PART B

Chapter 7

Movement

This chapter provides the design requirements for movement joints in masonry to control cracking due to shrinkage of the wall, concrete slab shrinkage, foundation movement and thermal expansion or contraction.

Contents

7.1 BASIS OF DESIGN

Unreinforced concrete masonry is a brittle material which will crack if long walls are constructed without a break or if its supports move. The following factors influence the formation of cracks in masonry which may be controlled by the methods set out in clause 7.1.2.

7.1.1 FACTORS INFLUENCING THE FORMATION OF CRACKS IN MASONRY

Shrinkage of Masonry Units

Concrete masonry units shrink as the concrete cures. To avoid this, units should be properly cured before delivery to the site. Saturated units should not be laid as they could be subject to subsequent drying shrinkage. AS/NZS 4456.12 provides two tests, *Coefficient of Residual Curing Contraction* and *Coefficient of Drying Contraction*, for contraction of concrete masonry units. These tests are not routinely performed, and are specified only when dealing with specific problems related to shrinkage and cracking.

Coefficient of Residual Curing Contraction is the shrinkage which takes place in newly-manufactured concrete units (at constant saturated moisture content). It is an indication of the likelihood of shrinkage related cracking as a result of cement hydration in the units. It is indicative of the lower bound of shrinkage in the wall.

For example:

0.1 mm/m represents at least 0.8 mm in an 8 m length of wall.

0.3 mm/m represents at least 2.4 mm in an 8 m length of wall.

Although no limits are set in AS/NZS 4455 or AS/NZS 4456, a value over 0.1 mm/m would normally be regarded as relatively high.

Coefficient of Drying Contraction is the shrinkage which takes place in concrete units when dried from a saturated condition to a stable dry condition. It is an indication of the likelihood of shrinkage-related cracking as a result of expelling all of the moisture from the units. When combined with the shrinkage caused by the mortar, it gives an indication of the upper bound of the possible shrinkage in the wall.

For example:

0.6 mm/m represents at least 4.8 mm in an 8 m length of wall.

0.8 mm/m represents at least 6.4 mm in an 8 m length of wall.

No limits are set in AS/NZS 4455 or AS/NZS 4456. A value over 0.6 mm/m would normally be considered to be quite high.

Shrinkage of the Mortar

If mortars with a particularly high cement content are used, their shrinkage could provide sufficient tensile force to crack the masonry.

Shrinkage in applied renders and coatings

Renders are prone to cracking if a high cement content is used, if excessively fine sands are used (requiring additional water) or if the render is too thick.

Temperature Differential

Walls that are exposed to large temperature differentials (including those on the northern or western facades of buildings in temperate areas) will be more likely to suffer cracking than similar walls in benign environments.

Footing Movement

Footing movement is a major source of cracking in unreinforced masonry and is discussed fully in **Part B:Chapter 10**.

Support Movement

Differential movements of supports can lead to cracking. For example, if a masonry wall is fixed to large steel portal frames it will move sympathetically with the frames as they deflect under the action of lateral loads. A crack will develop in the bottom bed joint but this would not normally be noticed. However, if the masonry wall is also bonded to a masonry shear wall (parallel to the frames) which is much stiffer than the frames, there is potential for diagonal cracks to develop in the masonry.

Mixing Clay and Concrete Masonry

Clay units expand while concrete units contract. It is permissible to construct cavity walls with one leaf of clay units and the other leaf of concrete units, provided they are separated by cavities with flexible ties. While little harm is done by incorporating the odd clay unit into a concrete masonry leaf or the odd concrete unit into a clay masonry leaf, large area of each should not be mixed in the same leaf since this will lead to differential movement and cracking.

7.1.2 METHODS OF CONTROLLING CRACKING IN MASONRY

Mortar

To avoid potential cracking from mortar shrinkage, the mortars recommended in the Standard Specification, provided in **Part C: Chapter 2** should be used, viz:

M3 applications – 1:0:5 + water thickener or

M4 applications – 1:0:4 + water thickener.

Applied Renders and Coatings

To minimise the risk of cracking, the specified render mix should be suitable for the type of masonry and the thickness of any coat not more than 12 mm. If necessary, wire or expanded metal reinforcement can be used to control cracking. Control joints in renders and coating should be included wherever control joints are provided in the masonry.

