6.3 Control Joints

Introduction
Concrete masonry walls, whether they be walls forming part of a building structure, retaining or garden walls, often require control joints to be built in to counter the effects of drying shrinkage and other movement effects not related to their primary structural purpose. The requirements for these are spelt out in most design and construction standards dealing with concrete masonry and that are referenced by the New Zealand Building Code. There are, however, differences in the presentation of control joints between these standards, and in some cases a lack of rationale in specific provisions.

This section is written with the aim of clarifying for both designers and tradespeople the reasons for providing control joints, at what locations they are needed, and details for their construction.

This section applies to reinforced concrete masonry but excludes masonry veneer construction. Refer to Section 5.1 for veneer construction requirements.

Regulations
Concrete masonry construction is covered under a number of standards cited by the New Zealand Building Code. These are as follows:

Acceptable Solutions
Clause B1/AS1:
- NZS 4229 Concrete masonry buildings not requiring specific design
- NZS 3604 Timber-framed buildings (specifically, masonry foundation walls)

Verification Methods
Clause B1/VM1:
- NZS 4230 Design of reinforced concrete masonry structures

Additionally, all the above standards reference the standard for masonry construction -
- NZS 4210 Masonry Construction – Materials and Workmanship

Where there is any conflict between linked standards these would normally be picked up and clarified within the Building Code. Where conflict has not been identified, by inference the provisions contained within the acceptable solutions and verification methods would take priority over those of subordinate standards, in this case NZS 4210. Any advice contained within this section of the Masonry Manual which does not follow the Building Code needs to be considered as an Alternative Solution, and be presented as such where approval for building consent is being sought.

An organizational chart of how the regulations are related is provided in Figure 1 on page 2.

At the time of writing NZS 4210:2001 precedes updates to all the other standards referenced above. It should be noted that NZS 3604 makes no specific provision for control joints and so the requirements of NZS 4210 (which is referenced by NZS 3604) should apply. NZS 4229 also references NZS 4210 however as it has its own specific requirement for control joints (refer Section 12, Shrinkage) they will take precedence over NZS 4210. Similarly, NZS 4230 references NZS 4210 but has its own control joint requirements, which should take precedence where applicable.

Reasons for Control Joints
Cracking in blockwork structures can be due to a combination of actions which may include drying and carbonation shrinkage, temperature fluctuations, moisture content, creep, and building and foundation movement. Cracking will only occur when the blockwork is restrained against such movement effects. Most blockwork structures contain rigid restraints and therefore require consideration for crack control.

Some consequences of uncontrolled cracking include:
- Loss of durability, potential for accelerated corrosion of reinforcing steel
- Loss of weather-tightness
- Unsightliness

Crack widths less than 0.5 mm in width are generally considered to be of cosmetic concern only. Applied finishes can usually bridge that order of width.
Vertical action effects that might lead to cracking in blockwork are rare, principally because most structures are not restrained in that direction and the blockwork is therefore free to move. Where blockwork is in the form of infilling to other primary structure, say inside a rigid concrete or steel frame potentially providing vertical restraint, vertical crack control may need to be considered.

Horizontal movement in blockwork, on the other hand, is more likely to result in cracking because there is usually some form of restraint provided to resist such movement. This is often in the form of foundations and floors (including stairs), and to a lesser extent, connected walls. Cracking also tends to concentrate at abrupt reductions in horizontal strength of blockwork such as those occurring at changes of thickness, height, and around opening penetrations.

Horizontal reinforcing steel contents that are typically provided in block walls are not sufficient to evenly distribute movement strains so that cracks are spread evenly and consequently their widths minimized. Most concrete masonry standards therefore provide for appropriately positioned and detailed control joints to provide fuse points for horizontal movement strains to concentrate at. As an alternative to these, by significantly increasing the horizontal reinforcing steel contents cracks are more evenly distributed and the cracks are individually of narrower width. Control joint spacing can usually be increased in this instance. This is a matter for specific engineering design and judgement and is not discussed further in this section.

Drying Shrinkage

Constituent blockwork components comprising hollow block, mortar, and grout infilling all lose free water on setting and curing until equilibrium, or ambient condition, moisture content is reached. This loss of water is accompanied by a loss of overall volume in the constituents and results in irreversible drying shrinkage of the blockwork as a whole. The process is time-, material-, and environment-dependent. Typical values for linear drying shrinkage strains of masonry constructed from lightweight pumice aggregate masonry units in...
tests carried out by the University of Auckland\(^2\) are as follows:

- Un-grouted masonry – 0.04\%, or 0.4 mm/m length
- Grouted masonry – 0.07\%, or 0.7 mm/m length, e.g. 3.5 mm in 5 m length

**Carbonation**

Concrete blockwork also undergoes irreversible shrinkage due to long term effects of carbonation, which is the result of a reaction between cementitious materials and carbon dioxide in the atmosphere. A suggested allowance for US concrete masonry\(^6\) which might reasonably be considered applicable for New Zealand blockwork pending advice of more accurate data is in the range 0.02\% to 0.045\%, or between 0.2 mm/m length and 0.45 mm/m length.

