NEPAL NATIONAL BUILDING CODE

NBC 201 : 1994

MANDATORY RULES OF THUMB
REINFORCED CONCRETE BUILDINGS
WITH MASONRY INFILL

His Majesty's Government of Nepal
Ministry of Physical Planning and Works
Department of Urban Development and Building Construction
Babar Mahal, Kathmandu, NEPAL
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This publication represents a standard of good practice and therefore takes the form of recommendations. Compliance with it does not confer immunity from relevant legal requirements, including bylaws

श्री ५ को सरकार (मन्त्रिपरिषद्) को मिति २०६०।४।१२ को निर्णयानुसार स्वीकृत

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Preface

This Nepal Standard was prepared during 1993 as part of a project to prepare a draft National Building Code for Nepal.

In 1988 the Ministry of Housing and Physical Planning (MHPP), conscious of the growing needs of Nepal's urban and shelter sectors, requested technical assistance from the United Nations Development Programme and their executing agency, United Nations Centre for Human Settlements (UNCHS).

A programme of Policy and Technical Support was set up within the Ministry (UNDP Project NEP/88/054) and a number of activities have been undertaken within this framework.

The 1988 earthquake in Nepal, and the resulting deaths and damage to both housing and schools, again drew attention to the need for changes and improvement in current building construction and design methods.

Until now, Nepal has not had any regulations or documents of its own setting out either requirements or good practice for achieving satisfactory strength in buildings.

In late 1991 the MHPP and UNCHS requested proposals for the development of such regulations and documents from international organisations in response to terms of reference prepared by a panel of experts.

This document has been prepared by the subcontractor's team working within the Department of Building, the team including members of the Department and the MHPP. As part of the proposed management and implementation strategy, it has been prepared so as to conform with the general presentation requirements of the Nepal Bureau of Standards and Metrology.

The subproject has been undertaken under the aegis of an Advisory Panel to the MHPP.

The Advisory Panel consisted of :

Mr. UB Malla, Joint Secretary, MHPP	Chairman
Director General, Department of Building (Mr. LR Upadhyay)	Member
Mr. AR Pant, Under Secretary, MHPP	Member
Director General, Department of Mines & Geology (Mr. PL Shrestha)	Member
Director General, Nepal Bureau of Standards & Metrology (Mr. PB Manandhar)	Member
Dean, Institute of Engineering, Tribhuvan University (Dr. SB Mathe)	Member
Project Chief, Earthquake Areas Rehabilitation & Reconstruction Project	Member
President, Nepal Engineers Association	Member
Law Officer, MHPP (Mr. RB Dange)	Member
Representative, Society of Consulting Architectural & Engineering Firms (SCAEF)	Member

Representative, Society of Nepalese Architects (SONA) Member
Deputy Director General, Department of Building,
(Mr. JP Pradhan) Member-Secretary

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SILT Consultants P. Ltd., Nepal
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0. Foreword

0.1 Introduction

For the last 15 to 20 years there has been a proliferation of reinforced concrete (RC) framed buildings constructed in the urban and semi-urban areas of Nepal. Most of these buildings have been built on the advice of mid-level technicians and masons without any professional structural design input. These buildings have been found to be significantly vulnerable to a level of earthquake shaking that has a reasonable chance of happening in Nepal. Hence, these buildings, even though built with modern materials, could be a major cause of loss of life in future earthquakes. Upgrading the structural quality of future buildings of this type is essential in order to minimise the possible loss of life due to their structural failure.

0.2 Objective

The main objective of these Mandatory Rules of Thumb (MRT) is to provide ready-to-use dimensions and details for various structural and non-structural elements for up to three-storey reinforced concrete (RC), framed, ordinary residential buildings commonly being built by owner-builders in Nepal using brick infill walls. The practice of using such walls is predominant, but they are treated as non-structural (and hence not accounted for) in the design of the frames. However, when such buildings have horizontal forces imposed on them (eg., from an earthquake), these infill walls cause the building to respond in an unpredictable manner which has not been considered by the designer. This is due to their contribution to overturning, soft-storey effects, short-column effects, etc. The infill walls could also contribute passively by sharing some of the lateral loads. However, it is anticipated that the present practice of placing such walls randomly will have more negative consequences than positive ones. Hence, the objective of this MRT is to ensure the proper placement of such walls in order to derive positive effects only and to achieve economy. Compliance with the MRT will lead to the present non-engineered construction being superseded by pre-engineered designs which should achieve acceptable minimum seismic safety requirements (such as those specified by NBC 105 and IS 1893-1884 etc.).

