TECHNICAL NOTE

CEMENT CONCRETE & AGGREGATES AUSTRALIA

Joints in Concrete Buildings

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TECHNICAL note

Joints in Concrete Buildings

Any joint, as in a physical break or gap between members, in a concrete structure or building is a potential weak link which may lead to serviceability problems, lack of durability or structural failure. Yet seldom, if ever, is a building constructed without them. In many situations they are necessary requirement (eg to accommodate anticipated differential movement between members) and are sometimes regarded as a necessary evil. Frequently, problems arise because they are given insufficient attention by designers both in terms of their location and detail design.

This Technical Note reminds designers of the reasons for including joints in buildings and the performance requirements they should meet. It gives some guidance on their planning, design and detailing and provides examples of joints which have performed satisfactorily.

Panel-to-panel joints and false joints articulate the cream GRC cladding and the reconstituted granite podium cladding at St George Private Medical Complex Kogarah NSW

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DEFINITION

The word 'joint' is used in building parlance to cover elements which have to perform quite different functions, eg beam-column joints and isolation joints. In the former the joint has to provide continuity of structural action between the members meeting at the joint. In the latter the joint has to ensure separation between the adjacent members to allow one member to move independently of the other.

This Technical Note deals primarily with isolation joints and tends to use 'joints' in this sense. However, a discussion of construction joints is included because they are frequently referred to in insitu concrete construction.

There are a number of ways in which joints can be classified apart from the broad division stated above. In this Technical Note a limited number of specific joints defined by their situation are considered.

WHY JOINTS ARE NEEDED

The four basic reasons for requiring joints are because

- the member or structure cannot be constructed as a monolithic unit in one placement of concrete;
- the member has to be of limited size so it can be handled by cranes, etc;
- the structure or member on one side of the joint needs to be able to move relative to that on the other;
- the design assumptions for the structure or building need the joint at that point so the analysis is simplified.

There is a major difference in the objectives and requirements for joints constructed for the first reason (construction joints) compared to the third (isolation joints) as already noted. This Technical Note does not address joints required for design reasons.

CONSTRUCTION JOINTS

A construction joint is defined by the ACI[1] as 'the surface where two successive placements of concrete meet, across which it may be desirable to achieve bond and through which reinforcement may be continuous'. Generally, because continuity of structural action will be required across the joint, bond will be desirable and the reinforcement will be continuous.

Construction joints may be either planned or unplanned.

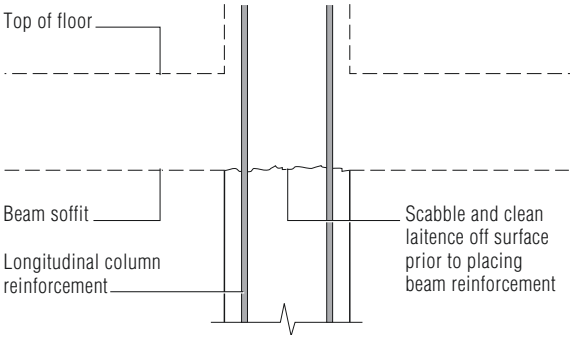

Figure 1

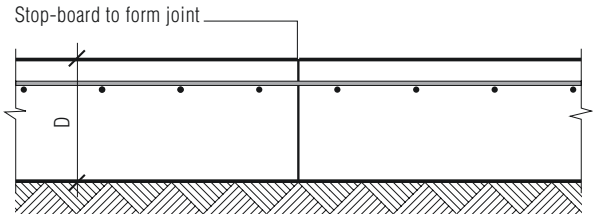

Figure 2

Planned construction joints The location and detailing of planned construction joints can be considered and prepared. The location should be determined in conjunction with the contractor. The contractor will be able to define the maximum size of concrete placement possible on the particular project taking into account the anticipated rate of placement and the constraints imposed by finishing requirements. Where possible, the day's placement should terminate to coincide with other joints in the structure.

Construction joints should be on a single plane and preferably located at right angles to the main reinforcement. They should preferably be vertical or horizontal to the member. Keys are sometimes included but these can lead to difficulties in stripping. If possible, they should be positioned away from regions of high shear or high moment.