**Temperature**

Temperature effects on blockwork can be significant, especially in climates where extremes of temperature are experienced, or where masonry is dark in colour and has a greater propensity to absorb solar radiation. The induced movements fluctuate and are largely reversible. Based on an assumed range of coefficient of linear expansion of between 5 x 10\(^{-6}\) / °C and 12 x 10\(^{-6}\) / °C, a temperature variation of, say, 50°C could translate to between 0.25 mm/m and 0.6 mm/m movement range in un-restrained blockwork.

**Moisture Fluctuations**

Changes in moisture content of the blockwork may occur where no surface protective coatings have been provided and the blockwork is subject to the fluctuations in atmospheric moisture, and in some cases groundwater. Specific data quantifying likely effects of moisture on blockwork are difficult to source, but changes in dimension should be significantly less than that for drying shrinkage.

**Building and Foundation Movement**

The prime function of blockwork in buildings and structures is to resist building forces that may be imparted by gravity, wind, seismic, and other action effects. Unintended, or incidental, movements can occur due to unidentified elastic deflection in support structure, differential foundation soils consolidation, and time-dependent creep in primary structure. Resulting stresses in the blockwork can often be relieved at locations where control joints are provided for shrinkage and temperature relief.

Specialised Joints

Specialised joints are not provided for in structures considered within the scope of NZS 3604 and NZS 4229. They may occur in structures specifically designed to NZS 4230 but are not considered in detail in the section. A brief explanation of specialized joint types is provided in the following.

- **Expansion joints** might be required in particularly long, or specialized, structures where the likes of thermal fluctuation movements can be significant. Note that relatively small expansions resulting from the thermal, moisture, and movement effects in non-specific design structures can usually be accommodated by normal control joints.
- **Contraction joints** might be provided in larger specific design structures for reasons similar to expansion joints, principally thermal fluctuation effects. Control joints considered in this section do provide for limited building contraction in non-specific design structures.
- **Separation joints** are sometimes provided to provide a break in the transfer of actions for earthquake-resisting structures, or for other specialised reasons.

**Provisions of Current Standards**

On review of provisions for control joints in current materials and design standards several matters requiring consideration and further comment were identified. Briefly, these are as follows:

**NZS 4210:2001 Masonry Construction, Materials and Workmanship**

1. Clause 2.10.1.2(c): **Control joint centres** for foundation wall blockwork in NZS 3604 structures are allowed at up to 24 m centres for low-height blockwork. The practical experience of the performance of semi buried foundation walls, by a Government Agency, was reflected in the decision to allow wider spacing between control joints than for fully exposed walls. This view is also similar to the views of NCMA (USA) who consider shrinkage to be of a lower overall value than in the exposed superstructure, with the foundation reinforcement able to satisfactorily to control the reduced shrinkage movement. Where users consider that foundation walls are subject to significantly greater exposure, then control joint centres should follow the practices of NZS 4229 and 4230.
2. Clauses 2.10.2(a) and 10.4.2: The control joint default width of 10mm does not fully provide for the extension capabilities of sealants that typically require sealant aspect ratios of 2:1 and width of bonded surface (sides only) of 8mm. A modification to existing detailing (refer Figure 4) or increasing the joint width by cutting the face of the block to the depth of the joint, say 10mm, would achieve a more resilient outcome.

3. Clause 2.10.5: These clauses apply to all referenced standards and require horizontal bond beam and lintel reinforcement to be continuous through control joints, with other horizontal reinforcement to be discontinuous using de-bonded dowels. From a structural continuity perspective this makes sense however the restraint provided by the combined effect of foundation and bond beam reinforcing will restrict overall movement and the effectiveness of the joint. It appears the provision does work in practice, however, and it is a structural compromise that must be accepted.