This MRT is intended to cater primarily to the requirements of mid-level technicians (overseers and draughtspersons) who are not trained to undertake independently the structural design of buildings. However, civil engineers could also use this document for effective utilisation of their time by using the design procedures outlined here.

0.3 Limitations

The requirements set forth in this standard shall be applicable only for buildings complying with the specified limitations. The intention is to achieve a minimum acceptable structural safety, even though it is always preferable to undertake specific investigations and design. Owners and builders are, however, encouraged to use the services of competent professional designers for better economy and tailor-made detailing. In such cases, the requirements stated here could be construed as advisory.

0.4 Alternative Materials and Construction

The provisions of this standard are not intended to prevent the use of alternative materials and methods of construction if such materials and methods are specifically prescribed by competent professional designers or other competent authorities equivalent to, or better than, those specified here.

0.5 What is a Pre-Engineered Building ?

A pre-engineered building is one which uses the sizes and detailing of structural and non-structural elements, including the amounts of reinforcement, which have been pre-established using standard design procedures for a given condition. All buildings constructed by following the requirements of this MRT could, in future, be called pre-engineered buildings.

1 Scope

1.1 General

1.1.1 This MRT addresses the particular requirements of those RC-framed buildings which have become very common with owner-builders, who even undertake the construction of this type of building without employing professional designers. However, the users of this MRT are required to comply with certain restrictions with respect to building configuration, layout and overall height and size.

1.1.2 The MRT is intended for buildings of the regular column-beam type with reinforced concrete slabs for floors and the roof. The walls are assumed to be of burnt bricks, or hollow concrete or other rectangular blocks whose density will not exceed that of burnt bricks. Here, all the calculations are based on solid clay burnt bricks. These can be replaced by the above-described blocks. The buildings have to comply with the limitations listed in Clause 4.2.

1.1.3 The MRT presents ready-to-use designs for all structural components, including detailing of structural as well as non-structural members, for infill framed buildings for :

a) two infill walls each way per 100 m^2 of column plan area and

b) two infill walls each way per 60 m^2 of column plan area.

1.1.4 Design guidelines presented in the MRT are for ordinary residential buildings with the seismic coefficient of 0.128 (equivalent to seismic **Zone C, (Figure 1.1).** However, if a building in all other respects complied with this MRT were to be constructed in higher seismic zone, it would be expected to have a better earthquake resistance than that of a similar non-engineered construction undertaken solely with the advice of craftsmen.

1.1.5 The building could, of course, be alternatively designed using the usual design standards for engineered structures. The design procedures here are simplified in order both to save design time and to help owner-builders to adopt the recommended design and details so that they will achieve earthquake-resistant structures.

