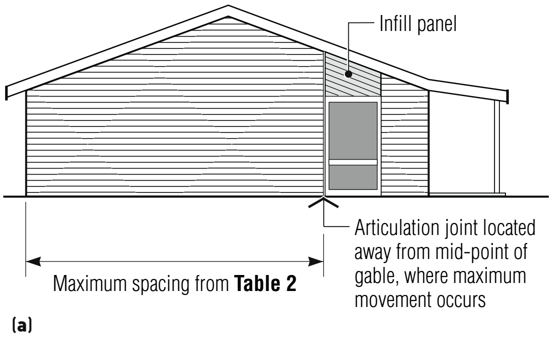


Figure 30 Articulated masonry gable-end wall
(**a**) Location of articulation joint
(**b**) Use of infill panels above openings

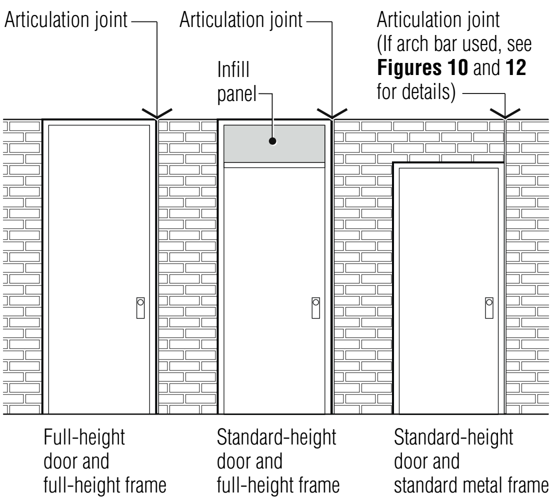


Figure 31 Options for installing door openings (and articulation joints) in internal walls

7.4 Gable Ends

When gable roofs are used it is recommended that the masonry in the gable end wall be terminated just above the eaves height, and framed construction used above that level to limit the height of masonry.

If the masonry does extend full height, it is preferable to avoid locating an articulation joint at the mid-point where there is maximum joint length and consequently maximum movement in the joint at the top. It is always preferable to locate the joint elsewhere in order to minimise its length **Figure 30**.

Because of potential differential movement between the wall panels and the roof structure, the roof tiles should not be bedded onto the top of the gable-end wall. When articulated walls are used, the joint between the roof and walls should also allow the masonry walls to move independently. This may be done by finishing a tiled roof-edge with a timber or metal barge.

7.5 Internal Partition Walls

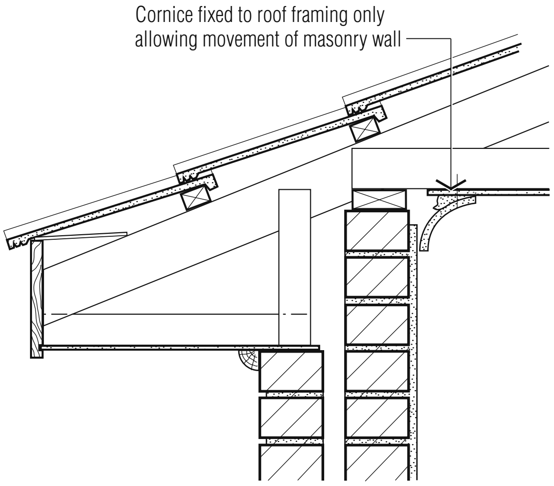
The majority of foundation movement generally occurs around the perimeter of a building where the soil is subject to seasonal moisture variations. Problems with cracking of brittle internal wall types (ie masonry walls) therefore typically occur at or near the junctions with external walls.

With careful planning, internal walls need not require articulation joints other than at openings such as doorways or in corners of rooms. Where an articulation joint is unavoidable in long, unbroken runs of wall, it should be the same width and formed in the same way as an external-wall joint. Where possible, articulation joints should be located in the corners of rooms or at doorways where they will be less obvious. Note that joints at corners should be located to maintain stability **Figure 17**.