4. In Figure 2 of NZS 4210:
   - R16 dowels shown should coincide with horizontal bars provided
   - Dowel bars should be saw-cut at de-bonded ends, and should not be sheared as this tends to deform the bar and create undesirable bond
   - Dowels should be contact lapped with horizontal reinforcing and not be offset as shown (it is very difficult to accurately place and retain bars offset as shown)
   - The use of grease to de-bond bars is not in common usage. Polythene tape is the preferred method as it doesn’t run the risk of inadvertently compromising other reinforcing, is more resilient, and is more readily identified and checked.

NZS 4229:2013 Concrete masonry buildings not requiring specific engineering design

5. Control joint locations in walls are purposely located away from door and window locations to allow the structural trim reinforcing to achieve its aim of transferring internal actions around the opening to adjacent structure, either side.

6. Clause 12.1.1(a), referring to masonry buildings having Tee and L shaped floor plans, may be difficult for users to interpret in the absence of diagrammatic representation. This is addressed in Figure 2 of this section.

NZS 4230:2004 Design of Reinforced Concrete Masonry Structures

This standard shows, in Figure 3.1, an alternative crack control joint having continuous reinforcing through the joint, de-bonded over a width of 300mm, and centred on the joint. There is little commentary on its usage other than that it has apparently performed well in practice. A potential problem with this detail is that the strains induced in the reinforcing steel in the vicinity of the joint are likely to cause the reinforcing steel to yield, and this could have undesirable structural consequences in certain circumstances. It should only be used where designers are confident that blockwork movement effects on the reinforcing are not critical to structural performance. It will also only be properly effective where the bond break tape has sufficient bulk and deformability to prevent binding of reinforcing bar deformations, for example using grease-impregnated tape such as Denso.

Joint Locations

The table on page 5 summarises the wall control joint location provisions of the four standards considered. For context and specific application users are advised to refer to the relevant standard.
<table>
<thead>
<tr>
<th></th>
<th>General Spacing</th>
<th>T and U-shaped floor structures</th>
<th>L shaped corners</th>
<th>Changes in Wall Height</th>
<th>Changes in Wall Thickness</th>
<th>At Door and Window Openings</th>
<th>Movement Joints in Floors and Foundations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Walls &lt; 2.0m – 8.0 m &lt; 1.2m – 12.0 m¹ &lt; 0.8m – 24.0 m¹</td>
<td>Per NZS 4229</td>
<td>Per NZS 4229</td>
<td>Per NZS 4229</td>
<td>Per NZS 4229</td>
<td>No</td>
<td>Per NZS 4229</td>
</tr>
<tr>
<td></td>
<td>5.0 m recommended, 6.0 m max</td>
<td>Within 0.6 m of return angles ²</td>
<td>Within 0.6 m of junction, or 3.2 m from corner in both directions</td>
<td>Yes, where the difference is &gt; 0.6 m</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>1.5H, 7.6 m max.</td>
<td>To align with movement joints in floors and roofs</td>
<td>Within 50% of general joint spacing, from the junction; in all walls connecting at the junction</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes/No (both options can be designed for)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. *Explanation for these figures is contained in Review 1 of NZS 4210, pending at the time of publication of this document.*

2. *Refer to Figure 2 below for interpretation.*

3. *Provisions shown for NZS 4230 assume a minimum horizontal reinforcing content of 0.03%, which is very low. Through specific engineering design and using considerably higher reinforcing contents control joints can be spaced further apart or removed altogether.*
Figure 2 below provides an example structure and the interpretation of control joint locations to NZS 4229, using a T-shaped floor plan. The provisions may also largely apply for structures constructed to NZS 3604 and, for practical applications, to many structures specifically designed to NZS 4230.

![Diagram of control joint locations](image)

*Figure 2 - Control joint locations (NZS4229)*
Joint Detailing

Some of the typical details provided in the standards are perceived to contain shortcomings. These are explained in this section. Figures 3 (applicable for NZS 4229), 4, and 5 following this section have been produced to provide more clarity and consistency in interpretation.

Dowels

Dowels are typically provided through joints to transfer shear forces both in-plane and out of plane. For structures designed to NZS 3604 (NZS 4210) and NZS 4229 the forces involved are likely to be nominal, the action of the dowels will principally be restraining the walls to provide alignment both sides of the joint, and will also be contributing to bridging against differential foundation settlement. It is the intention of both standards that R16 dowels are provided to align with specified horizontal wall (not bond beam) reinforcement.

NZS 4229 requires lintel and bond beam reinforcing to be continuous through control joints, i.e. do not use dowels at lintels and bond beams. For NZS 3604 structures the reinforcing in foundation beams supporting foundation walls will also be continuous through joints. These factors may lead to reduced movements at wall joint locations. Both non-specific design standards require vertical reinforcing to be provided in the first block cell either side of the joint. This will assist in tying the dowel bars in their required horizontal alignment however the likelihood of the bars being installed true, or remaining perfectly horizontal through the construction process when not in direct contact with the horizontal reinforcing, is questionable. Securely tying the dowel bars to the horizontal reinforcing is a more practical option.

