

SECTION 3. REINFORCEMENT

3.1 Mechanical properties

Reinforcement for **mortarless** masonry will generally be Grade 500 ribbed bars . Refer to 1.3.4.5 above for the mechanical properties of reinforcement.

3.2 Main reinforcement

BS 5628-2:2005 Clause 8.6.1 merely states that:

“Designers should consider whether the area of main reinforcement is such that the recommendations for unreinforced masonry given in BS 5628-1:2005 would be more appropriate than the recommendations given in this part of BS 5628:2005.”

BS 5628-2:2005 Clause 8.6.2 limits the size of main reinforcing bars in **mortarless** masonry to 25 mm.

BS 5628-2:2005 Clause 8.6.3 specifies the minimum clear distance between individual parallel bars as the maximum size of the coarse aggregate plus 5mm, or the bar diameter, whichever is the greater, but not less than 10mm.

It states that *“the maximum spacing of the main secondary tension reinforcement should not exceed 500mm”* but it is believed that this is meant to read *“... the main and secondary tension reinforcement*”. Regardless of this however, the Clause also states that *“where the main reinforcement is concentrated in cores the maximum spacing centre-to-centre between the concentrations of main reinforcement may exceed these recommendations.”*

This is interpreted to mean that in reinforced hollow block such as **mortarless** where the reinforcement is installed in cores, then the maximum spacing of 500mm is not a Code requirement.

It is also stated that in vertical pockets measuring less than 125 x 125 mm, only one reinforcement bar should be installed except at laps.

With respect to the 500 mm maximum centres specified in BS 5628:2005, take note of the requirement in AS 3700 for reinforcement to be considered close-spaced - see 3.7 below.

Overall BS 5628-2:2005 is considered quite vague in terms of the reinforcement requirements for the various actions such as compression, bending, shear etc. By comparison the requirements of AS 3700 are far more detailed and for this reason the requirements of AS 3700 are also included where considered appropriate to help designers gain confidence with their design and detailing of reinforced **mortarless** members.

3.3 Secondary reinforcement

BS 5628-2:2005 Clause 8.6.3 specifies a minimum area for secondary reinforcement (see below) and also states that it may be used to help control cracking due to shrinkage or expansion, thermal and moisture movements.

AS 3700 Clause 8.3.3 states that secondary reinforcement must be provided in any reinforced masonry member that is required to resist non-uniform loads or pressures, temperature or shrinkage. This is well known to anyone who designs reinforced concrete structures.

It is the secondary reinforcement that makes it possible to space control joints at greater centres than would otherwise be required.

3.4 Minimum reinforcement

BS 5628-2:2005 does not specify minimum main reinforcement. Clause 8.6.1 merely states that:

“Designers should consider whether the area of main reinforcement is such that the recommendations for unreinforced masonry given in BS 5628-1:2005 would be more appropriate than the recommendations given in this part of BS 5628.”

AS 3700 is far more detailed in the minimum reinforcement requirements. In AS 3700 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 might be of help to designers and they are summarized as follows:

3.4.1 Minimum main reinforcement

3.4.1.1 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 8.4):

- 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.

BS 5628-2:2005 does specify requirements for 'column links' as follows (Clause 8.6.5.3):

Where the area of the steel A_s is greater than 0.25% of the area of the masonry A_m , links should be provided if more than 25% of the design axial load resistance is to be used. In columns where A_s is not greater than 0.25% A_m , links need not be provided.

In this Clause A_m is the same as A_d in AS 3700

BS 5628-2:2005 Clause 8.6.5.3 also specifies the following with respect to the column links if provided:

- Minimum bar diameter 6mm
- Maximum spacing to be the lesser of the smallest dimension of the column, 50 x the link diameter, and 20 x the main bar diameter.

3.4.1.2 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 8.5):

- Maximum spacing 2000mm
- Minimum 100mm^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 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)				
	Vertical (M_{cv})				Horiz (M_{ch})
	Minimum bed joint compressive stress f_d (MPa)				
	0	0.1	0.2	≥ 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.

3.4.1.3 Minimum main reinforcement for members in shear

In AS 3700 the minimum reinforcement requirements for walls subject to in-plane shear are as follows:

- 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 100mm^2 must be placed within 300mm of each edge parallel to the main reinforcement.

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. (AS 3700 Clause 8.6.2)

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 8.6.3)

Beams of reinforced blockwork should be checked for shear strength in accordance with the requirements Clause 8.6.3. 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 8.6.4)

It should be noted that AS 3600 requires all shear reinforcement to comprise stirrups or ties making an angle of between 45° and 90° with the longitudinal bars. It 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° or a 180° 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

3.4.1.4 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 8.7):

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

3.4.2 Minimum secondary reinforcement

BS 5628-2:2005 Clause 8.6.3 specifies a minimum area of secondary reinforcement in walls designed to span in one direction only, i.e. walls subjected to bending. In such walls the minimum area of secondary reinforcement should be 0.05% based on the effective depth times the breadth of the section.

By comparison AS 3700 specifies the minimum area of secondary reinforcement at $0.00035A_d$ (AS 3700 Clause 8.3.3) where A_d is the bedded area of the masonry, not the effective depth times the breadth of the section.

The AS 3700 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**.

It should be noted that the AS 3700 requirement exceeds the BS 5628-2:2005 recommendation if the effective depth is less than 70% of the bedded width of the mortarless masonry, and the recommendation of the author that N12-1200 minimum be provided certainly exceeds the minimum requirement of BS 5628-2:2005.

3.5 Wide-spaced reinforcement

AS 3700 Clause 8.3.6 states that 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.

BS 5628-2:2005 does not prescribe anything with respect to wide-spaced and close-spaced reinforcement.

3.6 Close-spaced reinforcement

AS 3700 specifies the following are the minimum requirements for walls to be classified as walls with close-spaced reinforcement:

- 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 **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.

3.7 Laps in reinforcement

BS 5628-2:2005 Clause 8.6.7 requires that when bars in tension are lapped, the length of the lap should be at least equal to the anchorage length required to develop the stress in the smaller of the two bars, but not less than 25 times the bar size plus 150mm.

3.8 Anchorage of 90° bends

BS 5628-2:2005 Clause 8.6.8 requires that bends should be of a form and dimension that does not overstress the concrete. It also states that the anchorage length of a 90° bend should be measured from the start of the bend to a point four times the bar size beyond the end of the bend and may be taken as the greater of the actual length and four times the internal radius of the bend, but not greater than 12 times the bar diameter.