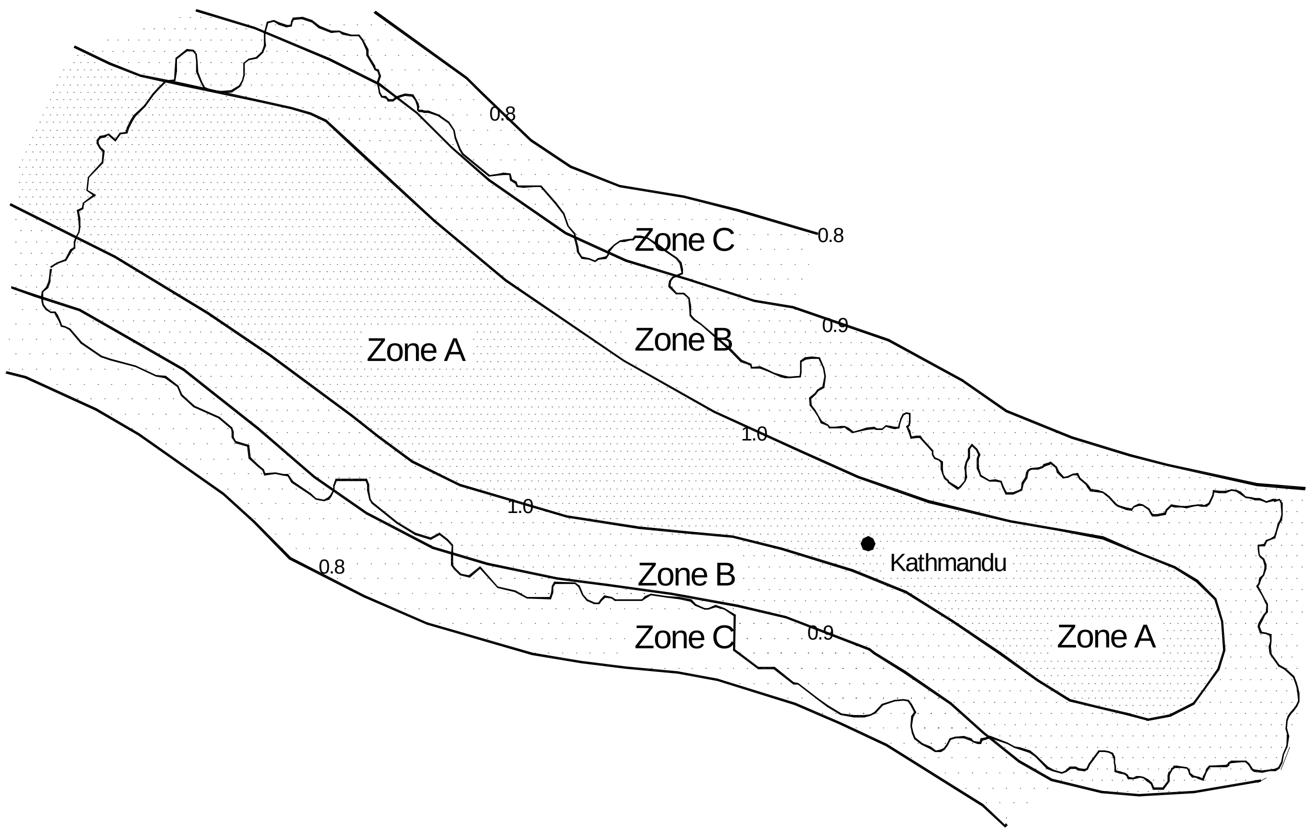


Figure 1.1 : Seismic Zoning Map of Nepal for this MRT

1.2 Related Standards

The requirements of this MRT are based on the following standards and documents. Compliance with this MRT will, therefore, result in compliance with these Standards :

i) NBC 110 : (Draft Nepal Standard for Plain and Reinforced Concrete).

ii) S.P. 16-1980 : Design Aids for Reinforced Concrete to IS: 456-1978.

iii) NBC 102/NBC 103 : (Draft Nepal Standard for Design Loads).

iv) NBC 105 : (Draft Nepal Seismic Design Standard)

v) IS : DOC : CED39 (5263) Guideline for Ductile Detailing of Reinforced Concrete Structure subjected to Seismic Forces (under printing).

2 Interpretation

2.1 General

2.1.1 In this MRT, the word `shall' indicates a requirement that is to be adopted in order to comply with the provision of this documents, while the word `should' indicates recommended practice.

2.1.2 References to `Code' indicate the draft standard for Seismic Design of Buildings in Nepal (NBC 105).

2.1.3 Words implying the singular only also include the plural and vice versa where the context requires this.

2.2 Terminology

In this Standard, unless inconsistent with the context, the following definitions shall apply :

ADDITIONAL BARS means the longitudinal bars that shall be provided in addition to regular bars at supports as top bars and at mid-span as bottom bars of a beam.

FREE-SPANNING BEAM means any beam that does not frame a structural wall.

BEAMS ABUTTING INFILL WALLS means those beams that abut structural walls.

CHAIR means an element made of steel bar which is used to maintain the vertical distances between top and bottom bars in slabs.

COLUMN PLAN AREA means the area enclosed by perimeter columns in a structure.

