CHAPTER 5 – EARTHQUAKE RESISTANT DESIGN REQUIREMENTS FOR MASONRY BUILDINGS

5.1. SCOPE

Dimensioning and reinforcing of masonry buildings and building-like structures to be constructed in seismic zones with load-bearing walls of natural or artificial materials, to resist both vertical and lateral loads shall be performed, along with currently enforced relevant standards and codes, primarily in accordance with the requirements of this chapter. Requirements for masonry building foundations are given in **Chapter 6**.

5.2. GENERAL RULES

5.2.1 – Sliding stress on the walls of building which is generated by seismic loads defined by taking $S\,(T_1) = 2.5$ and $R_a\,(T_1) = 2.5$ according to **Chapter 2**, shall be calculated and it shall be provided not to exceed permitted limit values.

5.2.2 – With the exception of the case given in **5.6.2** below, number of stories permitted for masonry buildings is given in **Table 5.1** depending on seismic zones.

TABLE 10.1 – MAXIMUM NUMBER OF STORIES PERMITTED

Seismic Zone	*Maximum number of Stories*
1	2
2, 3	3
4	4

5.2.3 – Maximum number of stories given in **Table 5.1** correspond to ground storey plus the upper stories. Area of a penthouse built in addition to those stories can not exceed 25 % of gross area of building at foundation level. The penthouse whose storey area is more than 25 % of gross area of the building shall be deemed to be a full storey. In addition, a single basement may be built. In the case where more than a single basement is constructed, maximum number of stories given in **Table 5.1** shall be reduced by one. In all seismic zones, masonry buildings with adobe walls can be constructed utmost single storey without considering basement.

5.2.4 – Storey height of masonry buildings shall be utmost 3.0 m from one floor top level to the other. In masonry buildings with adobe walls, storey height can not be more than 2.70 m and basement height can not be more than 2.40 m if it exists.

5.2.5 – Load-bearing walls of masonry buildings shall be arranged in plan, as much as possible, regularly and symmetric or nearly symmetric with respect to the main axes. Construction of partial basement shall be avoided.

5.2.6 - In plan, load-bearing walls shall be constructed so as to be placed one over the other.

5.3. ANALYSIS OF STRESS OF MASONRY WALLS

It shall be indicated that pressure and sliding stresses to be developed under the effect of vertical loads and seismic analysis loads to be calculated by the method given in this section do not exceed pressure and sliding stresses permitted according to type of masonry wall used in walls. If the stresses are exceeded, a new calculation shall be made by increasing structural solid wall areas. Calculation of stress shall not be made for masonry buildings with adobe walls.

5.3.1.1 – Because shear strength of walls is dependent on vertical stresses existing on the walls, it is required to calculate stress of walls of masonry buildings under vertical loads.

5.3.1.2 – Comparison of pressure stresses generated on walls with stresses permitted according to type of masonry wall shall be carried out. Loads coming from walls and floorings shall be taken into account in this analysis. The stress to be derived by dividing into cross section of the wall reduced as the cross sections of door and window spaces on the wall shall not be more than the pressure stress permitted according to type of the wall.

5.3.2 – Pressure Safety Stress on Walls

This stress can be calculated by various methods given below:

(a) 0.25 of wall strength calculated by pressure strength tests for wall particles made at equal strength as the pressure strength of masonnary unit and mortar to be used in construction of wall is the pressure safety stress.

(b) Wall safety stress can be taken from **Table 5.2** depending on the mortar class used in walls and the average free pressure strength of wall material given in TS – 2510.

(c) If strength test of wall particles is not made, 0.50 of free pressure strength obtained experientially for the block used in wall is pressure strength of wall f_d and 0.25 of this strength is the pressure safety stress f_{em} of wall.

(d) If pressure strength of masonnary unit used in wall is not given or strength test of wall is not made pressure strength stress for masonnary unit used in wall shall be taken from **Table 5.3**.

5.3.2.1 – Pressure strengths of masonnary units and mortar used in wall shall be determined by tests applied in accordance with concerned standards.

5.3.2.2 – Pressure strength stresses for walls shall be reduced by quantities given in **Table 5.4** according to slenderness rates of walls.

