

NEW AUSTRALIAN STANDARDS FOR MASONRY IN SMALL STRUCTURES

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SUMMARY

The Australian Masonry Structures Standard AS 3700 provides for fully engineered masonry in structures and is written in performance terms, starting with the highest-level performance statement. Although it includes some deemed-to-satisfy solutions, it does not provide all that is required for design and construction of simple structures such as houses.

Since the publication of AS 3700, much further work has been carried out to produce a new two-part standard, specifically for masonry in houses and other small buildings, designated AS 4773 Part 1 (Design) and Part 2 (Construction). The publication of these standards completes a tiered suite of Australian standards for masonry in buildings.

INTRODUCTION

While masonry has been used in buildings for several millennia, it is a composite material and has not been subjected to the same extent of research as have other structural materials. Masonry design standards throughout the world generally give the performance requirements in a ‘high level’ way, without spelling out in full detail the ways in which those requirements must be satisfied. This is left to the designer in each particular set of circumstances and is not always straightforward. In the case of the Eurocodes (CEN, 2005a; CEN, 2005b; CEN, 2006), the requirements are stated in general terms and the individual member countries must provide further details in ‘National Application Documents’. For the code writers, a conflict can arise between this need for ‘high level’ performance statements and the needs of the users for detailed guidance and deemed-to-satisfy rules that can be applied in the common situations.

Some countries have addressed this situation with tiered codes that provide the ‘high level’ performance statements in one document and the ‘low level’ guidance and rules for application to the simple, common circumstances in a separate document. An example for masonry is New Zealand, where the two tiers of the standard are NZS4229 ‘Concrete

Masonry Buildings Not Requiring Specific Design' (Standards New Zealand, 1999) and NZS4230 'Design of Reinforced Concrete Masonry Structures' (Standards New Zealand, 2004). In Australia, this approach has been successfully applied to the design of timber structures, with the standards AS 1684 'Residential Timber-framed Construction' (Standards Australia, 2006a) and AS 1720 'Timber Structures' (Standards Australia, 1997).

The Eurocodes have also adopted a 'tiered' approach, with the publication of a separate part of Eurocode 6 applicable to simplified calculation methods for unreinforced masonry structures (CEN, 2006b).

In Australia, at the present time, masonry design is covered by a single standard AS 3700 'Masonry Structures' (Standards Australia, 2001). In the 1970s, separate codes for clay brickwork (Standards Association of Australia, 1974) and concrete masonry (Standards Association of Australia, 1977; Standards Association of Australia, 1983) were developed. In 1988, these separate standards were combined, and extensively revised, to produce the first unified Australian masonry code AS 3700 (Standards Association of Australia, 1988). This was subsequently revised in 1998 and 2001. Throughout the development of this standard, up-to-date research was taken into account and emphasis was placed on clearly stating the 'high level performance' requirements to facilitate compliance with the Building Code of Australia (BCA) published by the Australian Building Codes Board (ABCB, 2007). A degree of 'tiered' approach to design has been achieved within the standard in relation to design for compression, where a simplified method can be used (if certain criteria are met) as an alternative to the full engineering design method.

While AS 3700 has facilitated good masonry design in Australia, and provided the means for research to be translated into practice, it has not been entirely without criticism on the part of the user community. It is a heavily engineering-oriented document and many users, who might be looking for rules to design simple brick houses, find the detailed engineering calculations difficult, even overwhelming. Ever since the publication of the first edition in 1988 there has been demand from the users for a simpler document to provide what is necessary for the design of simple structures such as houses, sheds, and fences.

The end users of masonry in Australia have been supported by the Australian Masonry Manual (Baker et al, 1991) and industry publications such as those of the Clay Brick and Paver Institute (CBPI, 1999; CBPI, 2001a; CBPI, 2001b; CBPI, 2004; CBPI, 2006; CBPI, 2007) and the Concrete Masonry Association of Australia (CMAA, 2005). However, these resources do not provide the same level of credibility and consistency that a mandatory standard called up in the building codes would have.

