

AS 3700 (2018) 'MASONRY STRUCTURES' REINFORCED MASONRY UNDER COMPRESSION

UPDATE

The **Concrete Masonry Association of Australia (CMAA)** identified that due to some impractical reinforcement detailing requirements the current design method for compression in AS 3700 'Masonry Structures' (2011) for reinforced masonry (RM) walls severely limits their design compressive capacity of RM walls.

SITUATION

Recent research funded by the CMAA at the Queensland University of Technology (QUT) has been accepted by the BD-004 Standards Australia committee into the AS 3700 (2018) revised design method which:

- Relaxes stringency on the detailing of the vertical steel
- Recognises the true contribution of grout to the walls compressive strength, and
- Removes the AS 3700 (2011) limitation on the allowable grout strength (being 1.3 x the masonry units strength)

RESEARCH AIMS

The research aimed to investigate the effectiveness of the vertical steel in contributing to the compressive strength of the wall, **despite being laterally unrestrained.**

HYPOTHESIS

It was hypothesised that the grout should provide **some degree of lateral restraint** to prevent the vertical steel from buckling when compressed.

PREVIOUS SITUATION

STRENGTH CONTRIBUTION PROVIDED BY MASONRY UNIT

STEEL REINFORCING CONTRIBUTION

FACTOR OF SAFETY

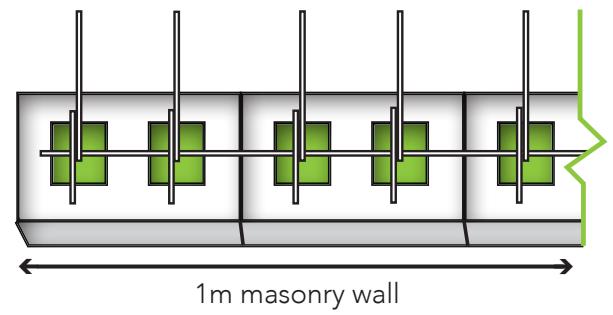
GROUT CONTRIBUTION

$$F_d \leq \phi k_s \left[f'_m A_b + k_c \sqrt{\left(\frac{f'_{cg}}{1.3}\right) A_g} + f_{sy} A_s \right]$$

DESIGN COMPRESSIVE LOADS

COMPRESSIVE CAPACITY

Equation 8.5 (left) is used to calculate whether the compressive capacity provided by a RM wall (RH side of equation) is enough to satisfy the design compressive forces (F_d) acting vertically through the walls cross section.



Where:

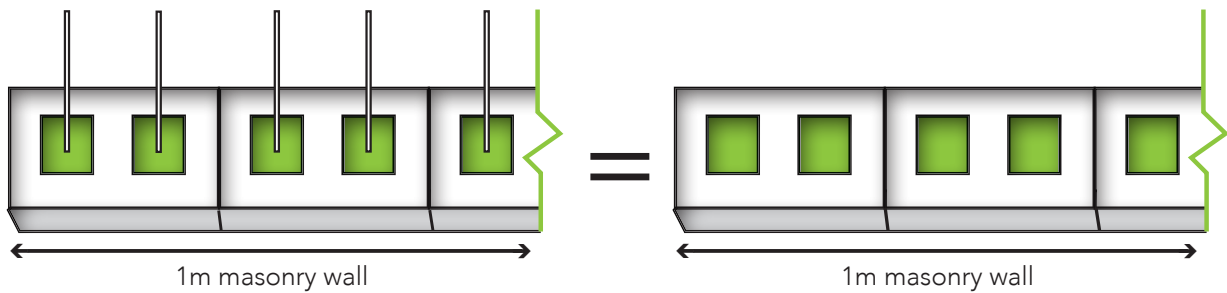
Φ = Capacity reduction factor = 0.75 (Table 4.1 AS 3700 (2011) for RM walls)

*See final page for a full list of all notation used

Currently, clause 8.5 (b) requires the vertical steel in RM to be laterally restrained by horizontal ties, in both directions, or else the contribution provided by the steel ($f_{sy} A_s$) is taken as zero and the wall designed as URM.

This is fine, however this detailing requirement is impractical, time consuming, costly and is rarely adhered to onsite.

In fact, if you do comply with clause 8.5 (b) you will find it difficult to comply with other areas of AS 3700, such as ensuring the grout flows into all the voids.



*Please note, this picture is purely a visual representation of a 1m length of a reinforced concrete masonry wall. The spacing between each vertical reinforcement is subject to the engineers specifications, and may not necessarily be placed in each core. Please see table at the back of this spreadsheet for spacing options.

The **left detail** is what ends up occurring, and is still considered as RM for satisfying wind and earthquake lateral loads, but in compression, it is considered as URM.