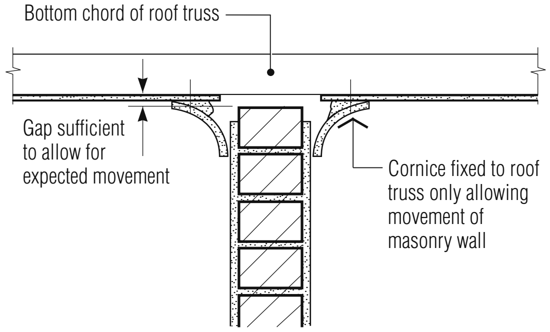
The abutting wall panels should be connected across the articulation joint with masonry expansion (sliding/extendable) ties of sufficient strength, number and spacing to transfer the calculated loads across the joint. As a guide, a minimum of three sliding ties should be installed.

When internal masonry walls are to be rendered, a neat joint should be formed in the render over the articulation joint. It is advisable to fill this joint with an elastomeric sealant, which may be coloured or painted to match the wall finish.

Sealants for internal articulation joints should be paintable such as polyurethane compounds. They may be applied to masonry, timber, metals or plasterboard. They are available in a range of colours or may be painted to match surrounding colours to reduce the visual impact of the joint. The manufacturer's recommendations regarding suitable paints should be followed.



(**a**) PERIMETER WALL WITH FRAMED OR TRUSSED ROOF
(Internal wall with framed roof similar detail)



(**b**) INTERNAL WALL WITH TRUSSED ROOF

Figure 32 Fixing of cornice at articulated masonry walls

7.6 Internal Doors

It is convenient to make most internal-wall articulation joints coincide with door openings. An effective joint can be made by making openings full height from floor to ceiling. Normally, an articulation joint will be provided on only one side of a door.

There are three ways of installing a door in a wall **Figure 31**:

- Full-height door and frame with or without a head
- Full-height door frame with an infill panel fixed above a standard-height door
- A standard-height door with masonry above separated from adjacent walling by articulation joints either offset (**Figure 10**), or more commonly, in line with the jambs (**Figure 12**).

To accommodate the movement at the articulation joint, the architrave on a timber door frame should be fixed only to the frame and be large enough to cover the articulation joint. Metal door frames should have allowance for a gap where the brickwork is built into the edge of the frame. When internal masonry walls incorporating metal door frames are to be rendered, a neat joint should be formed between the render and metal door frame which can be sealed and painted over.