TABLE 5.2 – PRESSURE SAFETY STRESSES FOR WALLS DEPENDING ON MORTAR CLASS AND FREE PRESSURE STRENGTH OF WALL MATERIAL

Average Free Pressure Strength of Wall Material (MPa)	Mortar Class Used in the Wall (MPa)				
	A (15)	B (11)	C (5)	D (2)	E (0.5)
25	1.8	1.4	1.2	1.0	0.8
16	1.4	1.2	1.0	0.8	0.7
11	1.0	0.9	0.8	0.7	0.6
7	0.8	0.7	0.7	0.6	0.5
5	0.6	0.5	0.5	0.4	0.4

TABLE 5.3 – PRESSURE SAFETY STRESSES OF WALLS IN WHICH FREE PRESSURE STRENGTH IS UNKNOWN

Type of Masonnary Unit and Mortar Used in the Wall	Pressure Safety Stress of Wall f_{em} (MPa)
Vertical hallow block brick (hallow rate is less than 35 %, with lime mortar supported with cement)	1.0
Vertical hallow block brick (hallow rate is in between 35 – 45 %, with lime mortar supported with cement)	0.8
Vertical hallow block brick (hallow rate is more than 45 %, with lime mortar supported with cement)	0.5
Filled block brick or clay brick (with lime mortar supported with cement)	0.8
Stone wall (with lime mortar supported with cement)	0.3
Gas concrete (with adhesive)	0.6
Filled concrete briquette (with cement mortar)	0.8

TABLE 5.4 – REDUCING COEFFICIENTS FOR SAFETY STRESSES ACCORDING TO SLENDERNESS RATE

Slenderness rate	6	8	10	12	14	16	18	20	22	24
Reducing coefficient	1.0	0.95	0.89	0.84	0.78	0.73	0.67	0.62	0.56	0.51

5.3.3. Calculation of Sliding Stress

Calculation of sliding stresses generated parallel to horizontal joints of walls by seismic design load shall be made as explained in this chapter.

5.3.3.1 – Relative sliding rigidity of solid wall parts rest among door or window spaces in each axis of masonry building shall be calculated by the expression $k\,A\,/\,h$. In here, A is horizontal cross section of solid wall part and h is the smallest of heights of spaces at both two sides of solid wall part. If cross section of the wall is rectangular k = 1.0, if the wall has an end element or there is a grinder or stay wall perpendicular to the wall on the edge of the wall k = 1.2 shall be taken.

5.3.3.2 – Sliding rigidity of a wall axis is the sum of sliding rigidities of wall parts on this axis. Center of sliding rigidity of building shall be calculated by using sliding rigidity of wall axes.

5.3.3.3 – Shear force on walls shall be calculated in the direction of both orthogonal axes of the building by considering storey torsion moment as well as storey shear force.

5.3.3.4 – Sliding stress developed on the wall shall be calculated by dividing seismic force on the wall into horizontal cross section area of the wall and it shall be compared with sliding safety stress of wall τ_{em}.

$$\tau_{em} = \tau_o + \mu\sigma \qquad \textbf{(5.1)}$$

In this equation τ_{em} = sliding safety stress of wall (MPa), τ_o = cracking safety stress of wall (MPa), μ = coefficient of friction (it can be taken as 0.5) and σ is vertical wall stress (MPa). Cracking safety stress of wall, $\tau_{o,}$ shall be taken from **Table 5.5** according to type of masonnary unit used in the wall.

TABLE 5.5 – CRACKING SAFETY STRESS OF WALLS

Type of Masonnary Unit and Mortar Used in the Wall	Cracking Safety Stress of Wall τ_o (MPa)
Vertical hallow block brick (hallow rate is less than 35 %, with lime mortar supported with cement)	0.25
Vertical hallow block brick (hallow rate is more than 35 %, with lime mortar supported with cement)	0.12
Solid block brick or clay brick (with lime mortar supported with cement)	0.15
Stone wall (with lime mortar supported with cement)	0.10
Gas concrete (with adhesive)	0.15
Solid concrete briquette (with cement mortar)	0.20

5.3.4. Elasticity Module

Elasticity Module (E_d) of masonnary units used in wall construction shall be calculated by **Equation (5.2)**.

$$E_d = 200\, f_d \qquad \textbf{(5.2)}$$

5.4. LOAD – BEARING WALLS

5.4.1. Materials of Load – Bearing Walls

5.4.1.1 – Natural stone, solid brick, bricks and block bricks with hole ratios which are not exceeded the maximum void ratios permitted in TS – 2510 and TS EN 771 – 1 as material of load – bearing walls, structural materials and elements of gas concrete, lime sandstone, solid concrete blocks, adobe or similar masonnary units may be used as masonry materials in the construction of load – bearing walls in accordance with Turkish Standards.