AS 3600[2] requires that in columns and walls a construction joint be formed logically at the soffit of the beams and slabs they support **Figure 1**. During placement the concrete adjacent to the joint should be well compacted and special attention should be paid to vibration. The joint should be stripped when the concrete has set and hosed down to expose the coarse aggregate. Any problems in stripping of the joint will be eased if it is located away from regions of high moment and reinforcement congestion. Immediately prior to placing concrete in the next section, the surface should be coated with a cement slurry.

Typical details for a construction joint in a concrete pavement or industrial floor on grade are shown in **Figure 2**. The slab reinforcement is carried through the joint and extra tie bars are inserted to hold the two sides together.

Unplanned construction joints These are joints that are forced upon the concrete-placing crew because of an interruption in supply of a duration long enough for the concrete to take its initial set. There is no opportunity to plan their location. Principles to follow can be only indicated. As with planned joints, the concrete should be cut back to broadly approximately a single plane and the face made vertical. Top ends should be used where possible and the concrete vibrated against these. After forming and clearing the excess concrete away, the joint should be treated as for planned construction joints.

JOINT REQUIREMENTS

Designers and specifiers of joints should have a clear understanding of the specific requirements for any joint on a specific project. These will range from weathertightness to ease of maintenance and repair, and will be discussed under each specific joint type.

However, there are a few aspects which warrant discussion before looking at the specific joint types:

- **Buildability and minimum size** Designers should be confident that the chosen detail can be easily fabricated and will permit easy and safe construction. Proven details should be reused where appropriate; reinvention of the wheel should be avoided. Joints must be wide enough to accommodate the tolerances of fabrication, construction and erection. This usually means a minimum width of 20 mm.
- **Maintenance and repair** As noted earlier, joints are the focal point for wear and deterioration; aspects of maintenance and repair should be considered at the design stage. The choice of a suitable sealant is important as is the appropriate sealant cross-section. Although today's sealants are long-lasting, they eventually will need replacement or repair; the process and ease of this should be part-and-parcel of joint design. There should be provision for inspection and maintenance of face sealants. Locating downpipes in front of a face-sealed joint, whilst protecting the sealant from UV light, impedes both inspection and repair.
- **Sealants** These are proprietary products and the advice on particular products should be obtained from the particular manufacturer/supplier, eg on cross-section dimensions for the sealant and precautions to be taken during installation. However, the ACI *Guide to Sealing Joints in Concrete Structures*[3] provides sound advice regarding the various types of sealant, how they function, joint details, installation and performance, repair and maintenance.

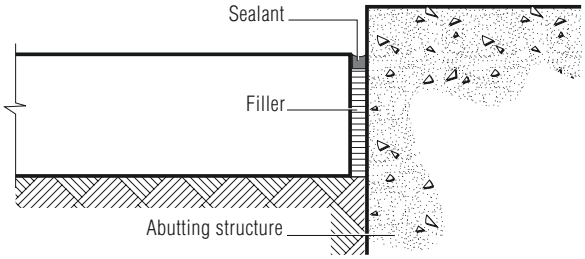

Figure 3

It suggests that the required properties of a joint sealant are that it:

- be impermeable material;
- deform to accommodate the movement and rate of movement occurring at the joint;
- sufficiently retain its original properties and shape if subjected to cyclical deformations;
- adhere to concrete.

In general, field-moulded sealants suitable for face sealing joints between precast wall cladding panels will be either polysulphides, polyurethanes or silicone.

To minimise the strain on the sealant as the joint opens or closes, a rectangular cross section with a larger width than depth across the joint is preferred. The use of backup materials to control the depth of sealant is therefore recommended.

PAVEMENT-ABUTTING STRUCTURE ISOLATION JOINT

Description A joint occurring where a pavement, (ground-supported floor) abutts a structure; it allows the pavement and adjacent structure to move relative to each other **Figure 3**.

Requirements The joint should not impede any relative movement. This may be horizontal, vertical or both and may include rotation. Concrete drying shrinkage in the pavement will mean the joint will usually open with time. However, temperature changes and prestressing forces may give rise to joint closing movements. The joints should be sealed to prevent ingress of detritus which may inhibit this movement. Ability to resist positive water pressure is not usually required; if it is required, reference should be made to joints for water-retaining structures.

Construction The filler material and sealant should be capable of accepting the required expansion and offer little resistance to any compression. The faces should be well compacted during construction to give a smooth finish which offers little resistance to vertical movement.

Location Usually determined by the location of the adjacent structure. Where possible, other joints should be aligned in the same plane **Figure 5**. Avoid the creation of re-entrant angles in the floor panels as these function as crack initiators.