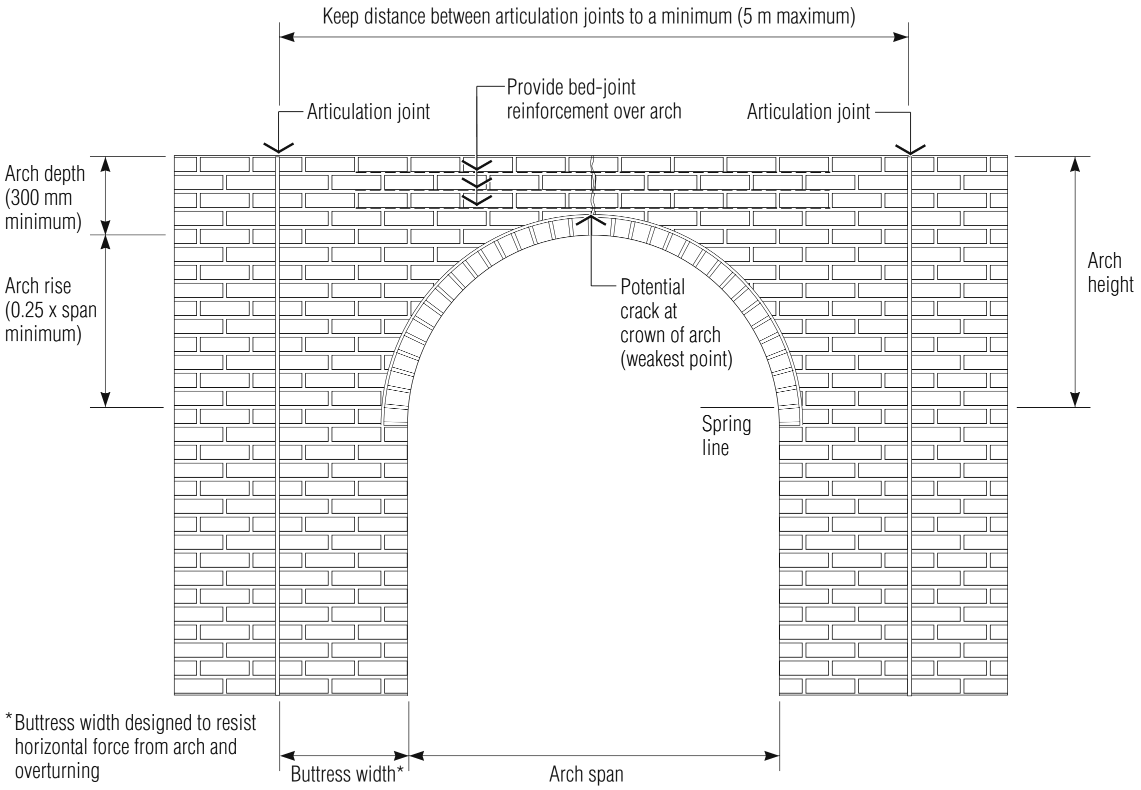


Figure 33 Detailing of arches (semicircular arch shown)

The use of full-height door frames provides an opportunity to run electrical cable for light switches or power points down from the ceiling between the wall and frame by increasing the gap between the two. Note that any services installed in the gap must not inhibit closing of the joint.

7.7 Wall/Ceiling Junctions

Masonry interior walls of a building with a framed roof require top plates to support ceiling joists. The ceiling lining is then fixed under the joists and butted to the top plate. The cornice may be timber or quarter-round plaster and should be fixed through the ceiling lining to the ceiling joists and/or to the top plate, not to the walling. As there may be some movement between the wall and the ceiling, the cornice must be large enough to conceal the top plate and be free to move independently of the wall **Figure 32**.

If a trussed roof is used, there is no need for a top plate on internal masonry non-load-bearing walls since the ceiling joists (bottom chords of the trusses) should not rest on internal walls.

A gap of at least 10 mm (AS 1684[9]) should be left between the bottom chord of the trusses (or ceiling battens when used) and the top of the wall where a trussed roof is used – after the roofing and ceiling are fixed. This gap, plus an allowance for movement must be covered with a timber or plaster cornice fixed only to the ceiling, allowing the wall/truss to move up and down and the wall to move in its own plane without causing cracking **Figure 32 (b)**.

8 MASONRY WALLS WITH ARCHES

Many different types of arches can be built into masonry walls. Unlike other openings in walls, all arched openings require a minimum arch depth (300 mm) or narrow band of masonry above the crown. Arches are particularly susceptible to cracking from footing movement. Such cracking occurs because any footing movement will cause a concentration of stresses at the crown or highest point in the arched section of masonry. Cracking could be severe enough to destroy the structural effectiveness of the arch. Unlike normal openings, articulation joints can not generally be located adjacent to the arched opening because sufficient masonry must be provided at each side of the opening to support (ie buttress) the arch. For these reasons arched openings are generally not recommended for buildings on reactive-soil sites.