5.4.1.2 – Concrete blocks with holes, light aggregated concrete masonnary units, bricks and block bricks with hole ratios which are exceeded the maximum void ratios permitted in TS – 2510 and TS – 705 (TS EN 771 – 1) as material of load – bearing walls, other bricks manufactured for infill walls in accordance with TS - 4377 and similarly formed blocks shall never be used as load-bearing wall material.

5.4.1.3 – Natural stone load-bearing walls shall be used only in the basement and ground stories of masonry buildings.

5.4.1.4 – Concrete load-bearing walls shall be used only in the basements of masonry buildings.

5.4.2. Strength of Wall Materials

5.4.2.1 – Strength and other specialties of natural and artificial masonnary units used in construction of walls and of mortars connecting those shall be as follows. These conditions are not valid for adobe. Adobe can only be used in adobe buildings.

5.4.4.2 – According to gross pressure area, minimum pressure strength of natural and artificial masonnary units to be used in load – bearing walls shall be 5.0 MPa at least. Pressure strength of natural stones to be used in basement stories shall be 10.0 MPa at least. In the case where concrete walls are constructed in basements, minimum quality of concrete to be used shall be C16.

5.4.2.3 – Lime mortar supported with cement (cement / lime / sand volumetric ratio = 1 / 2 /9) or cement mortar (cement/sand volumetric ratio = 1 / 4) shall be used in load – bearing walls or cement mortar.

5.4.2.4 – Pressure safety stress of walls (f_{em}) shall be calculated by using one of the methods given in **5.3.2**.

5.4.2.5 – Sliding safety stress of walls shall be calculated according to **Equation (5.1)**.

5.4.3. Minimum Thickness of Load-Bearing Walls

The minimum thicknesses of load-bearing walls, excluding plaster thicknesses, are given in **Table 5.6** depending on the number of stories in masonry building. In the case of no basement, minimum wall thicknesses given in the **Table 5.6** shall be valid for ground storey and upper stories. In penthouses permitted in accordance with **5.2.3**, wall thickness specified for the storey below shall be applied.

TABLE 5.6 – MINIMUM THICKNESSES OF LOAD – BEARING WALLS

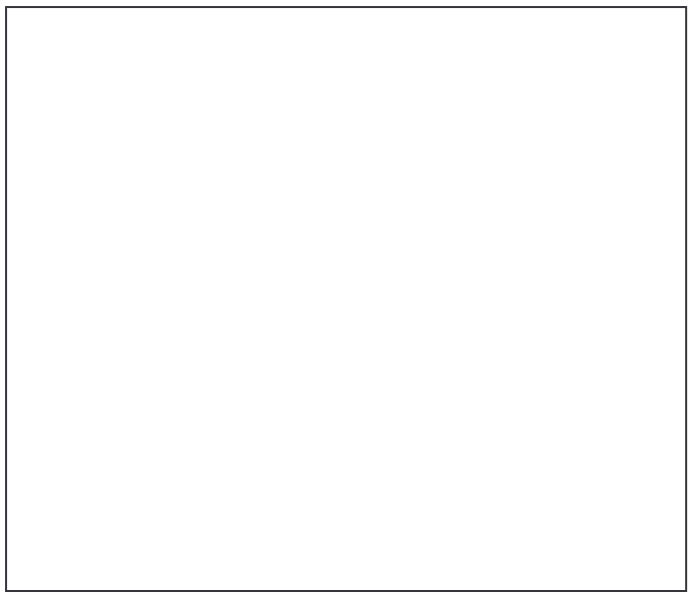
Seismic Zone	Permitted Stories	Natural Stone (mm)	Concrete (mm)	Brick and Gas concrete	Others (mm)
1, 2, 3 and 4	Basement storey	500	250	1	200
	Ground storey	500	-	1	200
1, 2, 3 and 4	Basement storey	500	250	1.5	300
	Ground storey	500	-	1	200
	First storey	-	-	1	200
2, 3 and 4	Basement storey	500	250	1.5	300
	Ground storey	500	-	1.5	300
	First storey	-	-	1	200
	Second storey	-	-	1	200
4	Basement storey	500	250	1.5	300
	Ground storey	500	-	1.5	300
	First storey	-	-	1.5	300
	Second storey	-	-	1	200
	Third storey	-	-	1	200