GROUND-SUPPORTED FLOOR – FLOOR CONTRACTION JOINT

Description A joint between one section of a ground-supported floor or pavement and the adjacent section to allow the shrinkage of the concrete to occur at defined locations.

Requirements The Joint should allow the shrinkage of the adjacent sections to take place across the joint, preferably at right angles to the plane of the joint. Any relative vertical displacement across the joint should be prevented. Although movement will open the joint, it should nevertheless be sealed to prevent ingress of detritus which could inhibit any partial closing of the joint due to temperature changes.

Ability to resist positive water pressure is not usually required.

Construction The joints are usually constructed by sawing a groove to at least a quarter of the depth of the slab. Reinforcement should be terminated at least 50 mm, preferably 75 mm, from the joint location. Dowels should be placed through the joint parallel to the direction of shrinkage, ie perpendicular to the plane of the joint **Figure 4**.

The timing of the saw cuts is critical and generally will be between 6–24 hours after placing. If the cut is made too early the edges of groove will ravel; if too late, the slab will randomly crack, defeating the object of the joint. The advice of specialist saw-cutting contractors should be obtained for each project as the timing for saw cutting is affected by concrete mix design, ambient temperatures, and concrete placing temperature. Other control joint details can be found elsewhere[4].

Location The plan shape of the particular pavement will have a marked influence on the joint layout and location as will the anticipated construction technique. Generally, for reinforced floor slabs strip placement is preferred; the width of the strip is limited by the span of the beam vibrators to be used. A typical rectangular layout is shown in **Figure 5**.

The proportion of rectangular bays will depend on the reinforcement ratio in both directions. For unreinforced slabs the proportions should not exceed 1.5:1 as shown in **Figure 5**. Where the slab is heavily reinforced eg 0.8% then the joints can be spaced further apart.

Rectangular bays are preferred. Acute angles between joints should be avoided as it is difficult to compact concrete in narrow spaces. Re-entrant corners should also be avoided as these function as crack initiators.

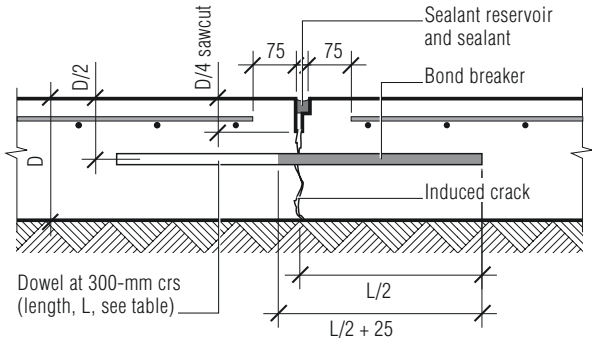

Figure 4

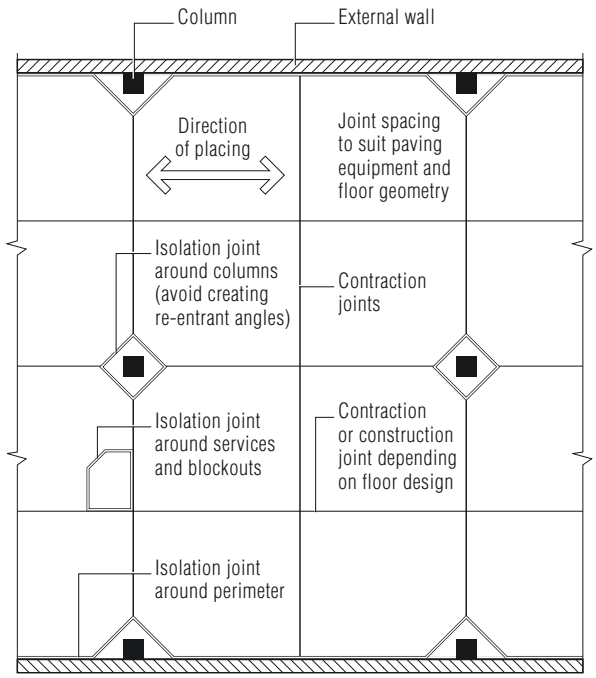

Figure 5

PRECAST CLADDING PANEL – CLADDING PANEL (low rise)

Description A joint between one cladding panel and the next. It is provided to allow the panels to be fabricated and erected, and to enable the panels to act as independent units in the final structure.