Footings

To limit cracking from footing movement, suitable precautions include:

- Adequate drainage for the removal of water from the foundations
- Ensuring that large trees are not placed adjacent to the footings
- Correctly sized footings
- Inclusion of reinforcement in the wall.

Supports

The potential for diagonal cracks to develop where masonry walls are bonded to masonry shear walls (parallel to and in conjunction with portal frames) which are much stiffer than the frames, can best be avoided by the incorporation of reinforced bond beams.

Reinforcement

The inclusion of reinforcement within the masonry will greatly enhance its ability to spread the cracks and thus restrict their width. Reinforced masonry will tolerate larger deflections than unreinforced masonry before collapse occurs. Therefore, design for strength will not necessarily provide a guarantee of adequate serviceability performance. In particular, centrally- reinforced masonry walls may exhibit larger than expected lateral deflections and crack widths due to their small effective depth.

Control Joints

The strategic placement of control joints will limit the position and width of cracks.

Contraction joints are opening joints to cater for shrinkage of the wall. In a wall exposed to the weather, contraction joints must be weather-proof with a flexible sealant at the surface. They may also be filled with a compressible material if required to serve also as expansion joints (for thermal movement) or as articulation joints (for footing or support movement).

Expansion joints are closing joints. They are usually built into clay masonry to cater for brick growth and find application in concrete masonry only when there is the possibility of high thermal movement. Expansion joints incorporate a compressible material of sufficient thickness to cater for the expansion in the walls adjacent to the joint.

Articulation joints are both opening and closing joints that cater for movement of the footings or supports. The strategic positioning of articulation joints at points of weakness (such as door or window openings) will minimise cracking as the supports move due to foundation movement and similar actions. In some cases, contraction and expansion joints will function as articulation joints.

Control joints result in free ends of the masonry which may increase slenderness and decrease support conditions of walls. Therefore, the location of joints should be determined as part of the structural design.

Control joints should be detailed so as to maintain resistance to moisture penetration, fire, heat and sound.

7.2 DESIGN REQUIREMENTS

AS 3700 Clause 2.5.2 places an upper limit on crack width of 1 mm for *"masonry which is not subject to aesthetic limitations"*. Because it is often difficult to assess the crack widths which result from particular load actions (eg wind, earthquake and foundation movement), the 1 mm limit is not intended to cover all situations. However, it does define a quantifiable limit for use in design, construction and post-construction assessment.

The performance requirement for residential dwellings is set out in AS 2870 Appendix C which states that the footing systems used to support the masonry walls shall be such that there is *"usually no damage, a low incidence of damage Category 1* (fine cracks which do not need repair, crack < 1 mm) *and occasional incidence of damage Category 2"* (cracks noticeable but easily filled, doors and windows stick slightly, crack < 5 mm). Refer to **Part B:Chapter 10**.

AS 3700 Clause 4.8 requires that the opening movement shall not exceed 10 mm. The closing movement (if any) shall not exceed 15 mm and the width of the joint after closure shall not be less than 5 mm.

The strategic positioning of control joints will limit the formation of cracks, and those which do form will be kept small.

7.3 STANDARD DESIGNS

7.3.1 GENERAL

Design and detailing

All design and detailing shall comply with the requirements of AS 3700. It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties. Control joints and openings must be treated as free ends.

Masonry properties

The standard designs in this chapter are based on masonry properties complying with the Standard Specification set out in **Part C:Chapter 2**, modified as noted on the standard design. The Standard Specification includes the following requirements:

Unreinforced Masonry Construction

Vertical control joints or articulation joints at least 10 mm wide shall be built into unreinforced masonry at the following locations:

- centres not exceeding the following in straight continuous walls without openings:

  For Class A and S sites –

  Articulation is not required

  For Class M, H, M-D and H-D sites –

External masonry face finish, rendered or painted	7.0 m
Internal masonry sheeted and/or face finished	6.0 m
Internal masonry rendered and/or painted	5.0 m

- at not more than 5 metre centres in a wall with openings more than 900 mm x 900 mm, and positioned in line with one edge of the opening
- at the position where a wall changes height by more than 20%
- at a change in thickness of a wall
- at control joints or construction joints in supporting slabs
- at the junctions of walls constructed of different masonry materials
- at deep rebates

AS 4773.1 also places the following restrictions for residential building:

- at a distance from all corners not less than 470 mm for cavity walls or 230 mm for veneer walls and not greater than 4500 mm.

