

## **SECTION 1. AS 3700 - MASONRY STRUCTURES CODE**

AS 3700:2011 Masonry structures is the current Australian standard for the design of unreinforced and reinforced masonry structures of all kinds. The Standard originated as AS CA32-1963 and the previous edition to the current Standard was AS 3700:2001.

The Standard sets out the minimum requirements for the design and construction of masonry, including unreinforced, reinforced and prestressed, using manufactured units of clay, calcium silicate and concrete laid in mortar, autoclaved aerated concrete (AAC) laid in thin bed mortar, and square dressed natural stone laid in mortar.

The Standard is a comprehensive document consisting 196 pages and it is arranged in the following Sections:

Section 1.	Scope and general
Section 2.	Requirements for design
Section 3.	Design properties
Section 4.	General design aspects
Section 5.	Design for durability
Section 6.	Design for fire resistance
Section 7.	Structural design of unreinforced masonry
Section 8.	Structural design of reinforced masonry
Section 9.	Structural design of prestressed masonry
Section 10.	Design for earthquake actions
Section 11.	Materials
Section 12.	Construction
Appendix A	Assessment of strength values from test results
Appendix B	Determination of characteristic value
Appendix C	Method of test for compressive strength
Appendix D	Method of test for flexural strength
Appendix E	Durability Testing
Appendix F	Method of measurement of bow
Appendix G	Strength testing of insitu masonry
Appendix H	Guidance on the use of masonry in restoration work and masonry constructed using square-dressed natural stone

The Standard assumes that the structural design of masonry will be entrusted to experienced structural engineers or similar appropriately qualified persons. This is essential.

## 1.1 Scope of AS 3700:2011

The purpose of this section of the design manual is to show that the design of **mortarless** masonry structures clearly falls within the scope of **AS 3700**.

AS 3700 states that “This Standard sets out minimum requirements for the design and construction of masonry, ..... (including) ..... unreinforced, reinforced and prestressed masonry using manufactured units of clay or concrete laid in mortar.....”. (Clause 1.1)

**Mortarless** masonry units are not laid in mortar hence with respect to Clause 1.1 it could be construed that AS 3700 does not apply to the design of **mortarless**, however it is specifically stated that the Standard shall not be interpreted in a way that prevents the use of alternative methods of construction not specifically referred to in the Standard provided the requirements of Section 2 are met. (Clause 1.3)

It must be appreciated that **mortarless** masonry is not a new structural system. It is simply an alternative method of masonry construction that is different to the traditional method inasmuch as it does not make use of mortar to lay the masonry units and to bond them together. Another difference is that all **mortarless** masonry walls are always core filled (grouted) whereas traditional mortared masonry walls may be fully grouted, partially grouted or left ungrouted. Traditional mortared masonry walls are often ungrouted, and ungrouted walls are never as strong or robust as fully grouted walls.

A finished **mortarless** masonry wall is essentially a concrete wall in which masonry units are used as permanent formwork, and in which they also contribute somewhat to the total strength and robustness of the finished wall.

Clause 1.3 therefore clearly permits the use of AS 3700 for the design of **mortarless** masonry provided the requirements of Section 2 are met.

AS 3700 Section 2 is titled “Performance requirements for design”. The aim of Section 2 is stated as follows:

*The aim of design is to provide a structure that is durable, fire resistant and serviceable, and has adequate strength and stability while serving its intended function and satisfying other relevant requirements such as resistance to water penetration, robustness, ease of construction and economy.*

Section 2 sets out the general requirements for the design of masonry that are elaborated in the following clauses:

- Clause 2.3: General requirements
- Clause 2.4: Design requirements
- Clause 2.5: Serviceability, strength and stability
- Clause 2.6: Loads and load combinations
- Clause 2.7: Lateral support
- Clause 2.8: Other design requirements
- Clause 2.9: Thermal performance
- Clause 2.10: Acoustic insulation

As will be seen in the following sections of this Part of the design manual, each and every one of the requirements of Section 2 applies as much to **mortarless** masonry as it does to mortared masonry, and in many respects **mortarless** simply makes it easier to achieve the desired outcome. It is clearly demonstrated that **mortarless** masonry elements fully satisfy the

requirements of Section 2 and that the design of **mortarless** therefore falls well and truly within the scope of AS 3700:2011.

