APPENDIX A

Masonry Design

Introduction

Masonry in general is defined as any structural assemblage of masonry units like stones, bricks, blocks etc. with a binding material which is known as mortar. The walls of the masonry building and the building itself are designed to be stable, strong and durable enough to withstand the most severe combination of loads called as design load. Masonry construction is flexible in terms of building layout and is quite economical, provides thermal and acoustic insulation and as well as it is fire and weather resistant. Masonry units that have been previously used shall not be reused in brickwork or block work construction unless they are thoroughly cleaned and conform to relevant code. The minimum compressive strength of masonry units to be used in reinforced masonry shall be 7 N/mm^2. But the strength of bricks in India varies from region to region depending on the nature of local soil, technique adopted in moulding and burning.

NOTE

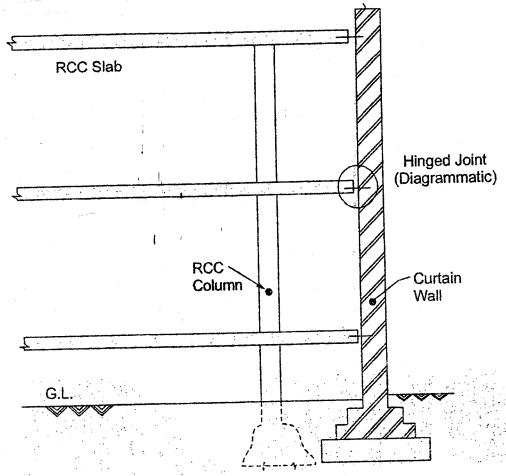
At present, in India, the IS code for masonry construction is **IS 1905:1987 (reaffirmed 1998) "Structural Use of Unreinforced Masonry"**. The corresponding detailed hand book on masonry design and construction is **SP 20**. The IS code for **Structural Use of Reinforced Masonry** is under preparation. **IS 4326** provides some guidelines for construction of reinforced masonry. **IS 13828:1998** provides guideline for earthquake resistant low strength masonry buildings.

Terminologies

Bed Block: A block bedded on a wall, a column or a pier in order to disperse a concentrated load on a masonry element.

Cavity wall: It is the wall consisting of two leaves with each leaf separated by a cavity and ties together with metal ties or the bonding units in order to ensure that the two leaves act as one unit. The space between the two leaves is either left free as a continuous cavity or filled with non-load bearing insulating or water proofing material.

Curtain wall: It is a non load bearing wall subjected to lateral loads only. It may be laterally supported by vertical or horizontal structural members.



Curtain Wall

ECB: Engineered Concrete Block

Effective height: It is the height of wall or column which is required for computing the slenderness ratio.

EMU: Engineered Masonry Unit – These are special units for architectural purpose (colour, shape, texture etc.), physical purpose (density etc.), structural requirement (strength, elasticity, durability etc.).

Free Standing Wall: It is the compound wall or parapet wall. It is acted upon by wind force which tends to over turn it. This tendency to overturning is resisted by gravity force due to self weight of wall, and also by flexural moment of resistance on account of tensile strength of masonry.

Grout: It the mixture of cement (or any other binding material), sand and water with a pourable consistency for filling the voids.

Grouted cavity reinforced masonry: Two parallel single leaf walls spaced at least 50 mm apart effectively tied together with wall ties. The cavity contains steel reinforcement and is filled with concrete so as to have a common action with masonry under load.

Grouted hollow masonry unit: It is that form of grouted masonry construction wherein certain designated cells of hollow units are continuously filled with grout.

Grouted multi wythe unit: It is that form of grouted masonry construction wherein certain the space between the wythes is solidly or periodically filled with grout.

HCB: Hollow Concrete Block – A masonry unit in which net cross sectional area in any plane parallel to the bearing surface is less than 75% of its gross cross sectional area measured in the same said plane.

Leaf: Inner or outer section of a cavity wall is called as leaf.

Load bearing wall: It is the wall which is designed to carry an imposed vertical load in addition to its own self weight along with lateral loads, if any. The following table gives maximum slenderness ratio for reinforced load bearing wall.

Table: *Maximum slenderness ratio for reinforced load bearing wall*

End Condition	Ratio of span to effective depth
Simply supported	35
Continuous	45
Spanning in two directions	45
Cantilever	18

Masonry unit: Individual units bonded together with mortar to form a masonry element like column, wall etc.

Panel wall: It is the exterior non-load bearing wall in framed constructions wholly supported at each storey and subjected to lateral loads in an out plane direction like wind loads, earthquake etc.

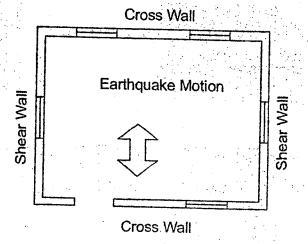
Partition wall: It is an interior non-load bearing wall which is one storey or part storey in height.