Reinforced Masonry Construction

Control joints shall be built into reinforced concrete masonry at all points of potential cracking and at the locations shown on the drawings. The spacing of control joints should not exceed 16 metre.

The spacing of control joints may be increased in reinforced masonry walls meeting the following criteria:

- Consisting of at least 190 mm hollow concrete units, and
- Built less than 3 metres high, and
- Incorporating a top reinforced bond beam, and
- Incorporating N16 horizontal reinforcement at not greater than 400 mm centres
- On a soil of type A or S Site Classifications in accordance with AS 2870, and
- With a reinforced concrete footing of adequate stiffness.

No control joints are required for single-leaf, partially-reinforced masonry for houses as defined in AS 3700 Section 12.

Hollow concrete blocks

Width 90 mm, 110 mm, 140 mm and 190 mm

Height 190 mm

Length 390 mm

Face-shell bedded

Minimum face-shell thickness,

t_s = 25 mm for 90 mm, 110 mm and 140 mm units

t_s = 30 mm for 190 mm units

Minimum characteristic compressive strength,

f'_{uc} = 15 MPa

Minimum characteristic lateral modulus of rupture,

f'_{ut} = 0.8 MPa

Solid or cored concrete bricks

Width 110 mm

Height 76 mm

Length 230 mm

Fully bedded

Minimum characteristic compressive strength,

f'_{uc} = 10 MPa

Minimum characteristic lateral modulus of rupture,

f'_{ut} = 0.8 MPa

Mortar joints

Mortar type M3 (or M4)

Joint thickness 10 mm

Concrete grout

Minimum characteristic compressive strength,

f'_c = 20 MPa

Minimum cement content 300 kg/m^3

Steel reinforcement

N12, N16 or N20 as noted.

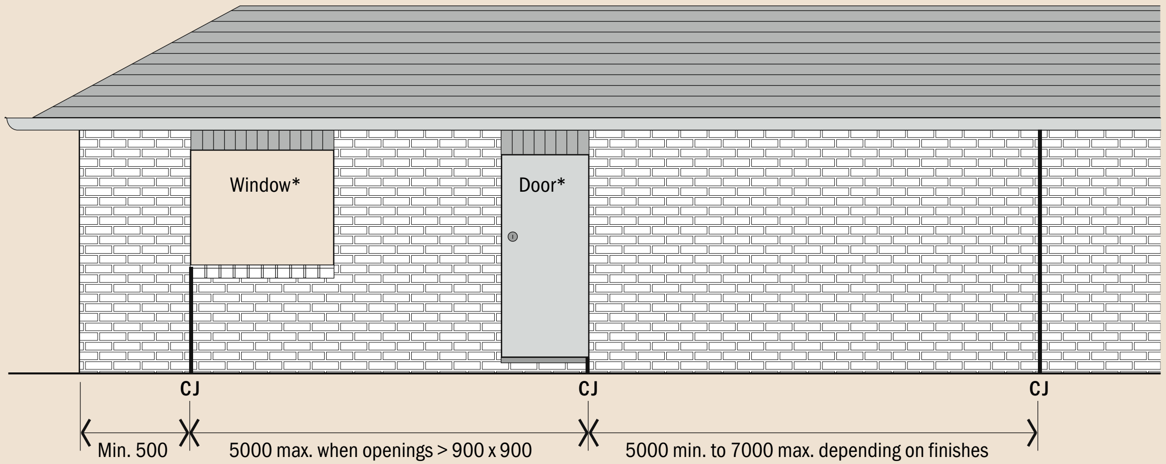
7.3.2 INDEX TO DESIGN DETAILS

The following diagrams show the suggested positions of control joints in concrete masonry houses and industrial or commercial buildings.