## 1.2 Requirements of AS 3700 Section 2

AS 3700 Section 2 Clause 2.3 sets out the performance requirements for masonry elements and structures if they are to be considered designed in accordance with the Standard.

### 1.2.1 General requirements:

The general requirements of AS 3700 place responsibility on the engineer to design and detail a masonry element or structure that is fit for purpose regardless of the interpretation or application of any other specific design clause. The performance requirements of Section 2 are as follows:

**Durability:** A masonry member or structure must be able to withstand the expected wear and deterioration throughout its intended life, taking into account the exposure environment and importance of the structure, without the need for undue maintenance.

**Fire resistance:** A masonry member or structure must have a fire resistance such that the member can, for the required period, perform its intended function and if necessary prevent the spread of fire.

**Serviceability:** A masonry member or structure must have a low probability of failure so as to be serviceable and fit for purpose throughout its intended life.

**Strength:** A masonry member or structure must have a low probability of structural failure when subjected to the loads that can reasonably be expected throughout its intended life.

**Stability:** A masonry member or structure must have a low probability of instability when subjected to the loads that can reasonably be expected throughout its intended life.

**Other:** A masonry member or structure must have a low probability of failing to meet any other appropriate design requirement (e.g. resistance to water penetration) throughout its intended life.

**Mortarless** masonry structures have many inherent features that assist engineers in achieving the performance requirements of Section 2. These include but are not limited to the following:

- Masonry units that are shaped for maximum grout cover to reinforcement.
- Connectors that are designed for accurate and secure positioning of reinforcement to satisfy design requirements.
- No mortar dags and perfectly aligned cores result in ability to readily and thoroughly fill all cores and voids.
- Solid concrete finished walls add to strength, water resistance, fire resistance and acoustic qualities.
- Even minimum reinforcing adds to strength, ductility and earthquake resistance.

As will be shown in the following sections, each and every one of the general requirements is readily achieved with **mortarless** masonry and in many respects **mortarless** masonry makes achievement of the desired outcome easier and more certain.

## 1.2.2 Design requirements:

AS 3700 Section 2 Clause 2.4 sets out the 'deemed to comply' design requirements for **mortarless** masonry elements and structures in terms of the general requirements of Clause 2.3.

### 1.2.2.1 Design for durability

(Key words: *grout, grout strength, cement content, cover*)

A masonry member or structure designed in accordance with AS 3700 Section 5 is **deemed to comply** with the performance requirement for durability.

The following summarises the essential requirements of Section 5:

- Core filling grout in **mortarless** masonry construction must have a cement content of 300 kg/m<sup>3</sup> minimum of GB or GP cement. (see section on *core filling grout*)
- Grout cover to reinforcement must be at least as scheduled in Table 5.1 (see section below on cover) and horizontal reinforcement must have grout cover along its entire length (see section on *cover to reinforcement*)
- Minimum salt attack resistance grade of **mortarless** masonry units is specified in Table 5.1 (see section on *cover to reinforcement*)

### 1.2.2.2 Design for fire resistance

(Key words: *slenderness, cover, thickness*)

A masonry member or structure designed in accordance with AS 3700 Section 6 is **deemed to comply** with the performance requirement for fire resistance.

As always, there are three aspects to fire resistance:

- Structural adequacy
- Integrity
- Insulation

#### **Structural adequacy:**

As mentioned above, **mortarless** masonry must always be fully grouted, however it can be designed as reinforced or unreinforced as required.

Unreinforced masonry and reinforced masonry must comply with slenderness ratio limitations provided in AS 3700 Table 6.1 (see section on *slenderness ratio*)

If the slenderness ratio limit of 36 in Table 6.1 for reinforced masonry is adopted, then the minimum requirements for horizontal or vertical reinforcement must be satisfied (refer Section 2).

#### **Integrity:**

Structural integrity can be assumed to be adequate if the requirements of adequacy and insulation are satisfied. Alternatively structural integrity can be established by test.