Prism: It is an assemblage of masonry units bonded by mortar with or without grout used as a test specimen for determining the properties of masonry (with height to thickness ratio of 2 to 5).

RM: Reinforced masonry

SCB: Solid Concrete Block

Shear wall and cross wall: It is the wall designed to carry the horizontal forces acting in its plane with or without vertical imposed loads. The walls normal to shear walls are referred to as cross walls.



SMB: Stabilized Mud Block

Specified compressive strength of masonry: It is the minimum compressive strength expressed as force per unit net cross sectional area required in the masonry to be used in construction.

TMB: Table Moulded Brick

URM: Unreinforced masonry

Wall tie: It is a metal fastener which connects wythes of masonry to each other or to other materials.

WCB: Wire Cut Brick

Wythe: It is the continuous vertical tie of one masonry unit in thickness.

Masonry Reinforcement

For general load bearing masonry construction, Fe 415 steel is quite acceptable. But for earthquake resistant masonry design, a variety of reinforcement is used.

Table: *Reinforcement specification in load bearing construction*

Tensile Strength	
MS Bars confirming to IS 432 (Part I)	140 MPa for diameter ≤ 20 mm 130 MPa for diameter > 20 mm
HYSD Bars (IS 1786)	230 MPa
Compressive Strength	
Size and spacing of reinforcement	130 MPa
The maximum size of reinforcement used in masonry shall be 25 mm diameter bars and minimum size shall not be less than 5 mm.	

Remember

The reinforcement diameter shall not exceed one-half the least clear dimension of the cell, bond beam or collar joint in which it is placed. Clear distance between parallel bars shall not be less than the diameter of bar or 25 mm whichever is more. In columns, clear distance between the vertical bars shall not be less than 1.5 times the bar diameter nor shall be less than 35 mm.

Design Loads

Loads to be considered in the design of masonry structures are:

1. Dead load of walls, columns, floors and roofs as per **IS 875 (Part-I)**.
2. Live load on floors and roof as per **IS 875 (Part-II)**.
3. Wind loads on walls and sloping roofs as per **IS 875 (Part-III)**.
4. Seismic loads as per **IS 1893 (Part-I)** and snow loads as per **IS 875 (Part-IV)**.

Load Combinations

In structural design of masonry structures, the most commonly adopted design philosophy is the allowable stress design method. As per this design method, the structure shall be designed for the following load combinations:

1. DL + IL
2. DL + IL + WL (or EQL)
3. DL + WL
4. 0.9DL + EQL

DL: Dead Load, **IL:** Imposed Load, **WL:** Wind Load, **EQL:** Earthquake Load

Permissible Loads and Stresses

In the design load combination wherein wind load (or earthquake load) is being considered, there permissible stresses may be increased by 33.33%.

Alternatively, instead of increasing the permissible stresses, we can use 25% reduced load for load combinations which involves wind load (or earthquake load) and take into account the full permissible stresses. Thus the modified design load combinations for loads involving wind load (or earthquake load) are:

1. 0.75(DL + IL + WL (or EQL))
2. 0.75 (DL + WL)
3. 0.75 (0.9DL + EQL)

Effective Height of Walls

It is the height of wall or column which is required for computing the slenderness ratio.

Table: *Effective height of wall*

S.No.	Condition of Supports	Effective Height
1.	Lateral as well as rotational restraint (that is, full restraint) at top and bottom. For example, when the floor/roof spans on the walls so that reaction to load of floor/roof is provided by the walls, or when an RCC floor/roof has bearing on the wall (minimum 9 cm), irrespective of the direction of the span (foundation footings of a wall give lateral as well as rotational restraint).	0.75 H
2.	Lateral as well as rotational restraint (that is, full restraint) at one end and only lateral restraint (that is, partial restraint) at the other. For example, RCC floor/roof at one end spanning or adequately bearing on the wall and timber floor/roof not spanning on wall, but adequately anchored to it, on the other end.	0.85 H
3.	Lateral restraint, without rotational restraint (that is, partial restraint) on both ends. For example, timber floor/roof, not spanning on the wall but adequately anchored to it on both ends the wall, that is, top and bottom.	1.00 H
4.	Laterai restraint as well as rotational restraint (that is, full restraint) at bottom but have no restraint at the top. For example, parapet walls with RCC roof having adequate bearing on the lower wall, or a compound wall with proper foundation on the soil.	1.50 H

Where,

H = Height of wall between centres of support in case of RCC slabs and timber floors.

In case of footings or foundation block, height (H) is measured from top of footing or foundation block.

In case of roof truss, height (H) is measured up to bottom of the tie beam.