Requirements The joint should accommodate the relative movements between the adjacent panels, eg concrete shrinkage and thermal movement. The joint will need to be weathertight. The joint will also need to be wide enough to accommodate the fabrication tolerances and erection tolerances. A recommended width is 20 mm.

Construction The panel edge is usually best constructed square, with 12-mm chamfers on the edges. The joints are usually face sealed as shown in **Figure 6**. To minimise deterioration the seal is recessed approximately 12 mm to give some protection from UV light. Sealants should be placed

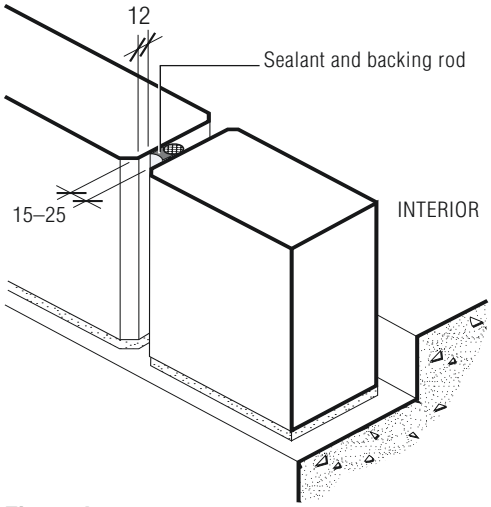

Figure 6

over a backing rod to give the design sealant a favourable cross section. The sealant should be chosen to accommodate the differential movement between the adjacent panels. As these joints are in low-rise buildings access to the joints for maintenance or repair of the seal is normally straightforward.

If fire resistance is required, it is preferable to install the fire resistance seal on the inside face as a separate seal.

The concrete panel should be vibrated along the edges to give a good dense finish. The panel edge should be cured, cleaned of any curing compound or form-release oil, and primed prior to installing the sealant. Cleaning is best carried out prior to erection.

Location Usually determined by architectural considerations and to maximise panel repetition while using as large a panel as possible (to minimise the number of joints).

Face-sealed joints can also be used on multi-storey buildings. In this case, the edge detail frequently incorporates a recess for a baffle strip but a flashing at the horizontal joint between the panels is not needed.

Face sealed joints offer two main advantages over open-drained joints on multi-storey projects:

- There is greater freedom in locating the joints (see comments later on restrictions for open drained joints).
- The sealant tends to mask irregularities in the joint width and further tends to reduce the joint's impact on overall appearance of the building.

PRECAST CLADDING PANEL – CLADDING PANEL (multi-storey)

Description A joint between adjacent precast cladding panels on multi-storey buildings. It is provided to allow the panels to be fabricated and erected, and to act as independent units in the final structure.

Requirements The joint should accommodate the fabrication and erection tolerances of the panels. It should also accommodate the differential movements due to shrinkage and thermal movement. In the vertical direction ie the horizontal joint, it will also need to accommodate the differential vertical creep of the supporting structure. The joint will also need to be weathertight, ie prevent rain entering the building and to require minimum maintenance.

Construction The recommended joint consists of an open-drained vertical joint and a rear-sealed, stepped horizontal joint as illustrated in **Figure 7**.

The minimum width of both joints should be 20 mm. This dimension should be checked to ensure that it will provide sufficient clearance on tall buildings, taking into account the clearance

