

## SECTION 2. REINFORCEMENT REQUIREMENTS OF AS 3700:2011

### 2.1 Mechanical properties

#### Yield Strength

Reinforcement for **mortarless** masonry will generally be deformed bars of D500N deformed bars or equivalent, or R250N plain bars or equivalent. The minimum yield strengths ( $f_{sy}$ ) for bars of these grades are 500 MPa and 250 MPa respectively. (AS 3700 Clause 3.6.1)

#### Modulus of elasticity

The modulus of elasticity of reinforcement ( $E_s$ ) for all stress values not greater than the yield strength ( $f_{sy}$ ) shall be either taken as  $200 \times 10^3$  MPa or determined by test. (AS 3700 Clause 3.6.2)

### 2.2 Main reinforcement

The quantity and disposition of main reinforcement in a reinforced **mortarless** masonry member must satisfy the specific requirements of AS 3700 Section 8 (AS 3700 Clause 8.4.2)

#### 2.2.1 Mortarless members in compression

The main reinforcement must be tied at regular centres in two directions as is required in reinforced concrete columns. This is not achievable in **mortarless** masonry walls and hence **mortarless** walls and piers are designed as unreinforced for compression. Any vertical reinforcement is simply disregarded when calculating the capacity in compression.

Reinforcement in compression members is limited to 4% just as it is in reinforced concrete unless the required bar spacing and cover can be achieved and unless the grout can be properly placed and compacted around the reinforcement.

#### 2.2.2 Mortarless members in bending

When designing **mortarless** masonry members for bending it might be necessary to consider only strips of the masonry acting as members resisting bending moments. AS 3700 Clause 8.6 requires the assumption that the width of the compression face ( $b$ ) extends beyond the line of the tensile reinforcement by a distance not exceeding the least of the following:

- Vertical reinforcement:
  - 400mm
  - twice the thickness of the wall
  - the distance to the structural end of the masonry.
- Horizontal reinforcement
  - 1.5 times the thickness of the wall
  - the distance to the horizontal edge of the masonry.

Therefore for example, if an element of 200 **mortarless** masonry is being designed for vertical bending and the vertical reinforcement is other than close-spaced (i.e. at greater than 800mm centres), then the bending moments must be resisted by 800 wide strips of masonry, and possibly 500 wide strips at the ends. This has been accounted for in design tables in Part 2 of this design manual.

For horizontal bending the maximum design width of each strip of masonry containing a horizontal bar is just three times the thickness of the wall; 420mm for 140 **mortarless** and 600mm for 200 **mortarless**. Again this has been accounted for in design tables that form part of this design manual.

## 2.3 Secondary reinforcement

Secondary reinforcement must be provided in any reinforced masonry member that is required to resist non-uniform loads or pressures, temperature or shrinkage. (AS 3700 Clause 8.4.3)

## 2.4 Minimum reinforcement

There are different minimum reinforcement requirements for main reinforcement and secondary reinforcement, and there are different minimum reinforcement requirements for members in compression, bending shear and tension. There are also minimum requirements (maximum spacings) for wide-spaced reinforcement and close-spaced reinforcement.

The minimum reinforcement requirements of AS 3700 are summarized as follows:

### 2.4.1 Minimum main reinforcement

#### 2.4.1.1 Minimum main reinforcement for members in compression

In the event that a masonry member in compression can be and is designed as a reinforced masonry member, then the following minimum requirements apply (AS 3700 Clause 8.5):

- Vertical bars to have a minimum cross sectional area of  $0.002A_d$
- Vertical bars to be restrained in both horizontal directions with ties.
- Vertical bars to be located symmetrically in the cross section.
- Ties to be fabricated in minimum 6mm dia bar or wire.
- Maximum tie spacing to be the lesser of 400mm or the least dimension of the cross section.

#### 2.4.1.2 Minimum main reinforcement for members in bending (vertical and horizontal)

The minimum requirements for main reinforcement in **mortarless** masonry members designed as reinforced for bending are as follows (AS 3700 Clause 8.6):

- Maximum spacing 2000mm
- Minimum  $100\text{mm}^2$  (i.e. 1N12) within 300mm of each edge of the member
- Design moment capacity  $M_d \geq 1.2$  times the bending capacity of the unreinforced masonry.

The vertical and horizontal bending moment capacities of unreinforced **mortarless** masonry is calculated in accordance with the requirements of AS 3700 Clauses 7.4.2 and 7.4.3 are as follows:

UNREINFORCED MORTARLESS MASONRY					
Mortarless blocks	BENDING MOMENT CAPACITY (kNm/m)				Horiz ( $M_{ch}$ )
	Vertical ( $M_{cv}$ )				
	Minimum bed joint compressive stress $f_d$ (MPa)				
	0	0.1	0.2	$\geq 0.3$	
140 mortarless	0.3	0.5	0.7	0.8	0.6
190 mortarless chamfered	0.5	0.8	1.2	1.4	1.1
200 mortarless chamfered	0.5	0.9	1.4	1.5	1.2
200 mortarless	0.5	1.0	1.5	1.8	1.4

As can be seen in the above table, 1.2 times the bending capacity of unreinforced **mortarless** masonry is a very small bending moment and minimum reinforcement requirements are therefore very low. The bending moment capacity tables that form part of this design manual can be used to check the minimum requirement, but N12-1200 both ways will generally be the minimum required for a **mortarless** masonry member reinforced for bending.