### **Insulation:**

Insulation relates to the thickness of a wall or element, and the adequacy of insulation can be established from tabulated minimum thicknesses or from test results. For concrete blockwork with normal density concrete in both the masonry units and the core fill grout, a material thickness of 135mm will provide an insulation rating of 180 minutes whereas a material thickness of 160mm will provide an insulation rating of 240 minutes. (refer AS 3700 Table 6.3)

**Mortarless** masonry is always fully grouted and hence the material thickness is the overall thickness of the single leaf wall, or the sum of the thickness of the leaves in a cavity wall.

The effects of recesses and services must be considered even though they are generally of no consequence in **mortarless** construction. These are addressed in AS 3700 Clauses 6.6. and 6.7.

Refer to AS 3700 Clause 6.8 for the requirements when **mortarless** masonry is used to protect structural steelwork.

#### **1.2.2.3 Design for serviceability**

A masonry member or structure designed for serviceability as set out in AS 3700 Clauses 2.5.1 and 2.5.2 is **deemed to comply** with the general requirement for serviceability.

AS 3700 Clause 2.5.1 addresses material properties, load paths, compatibility issues and the normal design principles for masonry.

AS 3700 Clause 2.5.2 addresses the need to control or limit deflections and cracking, and to properly consider and allow for differential movements arising from the thermal effects, expansion and contraction characteristics of different materials, deflections, shortening, shrinkage, creep of adjacent or associated materials, foundation movements and construction loads or sequences.

#### **1.2.2.4 Design for strength**

A masonry member or structure designed as set out in AS 3700 Clauses 2.5.1 and 2.5.3 is **deemed to comply** with the general requirement for strength.

**Mortarless** masonry units are designed and manufactured for maximum load bearing width when grouted. The inside edges of the face shells of each block have substantial chamfers so that the core fill grout can fill under the bottom surface of the face shells of the blocks over and thereby maximize the solid width of walls constructed with the units.

AS 3700 Clause 2.5.1 addresses material properties, load paths, compatibility issues and the normal design principles for masonry.

AS 3700 Clause 2.5.3 requires the member or structure to be designed for the loads and load combinations given in Clause 2.6 and it requires the design strength to be determined in accordance with AS 3700 Section 4 (general design aspects), Section 7 (structural design of unreinforced masonry), Section 8 (structural design of reinforced masonry), Section 9 (structural design of prestressed masonry) and Section 10 (design for earthquake actions) as appropriate.

### 1.2.2.5 Design for stability

A masonry member or structure designed as set out in AS 3700 Clauses 2.5.1 and 2.5.4 is **deemed to comply** with the general requirement for stability.

AS 3700 Clause 2.5.1 addresses material properties, load paths, compatibility issues and the normal design principles for masonry.

AS 3700 Clause 2.5.4 requires that a structure as a whole, and its parts, shall be designed to prevent instability due to overturning, uplift and sliding under the loads and other actions specified in Clause 2.6. This is a requirement for all structures, not just masonry structures.

### 1.2.2.6 Design for other requirements

A masonry member or structure designed as set out in AS 3700 Clause 2.8, in accordance with AS 3700 Section 4 (general design aspects), and in accordance with Section 7 (Structural design of unreinforced masonry), Section 8 (structural design of reinforced masonry), Section 9 (structural design of prestressed masonry) and Section 10 (design for earthquake actions) as appropriate, is **deemed to comply** with the general requirement of 'design for other requirements'.

AS 3700 Clause 2.8 requires design engineers to take into account requirements such as resistance to water penetration, fatigue, progressive collapse and any special performance requirement if significant.

When it is necessary to prevent moisture penetration, masonry members must be designed, constructed and protected against the passage of moisture in accordance with AS 3700 Clause 4.7. Clause 4.7 addresses the requirements for cavity wall construction, weep holes, damp proof courses and flashings, and waterproof coatings for single leaf walls and solid walls.

AS 3700 Clause 2.9 states that "where a wall is designed to contribute to the thermal performance of a building by insulation, thermal mass or both, it shall be of appropriate materials and construction".

AS 3700 Clause 2.10 states that "where it is necessary to limit the transmission of sound through a wall, the wall shall be of appropriate materials and construction".