DEVELOPMENT OF THE STANDARDS

During the development of the first Australian unified masonry code, prior to 1988, it was recognised by the committee that 'low level' design and detailing guidance was needed to supplement the 'high level' fully engineered design. Whereas the main thrust of the code was 'Engineered Masonry', the design of which was subject to full engineering calculations, the committee also began work to develop a section of the code for what they called 'Ordinary Masonry', which would be designed without calculation. However, this intention foundered on the difficulty of agreeing on acceptable solutions that could be listed and used without calculation. An example is the case of wall sizes to resist wind and earthquake loading, where there were wide differences of opinion amongst the experienced practitioners and academics

on the committee. It was argued by some that wall sizes could be used that could not be justified by calculation using the then best available theory. These differences proved insurmountable, and the endeavour was abandoned, with the 1988 edition of AS 3700 being published without the 'Ordinary Masonry' section.

The need remained, and the committee continued to work to resolve the issues around the acceptable designs and the appropriate level of safety for simple structures. The availability of a standard specifically for wind loads on houses (Standards Australia, 2006b), which was first published in 1992, helped the cause. This wind loading standard makes certain concessions for small structures and simplifies the task of determining design wind loads by introducing a classification scheme that takes account of location, terrain, etc. Most importantly, its scope sets out geometric limitations, covering single-occupancy houses and other structures, which provide the basis for the scope of a simplified masonry standard and those developed for other structural materials. These limits include a maximum height to the top of the roof ridge of 8.5 m, a maximum width, excluding eaves of 16 m, and a maximum length of any wing of the house of 5 times its width.

The efforts of the committee finally bore fruit with a revised edition of AS 3700 (Standards Australia, 2001) containing a section (Section 12) covering simplified design of masonry for small buildings. While this was a significant achievement, it was not very satisfactory, because although the design rules were consistent with the fully engineered design principles of the remainder of the standard, they were not entirely compatible with common practice in houses and other small buildings. These common practices, some would argue, had stood the test of time without failure and this could be taken to indicate that either the fully engineered design methods were too stringent or that the levels of safety being applied were too high for these simple structures. Others argued that there was a significant chance that the structures built to these common practices had not been subjected to their design loading and that, if they were, failures could be expected. Yet others were of the view that the common practices and standards were declining and that the trend should be halted if future problems were to be avoided.

Clearly, these difficulties needed to be addressed, and a middle path found, where designs for simple structures could be justified by calculation and experiment, while common practices were not unduly ruled as unsafe. Reaching this position has taken some effort, but has proved possible with the development of the new two-part standard, of which the first part AS 4773.1 (Standards Australia, 2007a) covers design.

In parallel with this development of a simplified design standard, there was an obvious need for a simplified construction document, covering the requirements for construction of masonry houses and other small buildings. As for the case of design, some construction guidance is provided by the Australian Masonry Manual (Baker et al, 1991) and particularly the industry publications referred to earlier (CBPI, 1999, 2001, 2004, 2006, 2007 and CMAA, 2005). However, the need for a standard, referenced in the Building Code of Australia (ABCB, 2007), was clear. The second part of the new standard, AS 4773.2 (Standards Australia, 2007b) was developed to cover this need for a construction document.

The new standards apply primarily to masonry in housing, and the provisions comply fully with the relevant parts of AS 3700. The committee has attempted to express the rules in a user-friendly manner by the use of illustrations and many charts and tables. The main users are expected to be building designers, engineers, architects, builders and regulatory authorities

where small buildings are being designed and specified but detailed design calculations are not warranted. The two standards are outlined in the following sections.

SIMPLIFIED DESIGN

The first part of the new standard covers design of simple masonry structures. It should be clearly stated here that, by design is meant the determination of the sizes, materials and details of structural elements and their assembly, such that the completed building will fulfil the necessary performance requirements of the building code (legislation). The aim, although not quite fully achieved, is to facilitate this design for simple structures without any calculation.

The standard contains sections covering design criteria (i.e. performance requirements etc.), materials, durability, fire resistance, and design of walls, including veneer walls, cavity walls, single leaf unreinforced walls and reinforced walls. Other sections cover detailing aspects such as bracing capacity, lintels and movement control joints. Some examples of the provisions are illustrated here.

Design for Vertical Bending

An ever-present difficulty with design for vertical bending is that sections of masonry spanning between top and bottom supports, which are commonly built in houses, cannot be justified by calculation using the default flexural strength and capacity reduction factor adopted by AS 3700 (0.2 MPa and 0.6 respectively), combined with simple bending theory. The cause of this difficulty is not entirely clear, but can be attributed to all or a combination of the following: the assumptions made for the flexural strength; the value of the partial safety factor (ϕ -factor); and the modelling of the structural behaviour (i.e. simple bending theory).