5.4.3.1 – In buildings with adobe walls, external load – bearing walls shall be at least 1.5 brick size, whereas internal adobe load-bearing walls shall be at least 1 brick size. Nominal adobe brick dimensions to be used in load – bearing walls shall be 120 x 300 x 400 (main) and 120 x 190 x 400 (lamb) or 120 x 250 x 300 (main) and 120 x 180 x 300 (lamb) in mm's.

5.4.4. Total Length Limit for Load – Bearing Walls

The ratio of the total length of masonry load-bearing walls in each of the orthogonal directions in plan (excluding window and door openings), to gross floor area (excluding

cantilever floors) shall not be less than (0.2 *I*) m/m^2 where *I*, represents Building Importance Factor defined in **Chapter 2.**



ℓ_d: *Length of hatched area* (m)
A: *Gross floor area* (m^2)
I: *Building importance factor* (**Chapter 2**)

Figure 5.1

5.4.5. Maximum Unsupported Length of Load-Bearing Walls

5.4.5.1 – Unsupported length of any load-bearing wall between the load – bearing wall axes in the perpendicular direction in plan shall not exceed 5.5 m. in the first seismic zone and 7.5 m in other seismic zones. Maximum unsupported length of wall in masonry buildings with adobe walls shall be 4.5 m.

5.4.5.2 – In the case the condition given in **5.4.5.1** above is not satisfied, reinforced concrete vertical bond beams shall be constructed along the full storey height at the corners of building and in walls with axis to axis spacing in plan not more than 4.0 m. However unsupported length of such walls shall not be more than 16 m **(Figure 5.2)**.

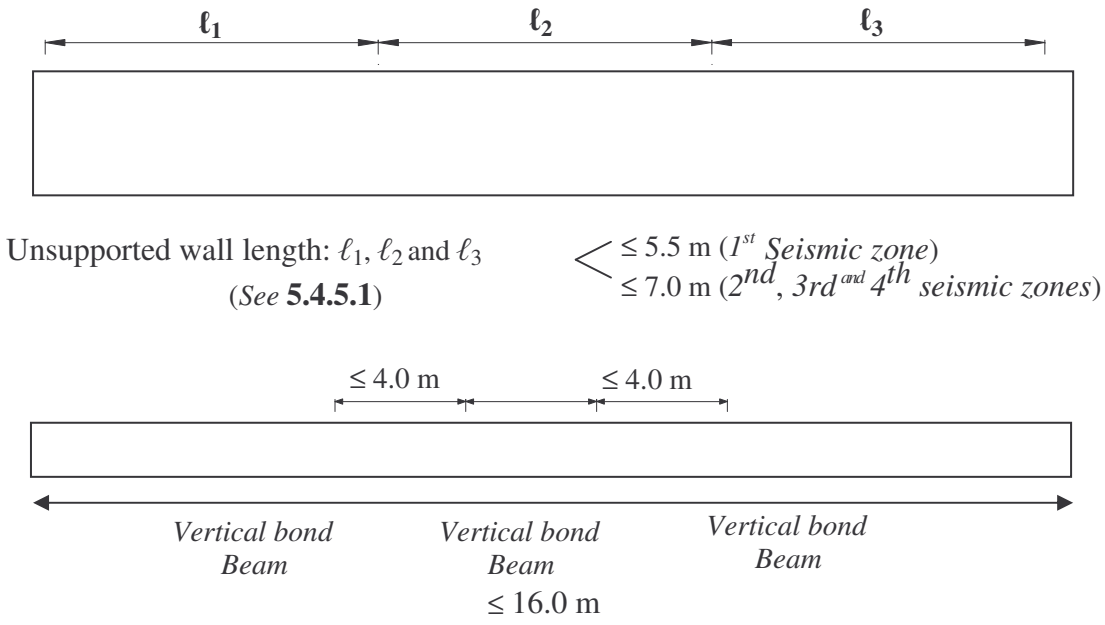


Figure 5.2

5.4.6. Openings in Load-Bearing Walls

The following rules shall be followed in openings to be provided in load – bearing walls **(Figure 5.3)**:

5.4.6.1 – Plan length of the solid wall segment to be set between the corner of a building and the nearest window or door opening to the corner shall not be less than 1.50 m in the first and second seismic zones and 1.0 m in the third and fourth seismic zones. This quantity shall be at least 1.0 m in buildings with adobe walls in all seismic zones.

5.4.6.2 – Excluding the corners of buildings, plan lengths of the solid wall segments between the window and door openings shall not be less than 1.0 m in the first and second seismic zones and 0.8 m in the third and fourth seismic zones. This quantity shall be at least 1.0 m in buildings with adobe walls in all seismic zones.

5.4.6.3 – In the case where reinforced concrete vertical bond beams according to **5.5.3** are made on both sides of the window and door openings, condition of minimum lengths of wall segments given in **5.4.6.1** and **5.4.6.**2 may be decreased by 20%. If two timber pillars with section of 0.10 m x 0.10 m are set on both two sides of the window and door openings, solid wall segment between two openings may be 0.80 m in buildings with adobe walls. These timber pillars shall be connected to the timber bond beams of window and door.

5.4.6.4 – Excluding the corners of buildings, plan length of a solid wall segment between intersection of the walls and the nearest window or door opening to the intersection of the orthogonal walls shall not be less than 0.50 m in the all seismic zones. In case where reinforced concrete vertical bond beams according to **5.5.3** are exist on both sides of the openings along the height of the storey solid wall segment may be less than 0.50 m
.

5.4.6.5 – Plan length of each window or door opening shall not be more than 3.0 m. In buildings with adobe walls, door openings shall not be more than 1.0 m in horizontal axis and 1.90 m in vertical axis; window openings shall not be more than 0.90 m in horizontal axis and 1.20 m in vertical axis.

5.4.6.6 – Total plan lengths of window or door openings along the unsupported length of any wall defined in **5.4.5** shall not be more than 40% of the unsupported wall length.

5.4.6.7 – In the case where reinforced concrete vertical bond beams according to **5.5.3** are made on both sides of the window or door openings, the maximum length of openings defined in **5.4.6.6** and the maximum ratio of openings defined in **5.4.6.5** may be increased by 20%. This condition is not valid for buildings with adobe walls.

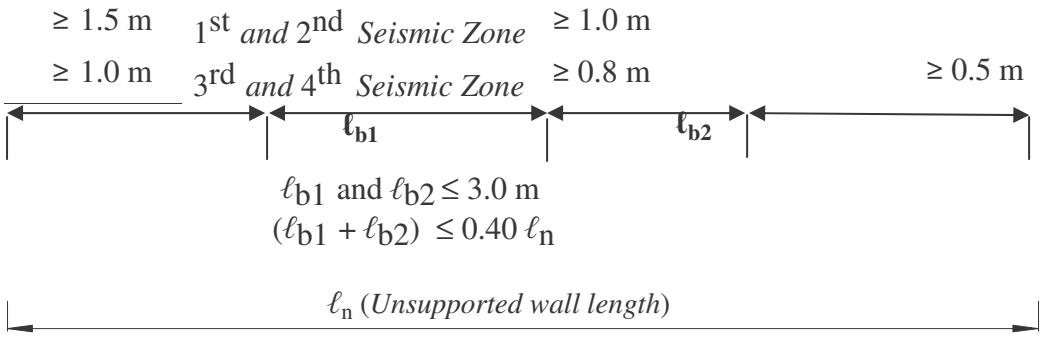


Figure 5.3

5.5. LINTELS AND BOND BEAMS

5.5.1. Lintels

5.5.1.1 – Each of seating lengths of window and door lintels on the walls shall not be less than 15% of lintel clear span and less than 200 mm.

5.5.1.2 – Cross sections dimensions of lintels as well as longitudinal transverse reinforcement shall not be less than the values given in **5.5.2.1** for horizontal bond beams.

