SECTION 1. AS 3600:2009 – PLAIN AND REINFORCED CONCRETE - CODE OF PRACTICE

1.1 Overview of AS 3600:2009

AS 3600:2009 is the latest Australian Standard for the design of reinforced concrete. This is a 208 page document covering all aspects of the design of reinforced and prestressed concrete structures and members.

The Standard is arranged in the following Sections:

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1.2 Scope of AS 3600:2009

AS 3600:2009 sets out the minimum requirements for the design and construction of plain and reinforced concrete structures and members. For the purposes of the Standard plain concrete structures are those where the reinforcement, if provided, is ignored for the determination of strength of the structure or member. This is precisely the approach taken for the design of ***mortarless*** walls in compression.

When designing ***mortarless*** members to AS 3600, the masonry units are merely considered permanent shuttering units that contribute just a little to the strength of the member.
When making calculations for the load tables and diagrams in this manual a small portion of the face shells of the masonry units has been taken as acting in compression and bending. The design thickness of the wall is the overall width of the core fill grout and this is tabulated in Section 1 of Parts 2a, 2b and 3. It is this width that has also been used when calculating slenderness ratios.

The core fill concrete in any wall must be of compressive strength at least equal to the unconfined compression strength of the blocks even though that is considered to be possibly conservative. For the purposes of the strength calculation in the design aids in this manual it has been assumed that the grout f'_c is at least equal to the strength of the blocks. Grout of greater strength however may be used.

1.3 Design procedures

AS 3600 Section 2 outlines the requirements for design procedures, actions and loads.

Clause 2.1 sets out the requirements when designing for strength and serviceability, earthquake actions, robustness, durability and fire resistance.

Clause 2.1.1 states that structures shall be designed for ultimate strength and serviceability limit states in accordance generally with the provisions of AS/NZ 1170.0 and the specific requirements of AS 3600 Clauses 2.2 and 2.3.

The limit state method has been used in the generation of all tables and other design aids in this manual.

1.3.1 Design for strength

Clause 2.2 outlines the various options for designing members and structures for strength. It is mentioned in Clause 2.2.1 that it is permissible to use different strength check procedures for different members in the one structure, and the structure as a whole, provided it can be shown that all external actions and forces and calculated internal stress resultants are consistent with the requirements for equilibrium and compatibility of the entire structure.

Clause 2.2.2 states that the strength check procedure for use with linear elastic methods of analysis, with simplified methods of analysis, and for statically determinate structures shall be that

$$R_d \geq E_d$$

Where
R_u is the ultimate strength of a member
R_d is the design capacity (= ΦR_u), and
E_d is the design action effect

This condition must be satisfied at all critical cross sections and regions.

The capacity reduction factors Φ are given in Table 2.2.2 and these are summarized below for members with Class N reinforcement:

Type of action effect	**Capacity reduction factor Φ**
Axial tension without bending	0.8
Axial compression without bending	0.6
Bending without axial compression or tension	$0.6 \le (1.19\text{-}13k_{uo}/12) \le 0.8$
Bending with axial tension	Refer AS 3600Table 2.2.2
Bending with axial compression where $N_u \ge N_{ub}$	0.6
Bending with axial compression where $N_u < N_{ub}$	Refer AS 3600Table 2.2.2
Shear	0.7
Bearing	0.6

The ultimate strength of a member (R_u) is to be determined in accordance with AS 3600 using characteristic values for material strengths.

The design action effect (E_d) is to be determined for critical combinations of factored actions specified in AS 1170.0 and AS 3600 Clause 24 by one of the following methods of analysis:

- Linear elastic analysis in accordance with AS 3600 Clause 6.2
- Linear elastic analysis incorporating secondary bending moments due to lateral joint displacement in accordance with AS 3600 Clause 6.3
- One of the simplified methods of analysis in accordance with AS 3600 Clauses 6.9 and 6.10.
- Equilibrium analysis of a statically determinate structure.