## 1.2.3 Loads and load combinations

**Mortarless** masonry must be designed for the dead loads, live loads, wind loads, snow loads and earthquake loads specified in AS 1170.1, AS 1170.2, AS 1170.3, AS 1170.4 and AS 4055 as appropriate. For earthquake actions the additional requirements of AS 3700 Section 10 must be applied. (AS 3700 Clause 2.6.1.1)

AS 3700 also requires consideration be given to other forces and action that could significantly affect the stability, strength and serviceability of a structure and its component members. These include the following (AS 3700 Clause 2.6.1.2):

- Earth pressure with or without ground water pressure
- Liquid pressure
- Construction loads and procedures
- Foundation movements
- Shrinkage or expansion effects
- Axial shortening effects

- Creep effects
- Temperature effects
- Interactions with other materials and members or between different masonry materials
- Floods or collision for masonry members of bridges.

Structures as a whole, and component members, must be designed to resist each compatible simultaneous combination of applied forces acting on them, including each of the load-factored combinations for factored loads given in AS 1170.0 and AS 1170.4. (AS 3700 Clause 2.6.2)

## Combinations of actions for Strength Limit State

Basic combinations:

- |      |                               |  |
|------|-------------------------------|--|
| i)   | $E_d = 1.35G$                 | permanent action only  |
| ii)  | $E_d = 1.2G + 1.5Q$           | permanent and imposed action   |
| iii) | $E_d = 1.2G + 1.5\psi_l Q$    | permanent and long term imposed action                                       |
| iv)  | $E_d = 1.2G + W_u + \psi_c Q$ | permanent, wind and imposed action   |
| v)   | $E_d = 0.9G + W_u$            | permanent and wind action reversal   |
| vi)  | $E_d = G + E_u + \psi_E Q$    | permanent, earthquake and imposed action                                     |
| vii) | $E_d = 1.2G + S_u + \psi_c Q$ | permanent action, actions given in AS 1170.0 Clause 4.2.3 and imposed action |

where  $G$ ,  $Q$ ,  $W_u$  and  $E_u$  are the permanent action, imposed action, ultimate wind action, and ultimate earthquake action respectively,

and where for distributed imposed actions  $Q$

- |                       |  |
|-----------------------|--|
| $\psi_c$ and $\psi_l$ | = 0.4 for domestic, office, parking, retail floors |
|                       | = 0.6 for storage and other floors                 |
|                       | = 0.4 for trafficable roofs                        |
|                       | = 0.0 for non-trafficable roofs                    |

- |          |  |
|----------|--|
| $\psi_E$ | = 0.3 for domestic, office, parking, retail floors |
|          | = 0.6 for storage and other floors                 |
|          | = 0.3 for trafficable roofs                        |
|          | = 0.0 for non-trafficable roofs                    |

Refer to AS 1170.0 Table 4.1 for the factors applicable to concentrated imposed actions.

Refer to AS 1170.0 Clause 4.2.3 for  $S_u$ .

## Combinations of actions for Stability Limit State

For combinations that produce net stabilizing effects ( $E_{d,stab}$ ):

$$E_{d,stab} = 0.9G \quad \text{permanent action only}$$

For combinations that produce net destabilizing effects ( $E_{d,dst}$ ):

- |     |                           |                              |
|-----|---------------------------|------------------------------|
| i)  | $E_{d,dst} = 1.35G$       | permanent action only        |
| ii) | $E_{d,dst} = 1.2G + 1.5Q$ | permanent and imposed action |

- iii)  $E_{d,dst} = 1.2G + W_u + \psi_c Q$  permanent, wind and imposed action
- iv)  $E_{d,dst} = G + E_u + \psi_E Q$  permanent, earthquake and imposed action
- v)  $E_{d,dst} = 1.2G + S_u + \psi_c Q$  permanent action, actions given in AS 1170.0 Clause 4.2.3 and imposed action

### Combinations of actions for Serviceability Limit State

For short-term and long-term effects, combinations that include one or more of the following:

- i)  $G$
- ii)  $\psi_s Q$
- iii)  $\psi_l Q$
- iv)  $W_s$
- v)  $E_s$
- vi) Serviceability values of other actions, as appropriate.

Where  $\psi_s$  and  $\psi_l$  are the short-term and long-term imposed action factors respectively, which are given in AS 1170.0 Table 4.1