If arches are required, some options which may be considered include:

- Reinforce the arch depth (**Figure 33**) to ensure structural performance in the event of a crack. The arch may still be designed as an unreinforced masonry arch with the addition of bed-joint reinforcement intended only to hold closed any crack(s) that may occur (see Section 9).
- Locate articulation joints as close as possible to the arch (ie at the sides of the buttresses) to limit the differential movement that could occur across the arch. The minimum width of each buttress should be sufficient to resist the horizontal force from the arch and overturning. If detailed calculations are not carried out, the width of the buttress should be no less than the height of the arch.
- Provide a steel lintel to support the arch. The lintel can be curved to suit the shape of the arch with flat sections welded to each end for building into the buttresses. In this case the lintel will be designed to carry the entire weight above the arch and articulation joints may be located adjacent to the arch in a similar manner to other openings. Although not recommended aesthetically, articulation joints may be located at the arch crown.
- Ensure that the footings supporting arches are continuous so as to avoid having the two sides of the arch supported on separate footings.
- Provide a stiffer footing system under masonry walls containing arches. If the differential movement of footings due to ground movement is limited to the point where articulated walling is not required, the risk of cracking in arches will be significantly reduced. For slab-on-ground footings, only those edge/internal beams supporting masonry with arches will need to be stiffened.
- Maintain the area around footings to ensure consistent moisture conditions in the soil and thus reduce the potential for differential movements (shrinkage and swelling) of reactive soils. For more information refer to Section 2.

9 REINFORCED MASONRY

While the use of articulation is normally confined to unreinforced cavity and veneer construction, it is also relevant for reinforced brick masonry.

More-flexible footings may be used where articulated masonry containing correctly detailed and positioned reinforcement is used. The footings should be designed in accordance with engineering principles, with the additional crack-control provided by the reinforcement in the wall permitting a more generous maximum deflection to be adopted for the footing design **Table 3**.

According to AS 4773 articulation joints are not required for reinforced masonry designed in accordance with Part 1 Section 12. For information

TABLE 3 Suggested deflection ratios for reinforced masonry

Wall construction	Absolute maximum deflection, Δ as a function of span, L (mm)	Absolute maximum deflection, Δ (mm)
Reinforced masonry veneer	L/300	40
Reinforced full masonry		
Sheet and/or faced finish	L/400	30
Rendered or painted finish	L/600	20

on reinforced block walls refer to the *Concrete Masonry Handbook*[10].

Reinforced masonry may also include reinforced brick masonry containing bed joint reinforcement and/or reinforced cavities within the brickwork. Cavities may either be the cavities between two leaves of brickwork or those within brick piers. The standard footing design in AS 2870 for a stiffened slab with deep edge beam is an example of reinforced brick masonry where a minimum 75-mm-wide cavity is reinforced with SL82 mesh or N12 bars at 400-mm centres each way and then grout or concrete filled.

Unlike reinforcing bars and meshes used for structural applications, the lighter bed joint reinforcement (for brick or block walls) is usually incorporated to assist with crack control in wall panels between articulation joints, and especially around openings and above arches. In high-wind areas it may also be used to improve the structural performance of wall panels.

Bed joint reinforcement typically consists of two 3-mm (minimum) diameter longitudinal wires (galvanised or stainless steel depending on durability requirements) welded into a cage for easier installation and more accurate positioning. It typically comes in 3-m lengths and a range of standard widths to suit various masonry units. The maximum wire size should not exceed two thirds of the design bed joint thickness and at least 15 mm of cover should be provided between embedded metal wires and any exposed surface of the mortar joint. Light gauge wire products may also be used but will be less effective, may not be appropriate for the exposure conditions and as a consequence, result in corrosion problems.

Dwellings using bed-joint reinforcement to reduce footing sizes should be designed such that openings do not interfere with the reinforced courses. In general, this will mean that most sections of reinforced brick masonry (being full-height infill sections) will not contain openings such as doors and windows. However, small openings for air conditioners, toilet windows and the like are permissible provided that they do not interfere with the courses that contain the reinforcement.

Also, if more-flexible footings are used, the recommended maximum spacing of articulation joints in reinforced brick masonry remains similar to unreinforced masonry and should not exceed the values given in **Table 2**. The maximum recommended spacing for expansion joints in straight reinforced brick masonry walls without openings is 30 m[11] , although they may be required to be as close as 10 m depending on conditions.