For strength checks using other methods of analysis refer to AS 3600 Clauses 2.2.3 – 2.2.6, 6.1.1 – 6.1.3 and 6.2 – 6.10.

1.3.2 Design for serviceability

Clause 2.3.1 notes that it is a general requirement that design checks shall be carried out for all appropriate service conditions to ensure the structure will perform in a manner appropriate for its intended function and purpose.

There are no limiting values given for the deflection of walls but limiting values for the deflection of beams are given in Table 2.3.2.

Clause 2.3.2 b) states that members shall be designed such that under serviceability design loads the deflections shall not exceed the deflection limits given in Table 2.3.2. It further states that the deflection may be controlled by limiting the span to depth ratios in accordance with Clause 8.5 for beams and Clause 9.3 for slabs.

Clause 2.3.3 states that cracking shall be controlled such that structural performance, durability and appearance are not compromised.

These rules do not generally apply to walls.

1.3.3 Design for robustness

Clause 2.1.3 requires that concrete structures be designed to be robust in accordance with the procedures and criteria given in AS 1170.0 Section 6.

AS 1170.0 Section 6 requires structures to be detailed such that all parts of the structure are tied together in both the horizontal and vertical planes so that the structure can withstand an event without being damaged to an extent disproportional to the event. It is further stated in Clause 6.2.1 that this requirement applies to non-structural components as well.

This is a condition that can be readily be satisfied with load bearing ***mortarless*** construction, but a condition that is often not satisfied in column and beam structures and in traditionally detailed residential/domestic structures.

AS 1170.0 Clause 6.2.5 states that:

> *Walls shall be connected to the structure to provide horizontal resistance to face loads. The connection between the walls and the structure shall be capable of resisting the forces of 5% of G.*

It should be borne in mind that this requirement applies to interconnection of the walls to all structural elements including the footings.

1.3.4 Design for durability and fire resistance

Clause 2.1.4 requires concrete structures to be designed such that they are durable in accordance with the procedures and criteria given in Section 4, and such that they are fire resistant in accordance with the procedures and criteria given in Section 5.

1.4 Design Actions

All permanent, imposed and other actions are to be in accordance with AS 1170.1
All wind actions are to be in accordance with AS 1170.2
All earthquake actions are to be in accordance with AS 1170.4
All combinations of actions are to be in accordance with AS 117.0 Section 4

1.4.1 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*

Ψ_c and Ψ_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

Ψ_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.

1.4.2 Combinations of actions for Stability Limit State

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

$E_{d,stb} = 0.9G$ 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

1.4.3 Combinations of actins 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 Ψ_s and Ψ_l are the short-term and long-term imposed action factors respectively, which are given in AS 1170.0 Table 4.1

1.5 Structural properties

1.5.1 Characteristic compressive strength of *mortarless* walls

The adopted value for the compressive strength of the composite masonry unit and the core fill concrete is the characteristic compressive (cylinder) strength of the core fill concrete but not greater than the unconfined compressive strength of the masonry face shells. Note that the minimum cylinder strength of the core fill concrete (grout) is to be not less than the unconfined compressive strength of the face shells of the blocks.

1.5.2 Characteristic yield strength of reinforcing steel, f_{sy}

The design tables in this manual are based on the use of reinforcing steel with a characteristic yield strength of 500 MPa

1.5.3 Elastic Moduli

The modulus of elasticity of the core fill grout (E_c) at 28 days is as follows (Clause 3.1.2):

***E*$_c$ = 20,500** MPa for 15MPa Grout
***E*$_c$ = 24,000** MPa for 20MPa Grout
***E*$_c$ = 26,700** MPa for 25MPa Grout

It is noted in Clause 3.1.2 that consideration should be given to the fact that the above values have a range of +/- 20%.

The elastic modulus of steel reinforcement ***E*$_s$ = 200,000** MPa.