5.5.1.3 – Timber lintel may be set over and under the window and door in buildings with adobe walls. Timber lintels shall be made with two square timbers with section of 100 mm x 100 mm. Each of seating lengths of timber lintels on the walls shall not be less than 200 mm.

5.5.2. Horizontal Bond Beams

5.5.2.1 – Reinforced concrete horizontal bond beams satisfying the following conditions shall be made at places where each of the slabs, including stair landings, is supported by structural walls such that they shall be cast (monolithically) with the reinforced concrete slabs.

(a) Width of horizontal bond beams shall be equal to the width of wall, and their height shall not be less than 200 mm.

(b) Concrete quality for bond beams shall be at least C 16, Ø 8 hoops with a maximum spacing of 250 mm shall be set with together longitudinal reinforcement at least 6Ø10 on stone walls with three at the bottom and three at the top, and at least 4 Ø10 on other load – bearing walls. Longitudinal rebars shall be appropriately overlapped at the corners and intersections to achieve continuity **(Figure 5.4)**.

5.5.2.2 – In rubble stone walls, reinforced concrete bond beams shall be made excluding the slab and stair landing levels in accordance with the rules given in **5.5.2.1** with vertical axis to axis spacing not more than 1.5 m.

5.5.2.3 – Timber bond beams may be made in adobe masonry walls. Timber bond beams shall be tar emulsified two elements of square sections of 10 cm x 10 cm which are to be placed with outer faces coinciding with the exterior and interior wall surfaces. These pieces shall be tied each other at every 50 cm with nail jointed timber elements of cross section of 5 cm x 10 cm and holes in between shall be filled with stone aggregate.