CONTROL JOINTS –
Concrete Masonry Houses

CONTROL JOINTS –
Industrial or Commercial Buildings

CONTROL JOINTS – Concrete Masonry Houses



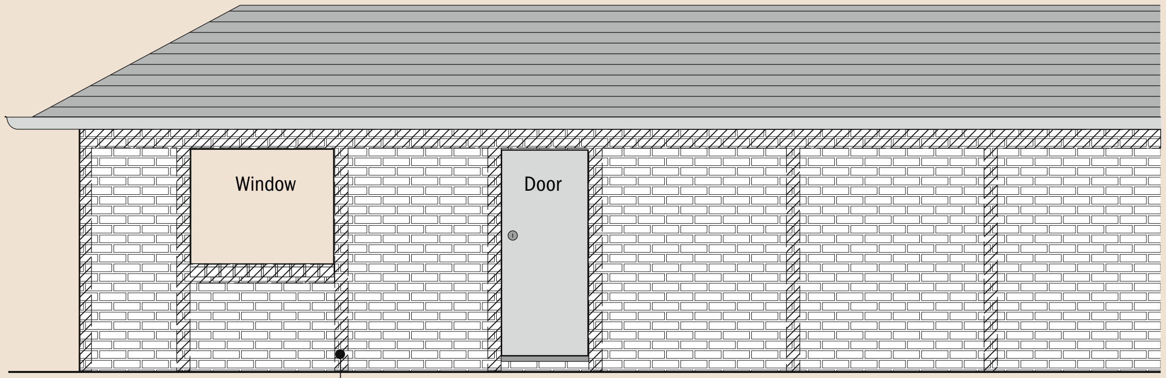
* Carry window and door openings to top of wall and use timber or similar infill panel

UNREINFORCED MASONRY VENEER CONSTRUCTION (Class M, H, M-D and H-D sites)

NOTE:
In addition, control joints are required in the following situations.

- At the position where a wall changes height by more than 20%
- At a change in thickness of a wall
- At junctions of walls constructed of different masonry materials
- At deep rebates
- At control joints or construction joints in supporting slabs.

CJ indicates control joint

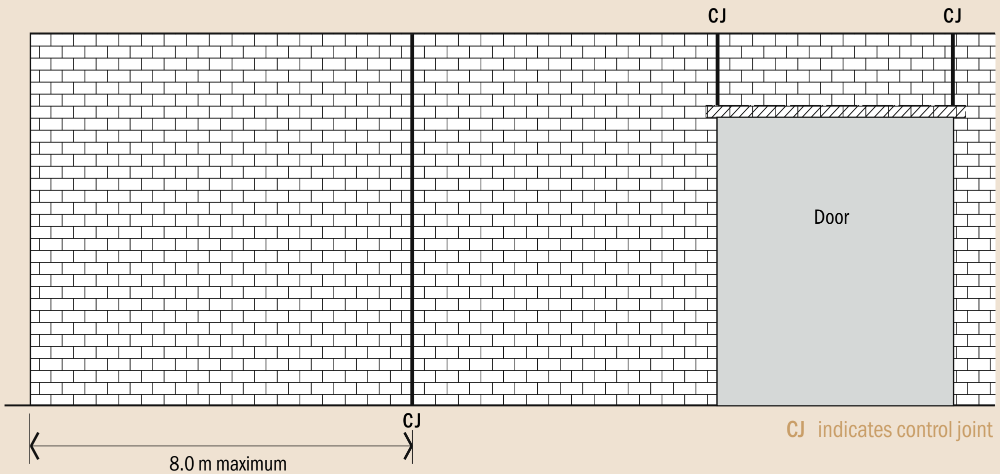


Reinforced masonry shown hatched

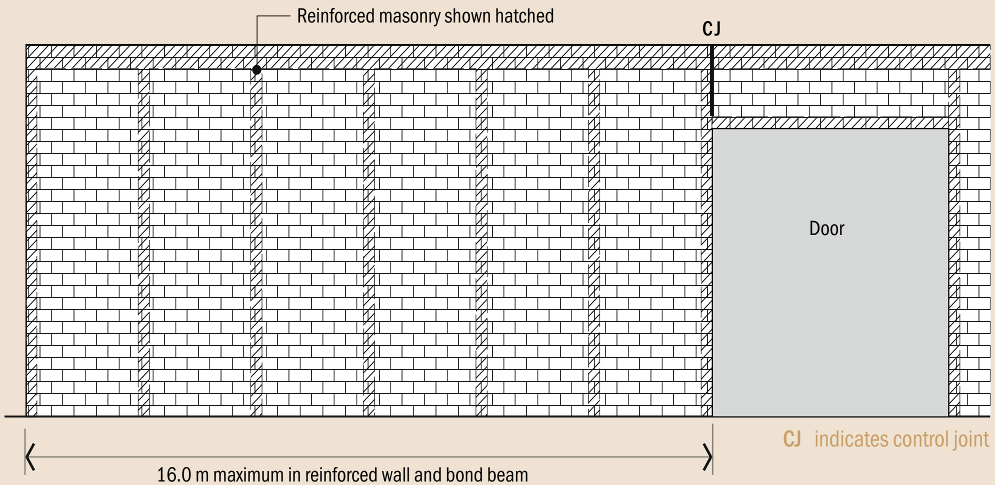
REINFORCED SINGLE-LEAF MASONRY CONSTRUCTION (As defined in AS 3700 Section 12)