A recent analysis of these factors (Lawrence, 2007) concluded with a recommendation for a modified treatment of simple bending cases, based on the assumption that three adjacent brick joints along a bed joint average their strength in determining the point of failure, rather than the action being a case of completely brittle failure based on the weakest joint in the wall. This is based on an understanding of flexural strength of masonry as a stochastic phenomenon and allows common practice in house design to align with design calculations. This method has been incorporated into the new design standard AS 4773.1.

Design of Wall Ties

A similar difficulty exists with the design of wall ties, either connecting a masonry leaf to a frame of timber or steel, or connecting the two leaves of a cavity wall. Common practice, which has stood the test of time, does not align with design calculations based on our current understanding of tie capacity and behaviour. The design problem has been treated up to now as a brittle phenomenon, where the capacity of a wall containing perhaps 50 or more ties has been determined by the failure of the most heavily loaded tie in the wall.

Again, treatment of this problem as a stochastic phenomenon (Lawrence, 2007) has resulted in a recommendation that design be based on the average tie strength instead of the lower five-percentile characteristic strength. This effectively allows for the ties to redistribute load before failure, which is closer to the observed mode of behaviour. The result is that designs align more closely with the common practices that have proved satisfactory. This method has also been incorporated into the new design standard AS 4773.1.

Design Tables

The design standard AS 4773.1 contains many design tables permitting the user simply to look up designs based on the wind loading category provided by the wind loading code (Standards Australia, 2006b) and other critical parameters. As an example, Table 1 (with Figure 1 and Figure 2) shows part of a lookup table for roof connections tying a metal sheet roof to a 90 mm thick brick wall. For various connection configurations and wind categories (N1 to N3) the table gives a maximum load width, measured normal to the wall, which determines the amount of roof area that can be tied down. Depending on the width of the building and the applicable wind category, a designer can choose an appropriate connection type from this table.

A second example is given by Table 2, which shows a lookup table for wall ties in a brick-veneer wall. From this table, for the appropriate wind category (N1 to N6 for normal wind areas, C1 to C4 for cyclonic wind areas) and wall height, a designer can choose a combination of tie spacing and tie duty rating (light, medium or heavy) to suit. Tables such as this avoid the need for a designer to calculate the requirement based on wind pressures and tie strengths, using the design rules of AS 3700.

Table 1. Load Widths for Tie-Down of a Sheet Roof to a Brick Wall

Connection	Wall Thickness (mm)	Maximum Load Width A (m) for Wind Category		
		N1	N2	N3
Galvanised strap 30 mm x 0.8 mm embedded 600mm down wall at maximum 1200mm spacings (see Figure 1)	90	8.9	7.3	4.1
Galvanised strap 30 mm x 0.8 mm embedded 600mm down wall at maximum 600mm spacings (see Figure 1)	90	8.9	8.5	4.8
Galvanised strap 30 mm x 0.8 mm embedded 900mm down wall at maximum 600mm spacings (see Figure 1)	90	8.9	8.9	5.1
Galvanised strap 30 mm x 0.8 mm attached to bar 600mm down wall at maximum 600mm spacings (see Figure 2)	90	8.9	8.9	5.4
Galvanised strap 30 mm x 0.8 mm attached to bar 900mm down wall at maximum 600mm spacings (see Figure 2)	90	8.9	8.9	6.1

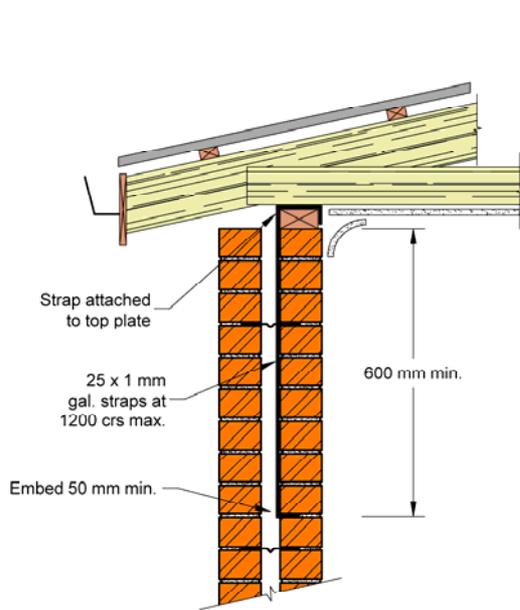


Figure 1. Tie-down (Low Capacity)