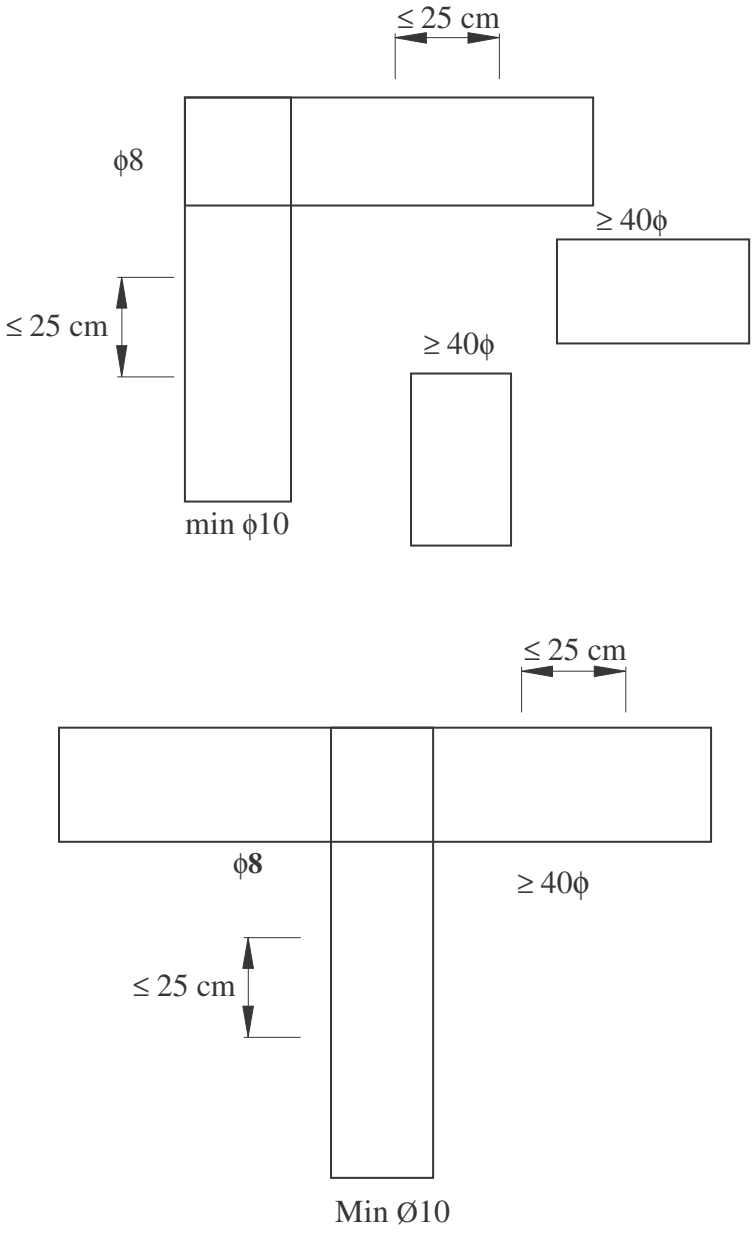


Figure 5.4

5.5.3. Vertical Bond Beams

5.5.3.1 – In order to enhance the earthquake resistance of masonry buildings, it shall be appropriate to construct reinforced concrete vertical bond beams in full storey height on the corners of buildings, along the vertical intersections of the load – bearing walls and on both sides of the door and window openings.

5.5.3.2 – Vertical bond beams shall be constructed by reinforcing and concreting the section in between the formworks to be placed parallel to the walls, following the construction of load – bearing walls on both sides **(Figure 5.5)**.

5.5.3.3 – Cross section dimensions of vertical bond beams shall be equal to thicknesses of walls intersecting at corners of the buildings and at the intersections of the load – bearing walls. In vertical bond beams to be constructed on both sides of window and door openings, cross section dimensions of the bond beam perpendicular to the wall shall not be less than the wall thickness, whereas the other cross section dimension shall not be less than 200 mm.

5.5.3.4 – Concrete quality for vertical bond beams shall be at least C16, Ø8 hoops with a maximum spacing of 200 mm shall be set with together longitudinal reinforcement at least 6Ø12 on stone walls with three parallel to both wall faces and at least 4Ø12 on other load – bearing walls. Longitudinal starter bars shall be provided at the foundation and at the intermediate floors for longitudinal rebars **(Figure 5.5)**.

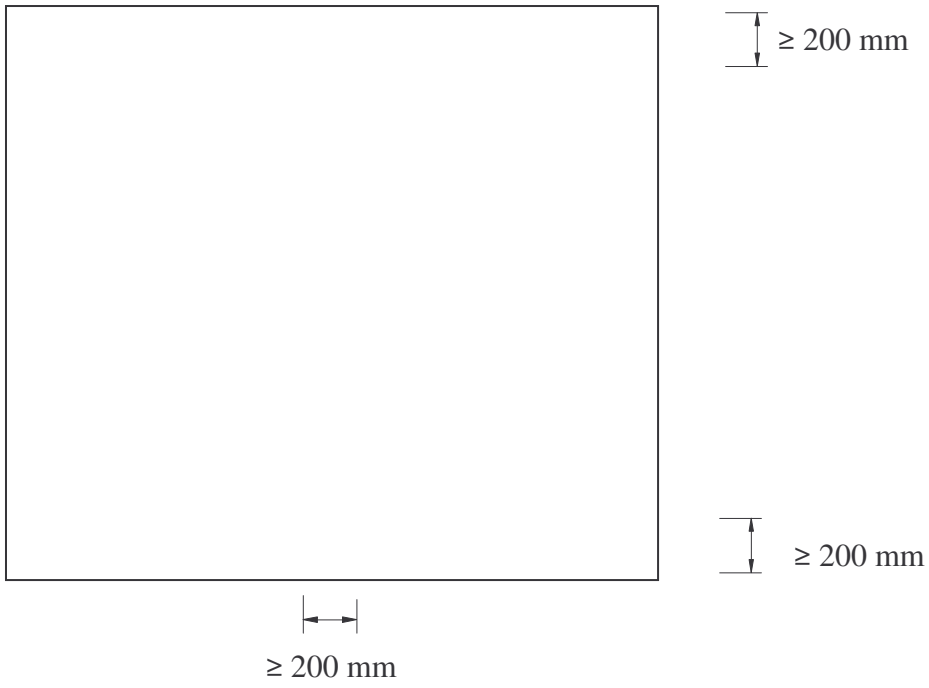


Figure 5.5

5.6 SLABS

5.6.1 – Floor slabs of masonry buildings shall be reinforced concrete plate slabs or joist floors whose dimensions and reinforcements are designed in accordance with the requirements of TS-500.