DEAD LOAD means the weight of all permanent components of a building, including walls, partitions, columns, floors, roofs, finishes and fixed plant and fittings that are an integral part of the structure.

DESIGN means the use of rational computational or experimental methods in accordance with the established principles of structural mechanics.

DIAPHRAGM means a member composed of a web (such as a floor or roof slab), or a truss which distributes forces to the horizontal load-resisting system.

DUCTILITY means the ability of the building or member to undergo repeated and reversing inelastic deflection beyond the point of first yield while maintaining a substantial proportion of its initial maximum load-carrying capacity.

FRAME means a system composed of interconnected members functioning as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.

HORIZONTAL LOAD-RESISTING SYSTEM means that part of the structural system to which the horizontal loads prescribed by this Standard are assigned.

IMPORTANT BUILDINGS means those buildings which either house facilities essential before and after a disaster (eg., hospitals, fire and police stations, communication centres, etc.), or which by their very purpose have to house large numbers of people at one time (eg., cinema halls, schools, convention centres, etc.), or which have special national and international importance (eg., palaces, etc.), or which house hazardous facilities (eg., toxic or explosive facilities, etc.).

INSIGNIFICANT OPENING means any opening outside the middle two-thirds of an infill panel, but which is not in any circumstances in the restricted zone that forms the diagonal compression strut. The opening should not be more than 10 % of the wall area.

LANDSLIDE means the downward and outward movement of slope-forming materials.

LIQUEFACTION means the phenomenon in which relatively loose, saturated sandy soils lose a large proportion of their strength under seismic shaking.

LEVEL OF LOCAL RESTRAINT means the level at which the ground motion of the earthquake is transmitted to the structure by interaction between the foundation materials and the foundation elements by friction and bearing.

LIVE LOAD means the load assumed or known to result from the occupancy or use of a building and includes the loads on floors, loads on roofs other than wind, loads on balustrades and loads from movable goods, machinery, and plant that are not an integral part of the structure and may be changed during the life of the building with a resultant change in floor or roof loading.

LUMPED MASS means the theoretical concentration of the mass of adjacent upper and lower half storeys at any floor level.

MASONRY INFILL WALL means any structural wall constructed in brick with cement sand mortar inside the frame and intended to carry horizontal load by equivalent compression strut action.

NON-LOAD BEARING WALL means any wall which is not intended to carry any significant external loads and which functions just as a cladding, partition wall or filler wall.

ORDINARY BUILDING means any building which is not an important building (eg., residential, general commercial, ordinary offices, etc.).

REGULAR BARS means the bars that shall run continually parallel to the walls of a beam to form a cage. The minimum number of regular bars in a beam is four.

RESTRICTED ZONE FOR OPENING means the zone at the corner of a panel bounded by the outer one-third of the panel dimension in a structural wall.

SHORT COLUMN means a column whose effective length is reduced due to sandwiching effect of a window sill wall spanning between two adjacent columns. The column effectively spans between the lintel and the sill level.

SIGNIFICANT OPENING means any opening inside the middle two-thirds of a wall panel but not inside the restricted zone in the infill wall.

STOREY means the space between two adjacent floors or platform.

2.3 Symbols

A	Maximum horizontal length of building
A_s	Area of steel bar
B	Maximum horizontal width of building
C_d	Design seismic coefficient
C_M	Centre of mass
C_R	Centre of rigidity
E_b	Modulus of elasticity of brick masonry
E_p	Modulus of elasticity of plaster
F_i	Horizontal seismic force applied at a level designated as *i*.
f_{ck}	Characteristic compressive strength of concrete
f_y	Characteristic yield strength of steel
H_i	Height of the i^{th} storey
h_i	Height of the level *i* above the lateral restraint imposed by the ground
I_i	Column moment of inertia in the plane of consideration at level *i*
K	Steel bars having f_y=550 N/mm² (steel grade Fe550)
K_1,K_2	Plan length of structural wings
l	Centre-to-centre span of beam
M	Steel bars having f_y=250 N/mm² (steel grade Fe250, mild steel bars)
T	Steel bars having f_y=415 N/mm² (steel grade Fe415)
t_e	Thickness at the edge of the foundation pad
t_{ei}	Effective wall thickness including plaster stiffness at level *i*
t_i	Thickness of infill wall
t_m	Maximum thickness of the pad foundation
t_{pi}	Total thickness of plaster acting with the wall at level *i*