STRENGTH CONTRIBUTION PROVIDED BY MASONRY UNIT

GROUT CONTRIBUTION

FACTOR OF SAFETY

$$F_o \leq \phi k \left[f'_m A_b + k_c \sqrt{\left(\frac{f'_{cg}}{1.3}\right) A_g} \right]$$

DESIGN COMPRESSIVE LOADS

COMPRESSIVE CAPACITY

The URM equation 7.3.3.2 is at left, where:

Φ = 0.5 (Table 4.1 AS 3700 (2011) for URM walls)

*See final page for a full list of all notation used

When applying each of these equations, there are significant differences in capacity provided.

EXAMPLE: For a commonly constructed reinforced concrete block wall on the ground floor of a common office building, with the wall being 2.7m high, 6m long, 190mm thick, 15MPa blocks with 20MPa grout and N16 bars @ 200 centres:

- Equation 8.5 for RM provides a capacity of **975 KN/m (allowing approximately 8-9 stories on top)*** whereas
- Equation 7.3.3.2 for URM will provide a capacity of **445 KNm (allowing approximately 3-4 stories on top)***
*These capacities are theoretical in nature. Other structural actions such as those induced by wind and earthquake forces will still need to be accounted for in the design, and may inhibit or govern the allowable stories a wall designed to AS 3700 can cater for.
- Because of the impracticality of clause 8.5(b), designers are forced to use the capacity of URM walls when designing RM, which presents a significant disadvantage to RM's design compressive capacity compared to other materials, and thus research by the CMAA was sought.

RESEARCH FINDINGS

- No benefit provided by laterally restraining the steel via ties
In 2018, the engineer may specify horizontal reinforcement (nominally N12's, N16's, etc...) for shrinkage purposes or other actions, however all the steel associated with laterally restraining the vertical steel (nominally 6mm ties) does not need to be installed anymore.
- The contribution of the grout to the overall compressive capacity of the wall was significantly higher than suggested by AS 3700 (2011)
- The magnitude of the contribution provided by the grout increased with increased grout strengths
- The strength of the grout is currently limited to 1.3 x the strength of the masonry unit, yet grout strengths of up to 3 times higher than that of the masonry were used in this testing without any adversity in the results

From this testing and subsequent analysis, equation 8.5 AS 3700 (2018) is:

$$F_d \leq \phi k_{es} \left[f'_m A_b + k_c \left(\frac{f'_{cg}}{1.3} \right)^{0.55+0.005f'_{cg}} A_g + \alpha_r f_{sy} A_s \right]$$

Where:

$$k_{es} = (1.0 - 0.025Sr)(1 - 2 \frac{e}{t})$$

e = effective eccentricity

$$e < 0.05t_w$$

t_w = overall thickness of the wall

$$\Phi = 0.75 \text{ (for RM walls as per Table 4.1)}$$

α_r = reinforcement contribution factor

$$= 0.4 \text{ (for RM walls)}$$

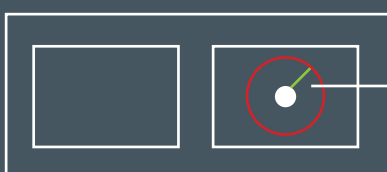
$$= 1 \text{ (for RM piers/columns)}$$

$$f'_{cg} \geq 12 \text{ MPa}$$

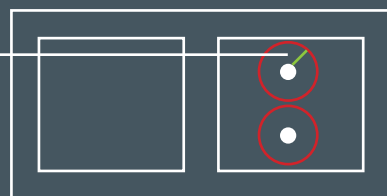
Note:

- Until further testing is pursued, it is recommended that specified grout strengths are not more than 35 MPa greater than the masonry unit strength. i.e. For 15 MPa units, grout strengths of less than or equal to 50MPa.
- To ensure confinement of the vertical steel, an annulus of grout of thickness not less than twice the radius of the reinforcing bar should surround the bar at all times. If this annulus cannot be achieved, then the steel contribution is considered as zero, and the wall designed as if it were unreinforced.

Verticality of the steel should also be maintained and controlled throughout the construction process. Bar chains, spacers and/or tie wires can assist in achieving this.