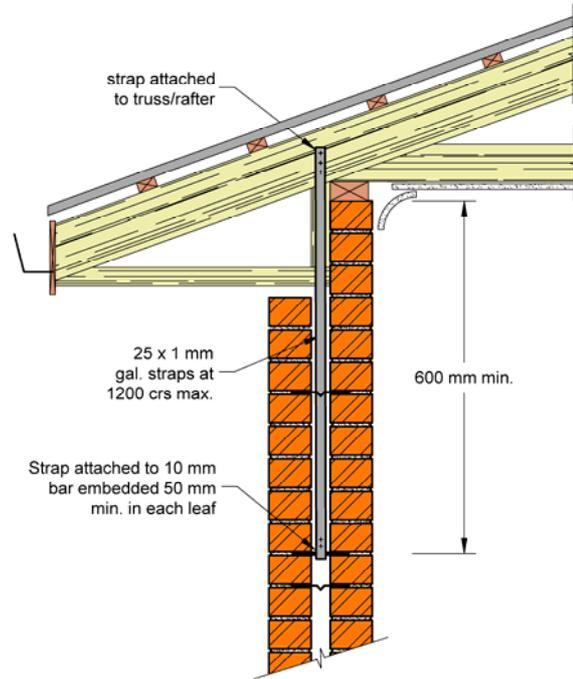


Figure 2. Tie-down (High Capacity)

Table 2. Required Duty Ratings for Type A Veneer Ties

Wind category	Wall height (mm)					
	2400		2700		3000	
	Horizontal spacing (mm)					
	450	600	450	600	450	600
N1	L	L	L	L	L	L
N2	L	L	L	L	L	L
N3	L	L	L	M	L	M
N4	M	M	M	M	M	M
N5	M	H	M	H	H	H
N6	H	H	H	H	H	H
C1	L	L	L	M	L	M
C2	M	M	M	M	M	M
C3	M	H	M	H	H	H
C4	H	H	H	H	H	H

Note: L = light duty, M = medium duty, H = heavy duty

Basis of Design

As well as the overall geometric limitations provided by the scope of the wind loads for housing code, the development of the design standard involved adopting certain simplifying assumptions regarding material properties, the analysis methods used etc. The committee took the view that these assumptions should be documented and, consequently, an informative Appendix A has been included in the standard, which lists the basis of design. This provides

transparency for the user and the necessary link between the overarching design rules in AS 3700 and the designs presented as deemed-to-satisfy solutions in the simplified design standard.

If models of behaviour or relevant material properties change in the future, it will be possible for the code writers to use this information and revise the tables appropriately to produce an updated version of the standard.

CONSTRUCTION

The second part of the new standard (Construction) is perhaps more significant than the first part (Design), because it is an entirely new standard. It is based on AS 3700, but this is the first time that a separate construction standard has been produced for masonry in Australia. The construction industry has been very keen to see such a standard produced, with sufficient detail to guide builders in constructing masonry and to form a truly consensus document that complements the existing guidance documents produced separately by the clay and concrete masonry industry associations. To ensure the practical relevance of the provisions, representatives of building designers, builders and bricklayers were also included as members of the committee.

Some examples of the provisions of this standard are as follows:

Subfloor Ventilation

The standard requires that the sub-floor space be cleared and adequately cross-ventilated. It also requires that the clearance between the ground surface and the underside of the floor be sufficient for ventilation and, where required, for on-going termite inspection. Limits are provided for the area of openings to ensure ventilation, depending on the climatic zone, and the distribution of these openings in both perimeter walls and internal walls.

Isolated Piers

Limits on the dimensions of isolated piers are provided, to cover situations where they are not adequately detailed on the documents. A 230 mm by 230 mm pier can be no more than 1500 mm from the top of the footing to the underside of the floor. A taller pier can be constructed up to 3000 mm in height, with sections of 230 mm by 230 mm not exceeding 1200 mm high, 350 mm by 350 mm not exceeding 1200 mm high and the remainder having the cross-sectional dimensions of 470 mm by 470 mm.