#### 2.4.1.3 Minimum main reinforcement for members in shear

The minimum reinforcement requirements for walls subject to in-plane shear are as follows (AS 3700 Clause 8.7):

- Reinforcement must be located symmetrically in the cross-section
- Vertical reinforcement must be spaced at centres not exceeding  $0.75H$  but not greater than 2000mm.
- Horizontal reinforcement must be spaced at centres not exceeding  $0.75L$  but not greater than 3000mm.
- The minimum area of vertical reinforcement must be  $0.0013 A_d$
- The minimum area of horizontal reinforcement must be  $0.0007 A_d$
- Minimum  $100\text{mm}^2$  must be placed within 300mm of each edge parallel to the main reinforcement.

AS 3700 Clause 8.7.2 gives the requirements for the design of long walls ( $H/L \leq 2.3$ ) for in-plane shear.

AS 3700 Clause 8.7.3 requires short walls ( $H/L > 2.3$ ) being designed for in-plane shear to be designed using the formula for out-of-plane shear given in Clause 8.8.

If a wall subject to in-plane shear is not reinforced in accordance with the minimum requirements, it must be designed as unreinforced for shear.

Walls subject to out-of-plane shear cannot be reinforced for shear hence there are no minimum reinforcement requirements. When checking out of plane shear strength however, the area of fully anchored main reinforcement in the tension zone of the cross section contributes to the shear strength. (refer AS 3700 Clause 8.8)

Beams of reinforced blockwork should be checked for shear strength in accordance with the requirements Clause 8.9. If shear reinforcement is required then it should be designed in accordance with the requirements of AS 3600 (concrete structures code) but any shear reinforcement shall not be spaced at greater than 600mm or  $0.75D$ , whichever is less. (AS 3700 Clause 8.9)

It should be noted that AS 3600 requires all shear reinforcement to comprise stirrups or ties making an angle of between  $45^\circ$  and  $90^\circ$  with the longitudinal bars. It also allows for the use of welded wire mesh but that is not appropriate for reinforced blockwork.

Most importantly it should be noted that AS 3600 requires that all bars used as shear reinforcement be fully anchored to develop the yield strength of the bar at any point in the legs. This requirement is deemed to be satisfied if the following requirements are met:

- Bends in bars used as fitments must enclose a longitudinal bar of larger diameter than the fitment bar and the enclosed bar must be in contact with the bend in the fitment bar.
- A fitment hook should be located in the compression zone of the structural member.
- The hook should consist of a  $135^\circ$  or a  $180^\circ$  bend with a nominal internal diameter of  $4d_b$  plus a straight extension of  $10d_b$  or 100 mm whichever is greater.
- If the fitment hook is located in the tensile zone of the member then the calculated spacing of the fitments should be reduced by 20% and the maximum spacing normally permitted should also be reduced by 20%.
- Regardless of the above deemed to comply requirements, fitment hooks must not be anchored solely within the concrete cover.

These deemed to comply requirements mean that **mortarless** masonry is not generally suited to the construction of beams requiring shear reinforcement

#### 2.4.1.4 Minimum main reinforcement for members in Tension

The minimum requirements for main reinforcement in mortarless masonry members designed as reinforced for tension are as follows (AS 3700 Clause 8.10):

- Vertical bars to be symmetrically located in cross section.
- Maximum spacing 2000mm
- Minimum  $100\text{mm}^2$  within 300mm of each edge of the member

#### 2.4.2 Minimum secondary reinforcement

The minimum area of secondary reinforcement is  $0.00035A_d$  (AS 3700 Clause 8.4.3)

The Code requirement would therefore be satisfied with N12-1800 for 200 **mortarless** and 200 chamfered **mortarless**, N12-2000 for 190 chamfered **mortarless**, and N12-2600 for 140 **mortarless**.

It is recommended however, for general good practice and for construction purposes, that the minimum secondary reinforcement in any **mortarless** wall is **N12-1200**.

### 2.5 Wide-spaced reinforcement

Walls with reinforcement that meets the above minimum requirements for compression, bending, shear and tension as appropriate are classed as walls with wide spaced reinforcement unless they also meet the requirements for close-spaced reinforcement described below. (AS 3700 Clause 8.4.6)

## 2.6 Close-spaced reinforcement

The following are the minimum requirements for walls to be classified as walls with close-spaced reinforcement (AS 3700 Clause 8.4.5):

- The wall shall be fully grouted (always the case with **mortarless**).
- It must contain vertical and horizontal reinforcement, both with a maximum spacing of 800mm.
- The minimum area of both the vertical and the horizontal reinforcement must be  $0.0013 A_d$

The minimum reinforcement is therefore:

- **N12-400 both ways** for 200 unchamfered **mortarless**, 200 chamfered **mortarless** and 190 chamfered **mortarless**, and
- **N12-600 both ways** for 140 **mortarless**.

Walls with close spaced reinforcement have an increased level of strength and ductility, and this helps with earthquake resistance. While 'general structures' in Design Category A for earthquakes can be regarded as ductile for design purposes if they have either wide-spaced or close-spaced reinforcement, 'general structures' in Design Categories B, C, D and E can only be regarded as ductile for design and detailing purposes if they have close-spaced reinforcement.