Reinforced brick masonry used for structural applications (similar to unreinforced masonry) is generally designed to span horizontally between vertical or lateral supports such as columns and cross/return walls. As such, if articulation joints are required, they should be located at these points and detailed such that loads can be transferred to the supporting elements **Figure 17**. This does not apply to masonry veneer construction as lateral support is provided by the structural framing to which it is attached.

The vertical spacing of reinforced bed joints depends on the design requirements and openings within the wall. If bed joint reinforcement is used for improved crack control between joints (articulation or other control joints), an appropriate location may be in the two courses above and below window/door openings and in the second or third course from the bottom and top of the wall **Figure 34**. Where there are no openings in the wall panel, reinforcement would typically be provided at 600-mm centres. An alternative arrangement in 2.4-m-high masonry block walls is to reinforce the top and bottom 3 courses and the middle course of the wall in lieu of distributing reinforcement evenly over the height of the wall[12]. Concentrating the reinforcement at the extremities of the wall improves the wall's resistance to in-plane bending from footing movements.

The reinforcement should be lapped by a minimum of 400 mm. One way of achieving this is to butt the ends of standards lengths together and provide an 800-mm length of the 3-mm-diameter wire(s) or other bed joint reinforcement as a lapping length. Ideally, laps should be staggered such that they are not in line. If reinforcement is provided only above and below window/door openings (to minimise/control cracking at these vulnerable locations) the reinforcement should extend about 600 mm past the openings.

The majority of buildings may be designed, detailed and articulated to minimise the risk of cracking in the walls. However, some wall panels containing openings (especially arches) may benefit from the addition of reinforcement to limit the number of articulation joints and/or minimise the risk of cracking at vulnerable points between articulation joints.

9.1 Bond Beams

In general terms, bond beams refer to the horizontal reinforced and grouted beams that are found in reinforced masonry block walls. They are formed by using either special lintel or 'U' shaped blocks or knock-out bond beam blocks and they are typically used to provide beams along the tops of walls to distribute wind loads or as lintels over window and door openings.

Both AS 3700 and AS 4773.2 do not allow control joints (including articulation joints) to continue through bond beams which rely on continuity for their structural performance, ie those described in the Standards. Whether joints may be continuous through bond beams will depend on the loads being carried, the design of the bond beam and the location and detailing of the joint. Two separate cases need to be considered, bond beams at the tops of walls and those forming lintels over window and door openings.

At tops of walls. Bond beams around the tops of masonry block walls are required in high-wind areas, particularly in the north of Australia. They are provided mainly to distribute wind uplift loads from the roof members to regularly spaced vertically reinforced cores which resist the uplift forces. For this reason it is essential that they be continuous around the perimeter walls of the building. They may also transfer some horizontal wind loads back to walls providing lateral support.

An articulation joint through a bond beam is formed by stopping the reinforcing bars within the bond beam 50 mm from each side of the joint. The articulation joint is then bridged with short, plain round steel bars (dowels), equal in diameter and number to the reinforcing bars in the bond beam.

