SECTION 7. DESIGN OF *mortarless* MASONRY MEMBERS FOR AXIAL COMPRESSION

When designing ***mortarless*** walls and piers for compression loads the vertical reinforcement is not considered to make any contribution to the compressive strength simply because it cannot be restrained in two directions with ties at close centres. For example in 140 thick walls it would be necessary to install ties at 114mm centres for all vertical bars, and in 200 thick walls it would be necessary to install ties at 164 to 174mm centres. This is not possible in walls constructed using ***mortarless*** masonry units. Tied column cages may be appropriate in larger freestanding piers or columns and therefore the steel may be considered to contribute to the load capacity.

For the reasons stated above it is normal practice when designing reinforced concrete walls to neglect any contribution the reinforcement might make to the compression load capacity however IS 456:2000 Clause 32.5.2 actually permits the contribution of unrestrained vertical reinforcement if the area of reinforcement does not exceed 1% of the gross cross sectional area of the wall. It also permits the omission of ties if the reinforcement is not required for compression, and this is the design approach taken with ***mortarless***. Regardless of this contribution of the steel to the compression load capacity is disregarded in the load tables and diagrams provided in this manual.

7.1 Design of *mortarless* masonry walls for axial compression

The design strength of a ***mortarless*** wall in compression is dependent on the following:

- Slenderness
- Effective eccentricity at the top
- Characteristic compressive strength of the masonry unit and the grout
- Cross sectional area of the wall.

In ***mortarless*** wall construction the ***mortarless*** masonry units are permanent shutters (formwork) that contribute just a little to the strength of the wall in compression. The design thickness is less than the total thickness; it is the overall thickness of the grout (concrete core fill). The portions of the masonry face shells that have no provision for concrete penetration are ignored in all calculations except mass. With unchamfered masonry units that generally means that 26mm of the wall thickness is ignored and with chamfered masonry units that generally means that 36mm of the wall thickness is ignored in the strength calculations.

IS 456:2000 Clause 32.1 states that reinforced concrete walls subjected to direct compression or combined flexure and direct compression should be designed using the limit state method outlined in Section 5 or the working stress method outlined in Annex B “provided the vertical reinforcement is provided in each face”.

The author is not clear about the requirement for reinforcement in each face; i.e. whether it applies to the design of walls to working stress method only or to the design of walls to both working stress and limit state. Clause 32.5.21 states that vertical reinforcement is required in both faces in walls of greater than 200mm thickness. This is the requirement the author is familiar with in his experience with other international codes.

The requirement for reinforcement in both faces may be aimed at walls in other than braced structures. The author will seek to clarify this.

In this design manual the limit state method has been adopted throughout.

Clause 32.1 further states that the minimum thickness of walls shall be 100mm and all ***mortarless*** walls are greater than 100mm thick.

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7.1.1 Design of walls using empirical method

IS 456:2000 Clause 32 permits walls to be designed for in-plane vertical loads using the empirical method. If this method is to be used the walls must be braced by being laterally supported by the structure and all of the following conditions must be satisfied (IS 456:2000 32.2.1):

- Walls or vertical braced elements must be arranged in two directions so as to provide lateral stability of the structure as a whole.
- Lateral forces must be resisted by shear in the planes of these walls or by braced elements.
- Floor and roof systems must be designed to transfer lateral forces.
- Connections between the walls and the lateral supports must be designed to resist horizontal forces not less than the simple static reactions, and 2.5% of the vertical load.

The minimum eccentricity on any wall designed using the empirical method is 5% of the wall thickness, i.e.$0.05t_d$.

The empirical method is the method that has been used to calculate the load capacities presented in the tables in the subsequent sections of this manual.

Each storey height of wall being designed using this method must be designed for the eccentricity calculated as shown in Parts 2 and 3 of this manual for the various ***mortarless*** masonry wall thicknesses, but not less than the minimum eccentricity. (IS 456:2000 Clause 32.2.2)

Note that the eccentricity is considered to be zero at the base of each storey height of wall.

In addition to the eccentricity at the top of each storey height of wall, an additional eccentricity at about mid height due to deflection of the wall must also be considered. This additional eccentricity increases as the slenderness of the wall increases and the design tables in Parts 2 and 3 of this manual take this eccentricity into account.

7.1.2 Design of walls as slabs

Walls can be subjected to out-of-plane horizontal loads in addition to axial compression loads and these walls need to be designed for combined bending and compression.

If the axial load is small then it can be permissible to design the wall as a slab. Clause 32.3.2 states that when the design axial load does not exceed $0.04f_{ck}A_g$ then the axial load can be disregarded and the wall can be designed for bending using the approach that is used for the design of slabs.

7.1.2 Design of walls as compression members

When a wall is subjected to an out-of-plane lateral load in addition to an axial compression load and the axial compression load is greater than $0.04f_{ck}A_g$ then the wall should be designed for combined bending and compression using the approach used for the design of compression members - refer Clause 25.

When designing walls as compression members using Clauses 25 and 39 the minimum eccentricity is increased to 1/500th of the unsupported height of the wall plus 1/30th of the design thickness of the wall but not less than 20mm (refer Clause 25.4). This minimum eccentricity of 20mm is much greater than the minimum eccentricity for walls designed using the empirical method but the slenderness limit is increased from 30 to 60.

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Most importantly when designing walls as compression members using Clauses 25 and 39 it is necessary to properly analyse the structure to obtain the design bending moments that include the bending moments due to secondary effects such as slenderness.

7.2 Design of *mortarless* shear walls for compression

When a load-bearing wall is also acting as a shear wall, in plane bending should be checked. When a horizontal force is resisted by more than one shear wall the load may be distributed between the walls in proportion to their flexural stiffness about an axis perpendicular to the plane of the wall.

The in-plane bending moment will result in non-uniform compression in the wall and the wall should be designed for the maximum resulting compression force.

IS 456:2000 Clause 32.3 provides guidance for the design of braced walls that are subjected to combined in-plane horizontal and vertical loads. It states that such a wall can be designed for the in-plane vertical loads using the empirical design method, and the in-plane horizontal loads using Clause 32.4 (it actually states that Clause 32.3 is to be used but this is clearly an error).

IS 456:2000 Clause 32.3.1 states that in-plane bending may be neglected in the case where the horizontal cross section is always under compression due to the combined effect of horizontal and vertical loads. It s recommended by the author however that the maximum compression in any wall due to the combined loading always be considered.

7.3 Increased stresses at concentrated loads (bearing stress)

IS 456:2000 Clause 34.4 should be used for checking the bearing stress at load concentrations. Reinforcement or equivalent will be required if the bearing stress on the area A_1 as defined in 34.4 exceeds $0.45f_{ck}$.