Minimum 2D, where D is the diameter of the steel reinforcing bar

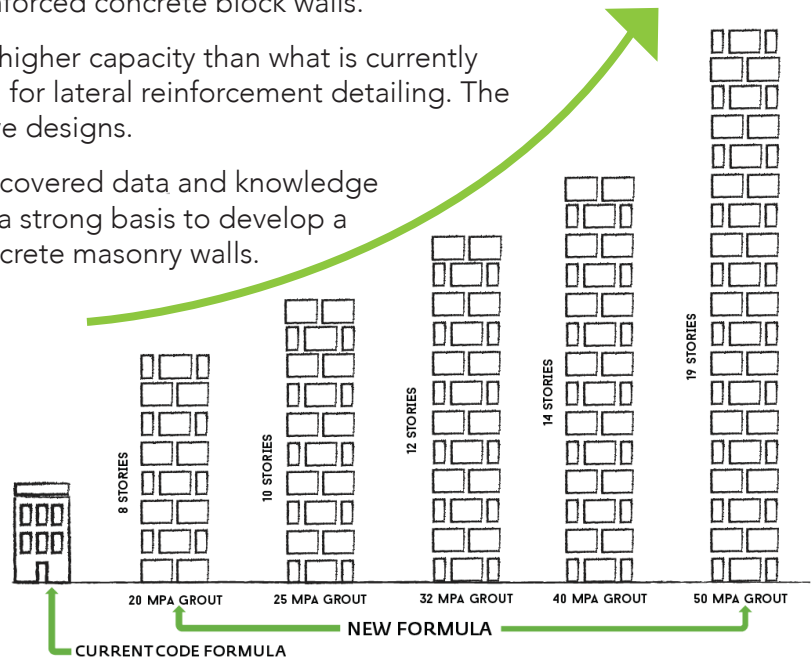


These formulas are evidence based, self-consistent and easy to use. Designers can now design RM walls under compression with ease, rationally allowing for slenderness and eccentricity without the stringent control on the detailing of reinforcement and the strength of the grout, which unnecessarily work to reduce the compressive capacity of reinforced concrete block walls.

The AS 3700 (2018) formula is shown to predict higher capacity than what is currently represented in AS 3700 (2011) without any need for lateral reinforcement detailing. The new equation will thus provide more competitive designs.

In conclusion, the experimental research has uncovered data and knowledge hitherto not well understood and has provided a strong basis to develop a more rational design formula for reinforced concrete masonry walls.

Note: the calculated allowable stories presented in this figure are theoretical and purely provided to give a visual representation of the capacities AS 3700 (2018) allows designers to achieve. Other structural actions such as those induced by wind and earthquake forces will still need to be accounted for in the design, and may inhibit or govern the allowable stories a wall designed to AS 3700 (2018) can cater for.



The below table shows a comparison of compressive capacities between codes. The wall height chosen was 2.7m and the masonry block strength was 15MPa.

COMPRESSIVE CAPACITY (kN/m)						
Block type/ wall thickness	Steel configuration	grout strength	AS 3700 (2011) $f'_{cg} < 1.3 f'_{uc}$		AS 3700 (2018)	
			RM	URM	RM	URM
		(Mpa)	eccentricity = 0			
150 series	N12 @ 200	20	570	283	555	369
		25	570	283	580	424
		32	570	283	693	515
		40	570	283	853	642
		50	570	283	1115	852
	N12 @ 400	20	497	283	486	369
		25	497	283	555	424
		32	497	283	668	515
		40	497	283	828	642
		50	497	283	1090	852
	N16 @ 200	20	683	283	550	369
		25	683	283	619	424
		32	683	283	732	515
		40	683	283	892	642
		50	683	283	1153	852
	N16 @ 400	20	554	283	505	369
		25	554	283	575	424
		32	554	283	688	515
		40	554	283	847	642
		50	554	283	1109	852
N16 @ 600	20	510	283	491	369	
	25	510	283	560	424	
	32	510	283	673	515	

COMPRESSIVE CAPACITY (kN/m)						
Block type/ wall thickness	Steel configuration	grout strength	AS 3700 (2011) $f'_{cg} < 1.3 f'_{uc}$		AS 3700 (2018)	
		f'_{cg}	RM	URM	RM	URM
		(Mpa)	eccentricity = 0			
150 series	N16 @ 600	40	510	283	833	642
		50	510	283	1094	852
200 series	N12 @ 200	20	840	445	795	589
		25	840	445	913	683
		32	840	445	1106	838
		40	840	445	1379	1056
		50	840	445	1826	1414
	N16 @ 200	20	975	445	841	589
		25	975	445	959	683
		32	975	445	1152	838
		40	975	445	1425	1056
		50	975	445	1872	1414
	N16 @ 400	20	821	445	788	589
		25	821	445	907	683
		32	821	445	1100	838
		40	821	445	1373	1056
		50	821	445	1820	1414
300 series	N16 @ 200	20	1501	764	1405	1027
		25	1501	764	1624	1203
		32	1501	764	1983	1489
		40	1501	764	2490	1895
		50	1501	764	3319	2559

NOTATION:

F_d = Design compressive force acting on the member's cross section

$k_s = 1.18 - 0.03S_r$

S_r = Slenderness ratio (CI 7.3.4.3)

k = Reduction factor for slenderness and eccentricity

f'_m = Characteristic compressive strength (CI 3.3.2)

A_b = Bedded area of a masonry member cross-section (CI 4.5.4)

k_c = Strength factor for grout in compression (CI 7.3.2)

f'_{cg} = Design compressive strength of grout (CI 3.5)

$f'_{cg} < 1.3f'_{uc}$ (AS 3700 (2011))

$f'_{cg} \geq 12\text{MPa}$ (AS 3700 (2018))

A_g = Design cross section area of grout (CI 4.5.7)

f'_{sy} = Design yield strength of reinforcement (CI 3.6.1)

A_s = Total cross sectional area of main reinforcement

The **Concrete Masonry Association of Australia (CMAA)** is the peak body representing the concrete masonry manufacturers of Australia, including bricks, blocks, pavers & retaining walls.

We support the concrete masonry industry by providing technical information and advice to architects, engineers, specifiers and educators.

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