NOTE: No control joints required

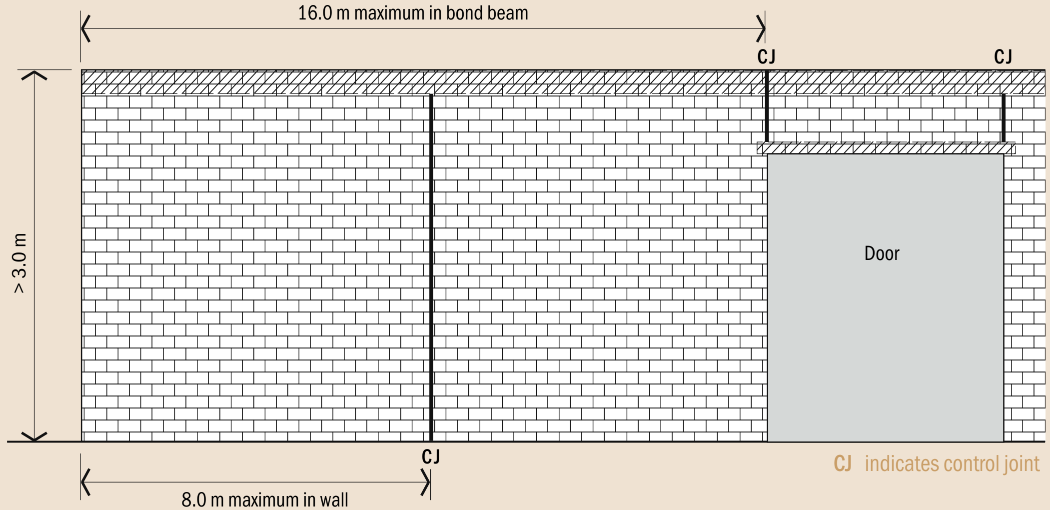
CONTROL JOINTS – Industrial or Commercial Buildings



UNREINFORCED MASONRY CONSTRUCTION



VERTICALLY-REINFORCED MASONRY CONSTRUCTION



HORIZONTALLY-REINFORCED MASONRY CONSTRUCTION

7.4 WORKED EXAMPLE

7.4.1 GENERAL

Purpose of the worked example
The purpose of the following worked example is to demonstrate the steps to be followed when performing manual calculations or when preparing computer software for the analysis and design of masonry. The worked example also serves the purpose of demonstrating the origin of the Standard Designs which are based on similar masonry capacity considerations. Although comprehensive in its treatment of AS 3700, the worked example is not intended to analyze or design all parts of the particular structure. It deals only with enough to demonstrate the design method.

Design and detailing
All design and detailing shall comply with the requirements of AS 3700. It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties. Control joints and openings must be treated as free ends as specified by AS 3700.

Masonry properties
The worked examples in this chapter are based on masonry properties complying with the General Specification set out in Part C:Chapter 2, modified as noted in the calculations and as noted below.