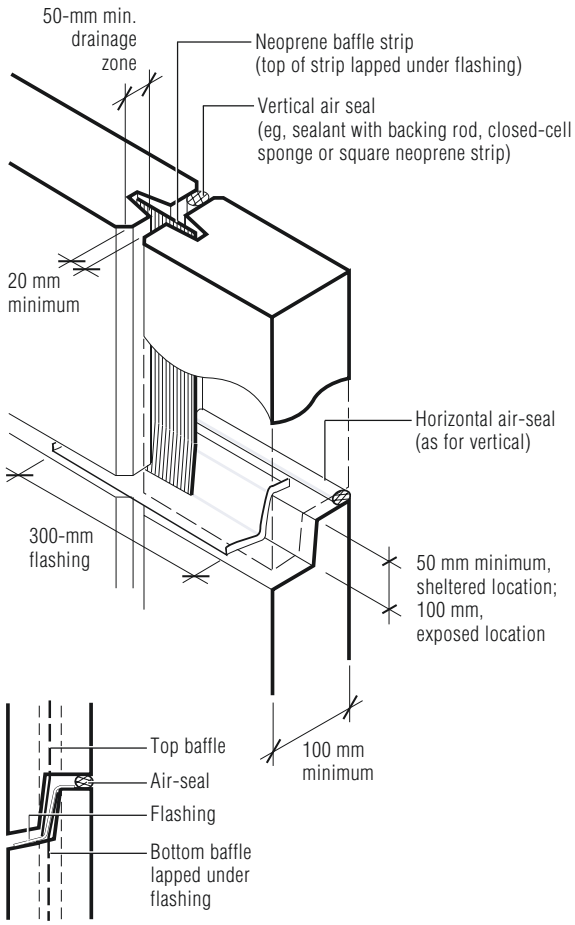

Figure 7

required to accommodate earthquake deflections and the vertical creep of the supporting structure.

Generally, the expansion chamber groove which holds the baffle strip is 20 mm deep and 20 mm wide tapered to allow easy withdrawal of the form. These considerations impose a minimum thickness on the panel of 100 mm as shown in **Figure 7**. A 12-mm chamfer is desirable on the front edge of the vertical joint to minimise damage.

The open-drain joint sealants should be chosen to accommodate differential movement. As they are installed on the back face they are not exposed to UV light which is destructive to sealants. If required, they can be fire resistant.

Care is required in the detailing and installation of the horizontal flashing. The width of the baffle strip can be adjusted during erection. It is necessary for the flashing strip to be installed after the installation of the lower baffle strip and it should overlap the lower baffle strip and be turned up at the edges. The flashing should be as detailed **Figure 7**. It should be flexible enough to be able to tolerate the non-alignment between adjacent panels without causing installation difficulties.

Location Usually determined by architectural considerations, maximisation of panel repetition, use of as large a panel as possible (to minimise the number of joints) and ensuring access to rear of joint.

For an open-drained joint to perform it is necessary for the rear face of the joint to be sealed. In consequence, the rear face must be easily accessible after the panel is erected. Open-drained joints should not be placed in front of columns and the horizontal joint should be kept clear of floor and spandrel beams. The supporting corbel may also interfere with access to the rear face.

FLOOR – FLOOR ADJACENT STRUCTURES

Description A joint required to separate the structure into two discrete structures, eg to separate the legs of an L-shaped building so that it becomes two rectangular structures. If vehicular and/or pedestrian traffic will travel across the joint, then the joint needs to be capped. In other cases, the gap can be treated as between two separate buildings.

Requirements The joint should separate the building into two structures. A level surface for wheeled and pedestrian traffic should be maintained. Provision should be made for the structures on either side to act independently and move with respect to each other. Where required, the gap should be sufficient to accommodate the design earthquake deflections of both buildings.

Fire resistance will probably be required.

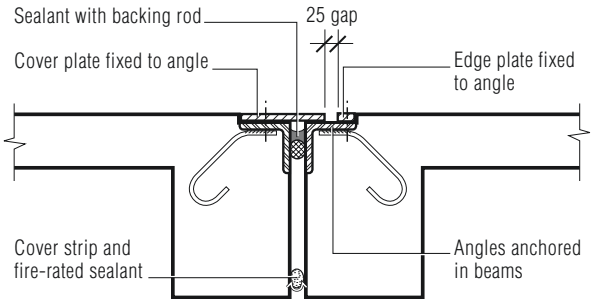

Figure 8

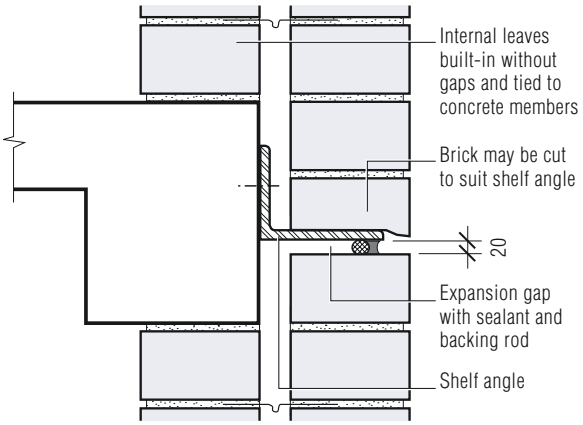

Figure 9

Construction A minimum width 25 mm is recommended to enable the buildings to be constructed adjacent to each other and to allow easy removal of formwork from the gap between the buildings. Cast-in angles at the top of the joint provide attachment and support for the cover strip as shown in **Figure 8**.