In case of beam and slab construction, height (H) should be measured from centre of bottom slab to centre of top beam.

Effective Height of Masonry between the Openings

When openings occur in a wall such that masonry between the openings is by definition a column shall be reckoned as follows:

(a) When wall has full restraint at the top:

1. Effective height for the direction perpendicular to the plane of the wall equals 0.75 H plus 0.25 H_1, where H is the distance between supports and H_1 is the height of the tallest openings; and
2. Effective height for the direction parallel to the wall equals H, that is, the distance between the supports.

(b) When wall has partial restraint at the top:

1. Effective height for the direction perpendicular to plane of wall equals H when height of neither opening exceeds 0.5 H and it is equal to 2 H when height of any opening exceeds 0.5 H; and
2. Effective height for the direction parallel to the plane of the wall equals 2 H.

Effective Length of Walls

The effective length of masonry wall is computed as per the table below:

Table: *Effective length of wall*

S.No.	Conditions of Support	Effective Length
1.	Where a wall is continuous and is supported by cross wall, and there is no opening within a distance of H/8 from the face of cross wall. or Where a wall is continuous and is supported by piers/buttresses.	0.8 L
2.	Where a wall is supported by a cross wall at one end and continuous with cross wall at other end. or Where a wall is supported by a pier/buttress at one end and continuous with pier/buttress at other end.	0.9 L
3.	Where a wall is supported at each end by cross wall or Where a wall is supported at each end by a pier/buttress.	1.0 L
4.	Where a wall is free at one end and continuous with a cross wall at the other end. or Where a wall is free at one end and continuous with a pier/buttress at the other end.	1.5 L
5.	Where a wall is free at one end and supported at the other end by a cross wall. or Where a wall is free at one end and supported at the other end by a pier/buttress.	2.0 L

Where,

$H \rightarrow$ Actual height of wall between centres of adequate lateral suppport

$L \rightarrow$ Length of wall from or between centres of cross wall, piers or buttresses

NOTE: In case there is an opening taller than 0.5 H in a wall, ends of the wall at the opening shall be considered as free.

APPENDIX B

Objective Brain Teasers

Q.1 In case of brick masonry
(a) mortar strength should be more than the brick strength
(b) mortar strength should be less than the brick strength
(c) mortar strength should be equal to the brick strength
(d) mortar strength and brick strength are not at all related to each other

Q.2 Consider the following statements:
1. Masonry containing rich cement mortar although is having good strength but is more prone to surface cracks.
2. Lime mortar has poor workability and also has high shrinkage.
3. Masonry with lime mortar has better resistance against rain penetration and is less prone to crack as compared to masonry with cement mortar.

Which of the above statements are true?
(a) 1 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

Q.3 It is required to protect the brick masonry walls and columns of a building from earthquake. For this, earthquake proofing is done by providing.
(a) less openings
(b) steel band at corners above windows below ceiling
(c) cross walls
(d) shear walls

Q.4 Mortar containing both lime and cement is called as
(a) cement mortar
(b) lime mortar
(c) light weight mortar
(d) gauged mortar

Q.5 The major drawback of lime mortar is that it
(a) does not set quickly
(b) swells
(c) is plastic
(d) is not durable

Q.6 Consider the following statements with respect to cement mortar is brick
1. In most of the cases, cracking in brick masonry is due to differential movement of structure.
2. Rich mix cement mortar is brick masonry makes the structure too rigid.
3. A small amount of hydrated lime in cement mortar reduces shrinkage cracks.

Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

Q.7 Consider the following statements:
1. Strength of brick masonry depends on type of mortar used.
2. Brick masonry with lime mortar gains full strength earlier than cement mortar masonry.
3. Mortar strength decides the strength of masonry.

Which of the above statement(s) is/are true?
(a) 1 and 3 (b) 1 only
(c) 1, 2 and 3 (d) 2 only

Q.8 As per IS code, the minimum wall thickness of any load bearing wall in case of public buildings should be less than
(a) $\frac{1}{2}$ brick (b) 2 brick
(c) $1\frac{1}{2}$ brick (d) 1 brick

Q.9 According to masonry code, the stiffening coefficient for walls stiffened by piers, buttresses or intersecting walls can be
(a) 0 to 1 (b) > 2
(c) 1 to 2 (d) equal to 1

Q.10 If effective length, effective height and effective thickness of a masonry wall are l, h and t respectively, then slenderness ratio of wall should be
(a) Larger of $\frac{l}{t}$ and $\frac{h}{t}$
(b) Smaller of $\frac{l}{t}$ and $\frac{h}{t}$
(c) $\frac{l}{h}$
(d) $\frac{h}{t}$

Answers

1. (c)	2. (a)	3 (b)	4. (d)	5. (a)
6. (b)	7. (a)	8. (d)	9. (c)	10. (b)