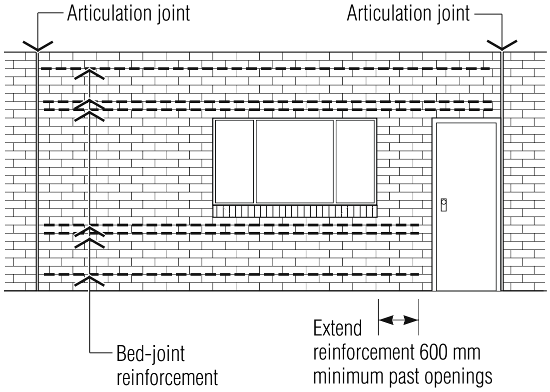


Figure 34 Typical location of bed-joint reinforcement

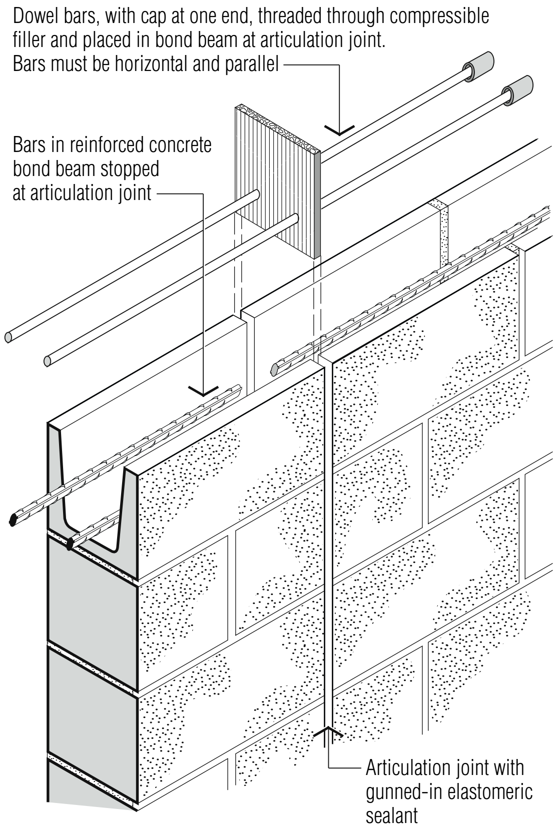


Figure 35 Articulation joints through masonry block bond beam at top of wall

Dowel bars are cast into the concrete on one side of the joint with the other end allowed to slide/move by wrapping and greasing this half of the bar, coating it with an approved bond-breaking compound or providing an appropriate sleeve within which the bar can slide. The sliding ends of dowel bars should have purpose-made plastic caps at the ends or plugs of polystyrene equal to the joint width taped at the end to enable the articulation joint to close. Articulation joints bridged by dowels should be finished with a filler strip and sealant where they are visible **Figure 35**. Note that the steel bars crossing the joint should be suitably protected from corrosion. Typically, galvanised bars are used. In coastal locations the use of stainless steel dowel bars may be required.

As bond beams will typically have either 12-mm or 16-mm-diameter dowel bars (ie bond beams are typically reinforced with N12 and N16 bars), a length of 600 mm should be sufficient for dowel bars.

Joints in bond beams must be considered in the design of the structural system. They should be located at returns/intersecting walls such that the joint in the bond beam does not result in instability of the wall or limit the ability of the bond beam to transfer horizontal loads to lateral supports **Figure 17**. In order to transfer wind uplift loads, a vertically reinforced and grouted core should be provided on both sides of the joint, similar to the requirement for window and door openings.

Above window and door openings. Bond beams above openings act as lintels to support the loads above.

Joints should be designed, located and detailed in such a way that the effectiveness of the bond beam to support loads is not affected. However, articulation joints should be moved away from the sides of openings to allow continuity of the bond beams and comply with AS 3700 requirements. The reinforced bond beams will mean that there is less risk of cracking at openings than would otherwise be the case.

Alternatively, if joints away from window and door openings are not acceptable, then more rigid footings should be provided.

10 ARTICULATED WALLING – KEY POINTS

- Reactive soils swell and shrink with moisture variation causing a doming or dishing of footing systems and possible distortion of both external and internal walls of domestic-scale buildings.
- Articulation greatly limits cracking or distortion of walling and jamming of windows and doors caused by foundation movement.
- Articulated walling reduces the size and cost of footings for buildings on reactive-soil sites. These benefits are most significant for masonry-walled buildings.
- Although articulation is most effective for masonry walling, it is also a benefit for frameclad-walls.
- Articulation increases the allowable deflection for the footings thus giving the engineer more latitude to design a more economical footing.
- Articulation joints should be positioned and detailed with care to allow the building fabric to flex in harmony with the footing movement.
- Wallheight should be minimised in order to limit the extent of movement that must be accommodated in an articulation joint.
- Bond beams should be carefully detailed where crossed by articulation joints.
- Arches in buildings on reactive-soil sites will require additional precautions as outlined in Section 8.
- The addition of appropriate bed-joint reinforcement may significantly strengthen a wall, reduces cracking and permits more-economical footings to be used.

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