The use of grease as a de-bonding agent is not widely practiced. Wrapping the de-bonded half of the plain round dowel with plastic tape (or a tight fitting plastic sleeve) is the preferred, and more common, option. It is important that the de-bonded end of the dowel is saw-cut and not sheared. Shearing is often undertaken by bar suppliers and induces a non-desirable deformation in the end of the bar which may inhibit slip.

A slightly modified detail for use with the two non-specific design standards is presented in Figure 4, on page 9.

NZS 4230 details provide for short-lapping and de-bonding the horizontal deformed reinforcing in lieu of providing plain round dowels. While this is a more practical detail than is provided for in the non-specific design standards it is necessary that the de-bonding tape possesses the ability to compress to allow the bar deformations to freely move without over-stressing the surrounding grout and masonry. The use of grease-impregnated tape such as Denso is considered capable of achieving that aim. NZS 4230 designers using that detail need to be aware the horizontal steel passing through the joint will not be developing bar strength in the same manner that a standard hooked or 90° returned bar would. This could be significant, particularly for short wall panels, if horizontal reinforcing is required to contribute to in-plane shear capacity.

Sealants

All standards require control joints on exposed external faces of walls to be weatherproofed. Typically, this is provided by using a flexible sealant to seal off the exposed joint.

The non-specific design standards call for this joint to be 10mm wide and for the sealant to have a movement capability of ±25%, equating to 2.5 mm total movement in the joint. Polysulphide or modified silicone sealants are generally capable of providing that level of movement, but typically require a sealant width/depth aspect ratio of 2:1 to achieve that. Commonly available sealants also require a minimum bonded surface of 8mm, applying to the two sides of the joint, and it is important that the rear face of the sealant is de-bonded from the block substrate. A modified detail applicable for the non-specific design standards is presented in Figure 5 on page 9.

Using the criteria discussed in the foregoing shrinkage and carbonation sections the total movement in a typical joint would be at least double the 2.5 mm accommodation allowance provided for in a 10 mm wide joint. In practice restraint provided by foundations, floor slabs, and bond beams are likely to reduce the total movement occurring in the joints (non-significant cracking of the blockwork might be experienced between control joints). Where these factors don’t exist, or otherwise as a result of specific design consideration, a wider sealant joint may be required. This could be achieved by saw-cutting the face shells to provide the minimum width to depth ratio required, with a limitation of 20 mm wide by 10mm deep.

Sealants in control joints should also be used in sub-floor spaces and the like where humidity in the atmosphere might compromise the reinforcing steel passing through the control joint.

Sealant is generally not required for joints in interior spaces of buildings that are not seen, ordinary pointing can be used.
Figure 3 - Control joint elevation (NZS4229)
Control Joints

Normal pointing may be used on joints not required to be weather-proof

Horizontal wall reinforcement, to be discontinuous through joint, terminate with 90° return

Used closed-end blocks, or otherwise fill gap with filler board

Provide vertical reinforcing in cell either side of joint

Ensure de-bonded end of dowel is cleanly saw-cut, and not sheared

R16 (plain round) dowels, 800 long, located centrally about joint and lapped and tied to horizontal reinforcing bars (centres to match)

Note: dowels would normally be tied on top of the main reinforcing as shown on Figure 3, the offset lap shown here is for clarity

Joint sealants shall be provided at control joint for all exposed external wall faces

Wrap half length of dowel with plastic tape or tight fitting plastic sleeve to de-bond

Figure 4 - Control joint detail for solid and partial fill walls (does not apply to bond beam and lintel reinforcing)

Ensure minimum width of bonded surface is provided, typically 8 - 10mm

PEF foam rod to de-bond back face and provide manufacturer’s sealant width/depth aspect ratio, typically 2:1

Prime both block side faces if required by sealant specifications

Filler board where open-ended blocks are used at joint, otherwise maintain 10mm gap.

Figure 5 - Sealant Detail
References

1. NZS 4229 Concrete masonry buildings not requiring specific design
2. NZS 4230 Design of reinforced concrete masonry structures
3. NZS 3604 Timber-framed buildings
4. NZS 4210 Masonry Construction – Materials and Workmanship
5. National Concrete Masonry Association Tek 10-1A Crack Control in Concrete Masonry Walls

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