Hollow concrete blocks
Width 90 mm, 110 mm, 140 mm and 190 mm

Height 190 mm

Length 390 mm

Face-shell bedded

Minimum face-shell thickness,
t_s = 25 mm for 90 mm, 110 mm and 40 mm units

t_s = 30 mm for 190 mm units

Minimum characteristic compressive strength,
f'_{uc} =15 MPa

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Solid or cored concrete bricks
Width 110 mm

Height 76 mm

Length 230 mm

Fully bedded

Minimum characteristic compressive strength,
f'_{uc} =10 MPa

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Mortar joints
Mortar type M3 (or M4)

Joint thickness 10 mm

Concrete grout
Minimum characteristic compressive strength,
f'_c = 20 MPa

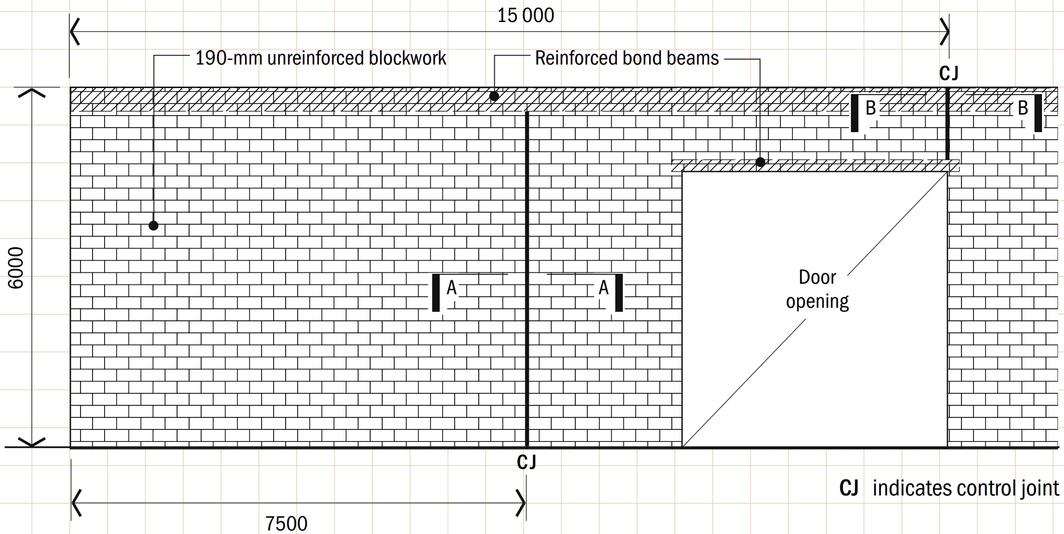
Minimum cement content 300 kg/m³

Steel reinforcement
N12, N16 or N20 as noted.

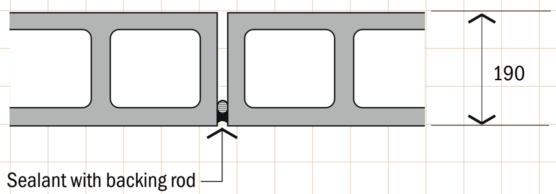
GO TO WORKED EXAMPLE

DESIGN BRIEF

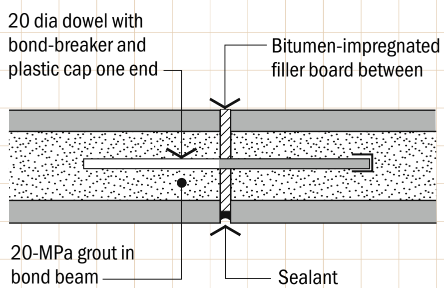
Design control joints in the walls of an industrial building at the locations indicated.



LAYOUT OF CONTROL JOINTS



SECTION A-A



SECTION B-B

H = height of wall
= 6.0 m
> 3.0 m   Provide articulation of both reinforced and unreinforced masonry

s_r = spacing of control joints in reinforced masonry
= 15.0 m
< 16 m   OK

s_u = spacing of control joints in unreinforced masonry
= 7.5 m
< 8 m   OK

C_c = coefficient of drying contraction
= 0.6 mm/m

δ_o = maximum possible opening movement under the condition of repeated wetting and drying of the unreinforced masonry
$= C_c\, s_u$
= 0.0006 x 8000
= 4.8 mm
< 10.0 mm   OK   *4.8*

NOTE: Actual opening movement under normal environmental situations will be much lower than the calculated maximum

Detail at control joints provides for weather-proofing   OK

Detail at control joints provides for the horizontal out-of-plane support of all reinforced and unreinforced masonry   OK

Relative in-plane movement between the reinforced bond beam and the unreinforced masonry panel may lead to a little localized bed joint cracking, but this is considered to be minor   OK