A fire-rated sealant can be installed at the bottom of the joint as illustrated in **Figure 8** or, if this is not required, an ordinary seal can be used. To allow freedom of movement of the structures on either side, the joint should not be filled.

Location Location should be chosen for engineering and architectural considerations of the total structure.

MASONRY CLADDING ON CONCRETE STRUCTURE

Description A joint provided where masonry cladding is supported on a concrete structure, **Figure 9**.

Requirements The joint is required to accommodate the differential movement of the outer skin of the cavity wall and the shrinkage creep deformations of the supporting structure. Clay masonry tends to expand with time whereas the concrete structure tends to shrink. The gap is required to accommodate this differential movement.

Well-defined joints give scale to the precast cladding on these offices for BDF Beiersdorf North Ryde NSW

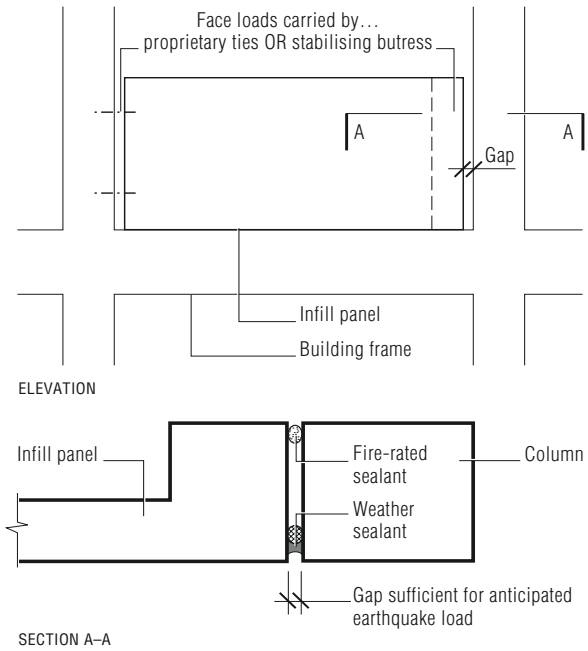

Figure 10

Construction The minimum gap under the angle supporting the outer skin should be detailed at 20 mm which will allow for tolerances of construction and the partial closure due to downwards-creep of the supporting structure and upwards-expansion of clay masonry.

It is imperative that this outer skin be supported by the base structure laterally as well as vertically. Ties back to the inner leaf which should be fixed to the concrete structure are required. The inner leaf can usually be built-in to the concrete frame. Compression problems can be avoided by limiting panel dimensions, or using clay masonry with a low coefficient of expansion, or concrete or calcium silicate masonry.

Layout At each floor level as shown in **Figure 9**.

INFILL MASONRY PANEL TO CONCRETE FRAMES

Description A joint between a masonry infill panel and the supporting structure to isolate the panel from the structure and prevent it from becoming part of the lateral load-resisting structure. This can lead to failure of the non-structural element or more disastrously, failure of the main supporting structure because it was not designed for the modified structural behaviour.

The joint should isolate the panel for in-plane loads due to deflection of the main structure. However, it must ensure that the panel is supported against free loads. The joint must also be weathertight and possibly fire-resistant.

Construction The infill panel may be able to be self-supporting against fire loading by the inclusion of buttresses as shown in the **Figure 10**. The main concern is to ensure that the joint is kept clear of mortar droppings, and other construction debris.

Alternative support can be provided by proprietary fixings designed to offer this type of support while not impeding in plane movements.

The joint should be sealed with a suitable proprietary sealant on the external and internal faces as shown. A backing rod should be used to ensure the sealant cross-section has favourable dimensions. If required a fire-resistant sealant can be provided at the inner face.

The width of the joint should be sufficient to absorb the anticipated deflections under earthquake loading.

CONCLUSION

The detailing of joints is an important aspect of building design and this article provides general principles and suggested details. Well designed and constructed joints will enhance both a building's appearance and give the desired performance in service.

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1 ACI 116R-00 *Cement and Concrete Terminology*, Manual of Concrete Practice Part 1, American Concrete Institute, Chicago, 2004

2 AS 3600 *Concrete Structures*, Standards Australia, 2001

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