Reinforced isolated piers can be constructed with 190 mm by 190 mm section up to 3000 mm high and reinforced with a single N12 bar.

Control Joints

Spacings for articulation joints in unreinforced masonry walls are provided, covering cases where they are not adequately detailed on the documents. These spacings are related to the site soil class obtained from the residential slabs and footings standard AS 2870 (Standards Australia, 1996).

Similarly, locations and maximum spacings are provided for expansion joints in clay masonry and contraction joints in concrete masonry. Methods of detailing joints where they are located near lintels and bond beams are given, as are the requirements for sealing of joints.

Damp-proof Course and Flashing Details

The standard provides a number of details for the location and construction of damp-proof courses, flashings and weepholes in veneer construction, cavity walls and single-leaf walls. These provisions bring together, for the first time in one place, accepted industry practices for the construction of these details within houses and other small buildings. The provisions include forming corners and lapping of damp-proof course materials, location of sill and head flashings, flashing of roof junctions with abutting walls, flashing of parapets, location of damp-proof courses to prevent rising damp from the ground, and locations of slip joints under slabs supported on masonry walls. Two examples of the type of details provided are shown in Figure 3 and Figure 4.

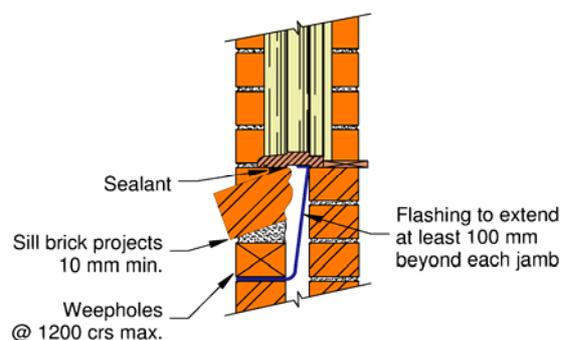


Figure 3. Window Sill Flashing – Timber Window in Cavity Wall

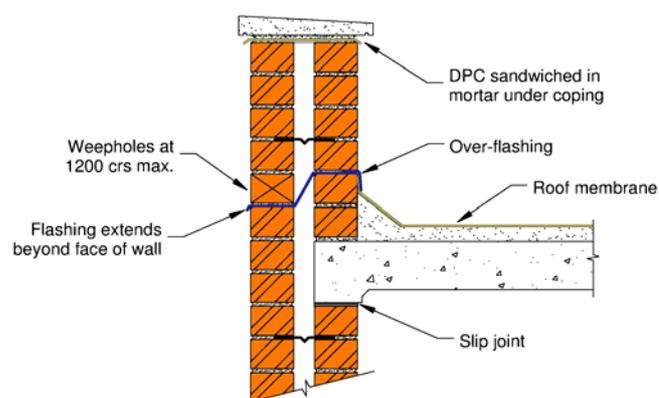


Figure 4. Parapet Flashing – Cavity Wall

Information to be Provided on the Drawings

An informative appendix is included in the standard that lists the information to be provided on the construction drawings or other documentation for the job. This is a common area of deficiency, where the builder undertaking the construction is not provided with the necessary details and must make decisions on site that are really design decisions.

An example of this is the case when the builder is not provided with the wind class, soil class and durability exposure conditions, all of which are fundamental to various aspects of the design. This problem would be compounded if the mortar mix or wall tie durability class were not shown on the documents. In such a case, the builder must make an assessment of the requirements in relation to the exposure environment, something that should have been done by the designer/specifier.

CONCLUSION

After much work over more than two decades, a two-part design and construction standard for masonry in simple structures has been produced. In preparing the standard, the committee needed to resolve some differences between common practices in masonry houses and the fully engineered design rules of AS 3700. It is expected that the two parts of the standard will be published during 2007 and it is hoped that they will be called up in the Building Code of Australia in 2008.

The response from users remains to be seen, but there has been encouragement and positive input so far from the bodies representing the house builders and building designers. Even if the legislative force that stems from the referencing of the standard in the Building Code of Australia does not eventuate, or is delayed, the committee is confident that designers will benefit from the publication of the standards and that they mark a significant step forward in the reliable design of small masonry structures.

The production of this two-part standard completes a tiered structure for masonry standards in Australia, providing for both the fully engineered design and the simplified no-calculation design. In this way, the full spectrum of users is catered for with a consistent suite of standards.

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