5.6.2 – Masonry buildings with slabs other than those defined in **5.6.1** above, shall be constructed in all seismic zones with maximum two stories excluding the basement, if any. In such buildings, horizontal bond beams supporting the slabs shall also be constructed in accordance with **5.5.2**. Buildings with adobe walls shall be constructed with maximum one storey excluding basement.

5.6.3 – Cantilever elements such as balconies, cornices and eaves of roofs shall be made only as an extension of floor slabs and the clear cantilever length shall not be more than 1.5 m. Clear cantilever length of cantilevered stairs shall be at most 1.0 m. This condition is not valid for buildings with adobe walls.

5.7. ROOFS

5.7.1 – Roofs of the masonry buildings may be constructed as reinforced concrete terrace roof, timber or steel truss roof bearing on roof slab.

5.7.2 – Connections of the timber roof elements to the roof slabs or to horizontal bond beams on load – bearing walls shall be made in accordance with the rules given in TS – 2510.

5.7.3 – In the case where the height of the end wall resting on the horizontal bond beam at the top storey exceeds 2.0 m, vertical and inclined bond beams shall be constructed (**Figure 5.6**).

5.7.4 – Roofs of the buildings with adobe walls shall be constructed in a way not to exceed external walls at most 500 mm and to be as light as possible. Soil roof shall not be made in first and second seismic zones. Soil cover thickness of soil roof shall not be more than 150 mm in third and fourth seismic zones. Roofs of adobe buildings may be constructed as timber spring or reinforced concrete plate.

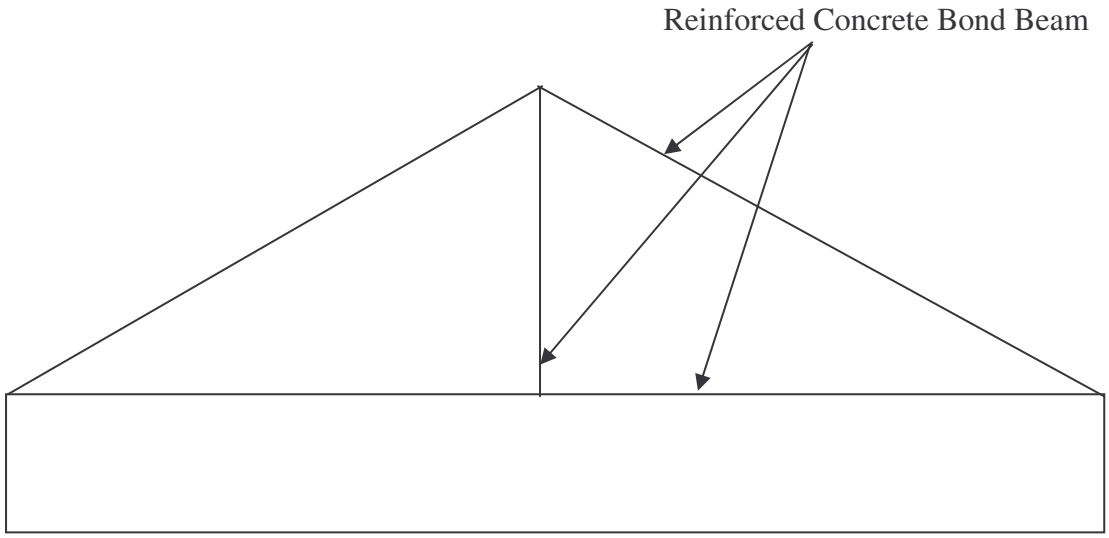


Figure 5.6

5.8. NON – BEARING WALLS

5.8.1 – Thickness of non-bearing partition walls shall be at least 100 mm. Such walls shall be constructed by connecting to load – bearing walls on both edges along the vertical intersection. At least 10 mm gap shall be allowed between the top of the non – bearing walls and floor bottom of the top slab, however required measures shall be taken in order to prevent the toppling of wall out – of – plane by the effect of seismic loads perpendicular to its plane.

5.8.2 – Height of parapets on terraces made of masonry wall material shall not be more than 600 mm. Required measures shall be taken in order to prevent toppling of such parapets under the seismic loads.

5.8.3 – Height of garden walls made of masonry wall material shall not be more than 1.0 m from the pavement level.