V	Total horizontal seismic base shear
V_{ij}	Horizontal load carried by a wall j at level i
W_i	Proportion of the W_t at a particulars level i
W_t	Total of the vertical dead loads and appropriate live load above the level of lateral restraint provided by the ground
x	Distance of the particular wall resisting lateral load along Y-axis
X_m	Distance of mass centre along X-axis
X_r	Distance for centre of rigidity along X-axis
y	Distance of the particular wall resisting lateral load along Y-axis
Y_k	Distance for centre of rigidity along Y-axis additional bars;
Y_m	Distance of mass centre along Y-axis
Θ	Angle of compression strut from horizontal
ϕ	Diameter of steel bar

3 Selection and Investigation of Site

3.1 General

This section sets out some of the requirements to be considered during site selection for the construction of buildings in order to minimise the risks to the buildings from primary geological as well as secondary seismic hazards such as fault rupture, landslides and liquefaction. A building shall not be constructed if the proposed site is :

- Water-logged
- A rock-falling area
- A landslide-prone area
- A subsidence and/or fill area
- A river bed or swamp area

3.2 Use of Local Knowledge

It is a good practice during the construction of a building to examine the existing local knowledge and the history of the performance of existing buildings. This will assist in identifying whether there is any danger from inherent natural susceptibilities of the land to the processes of sliding, erosion, land subsidence and liquefaction during the past earthquakes or any other natural/geological processes likely to threaten the integrity of the building. The local practice of managing such hazards, if any, should be judged against the required level of acceptable risk.

3.3 Site Investigation Requirements

Site exploration shall be carried out by digging test pits, two as a minimum, and more if the subsurface soil condition shows a significant variation in soil type.

Generally, the minimum depth of exploration for a building covered by this MRT shall be 2 m. In hilly areas, exploration up to the depth of sound bed-rock, if it lies shallower than 2 m, should suffice.

No exploration shall be required if the site is located on rock or on fluvial terraces (Tar) with boulder beds.

The soils encountered in the test pits should be classified as per **Table 3.1.**

3.4 Allowable Bearing Pressure

The allowable bearing pressure that can be used is given in **Table 3.1** in conjunction with the visual classification of the subsurface soil type.

4 The Building Structure

4.1 Description

The structure is a reinforced concrete frame with masonry infill panels complying with **Clause 4.2** below and designed to resist earthquake forces by composite action.

The masonry infill walls in such structures are intended to resist seismic loads elastically in moderate or severe earthquakes. However, in very large earthquakes, the infill walls could be severely damaged. For such an event, steel is provided in the walls to reduce the risk to occupants of the building from the uncontrolled collapse of the walls under shear or face loads. At this stage, the seismic loads will have to be resisted mostly by the frame alone. As the frame has been designed to resist the gravity loads and has been detailed for ductility, the frame may be severely damaged but the possibility of collapse will have been minimized.

4.2 Restrictions on the Structural Layout

For a structure to be built to the requirements of the MRT, it shall comply with the restrictions below. If the structure does not comply, it must be designed in accordance with the Standards referred to in **Clause 1.2** or latest appropriate standard

TABLE 3.1 : FOUNDATION SOIL CLASSIFICATION AND SAFE BEARING CAPACITY

S. No.	Type of Foundation Materials	Foundation Classification	Presumed Safe Bearing Capacity, kN/m^2
1.	Rocks in different state of weathering, boulder bed, gravel, sandy gravel and sand-gravel mixture, dense or loose coarse to medium sand offering high resistance to penetration when excavated by tools, stiff to medium clay which is readily indented with a thumb nail.	Hard	≥ 200
2.	Fine sand and silt (dry lumps easily pulverised by the finger), moist clay and sand-clay mixture which can be indented with strong thumb pressure	Medium	≥ 150 and < 200
3.	Fine sand, loose and dry; soft clay indented with moderate thumb pressure	Soft	≥ 100 and < 150
4.	Very soft clay which can be penetrated several centimetres with the thumb, wet clays	Weak	≥ 50 and < 100

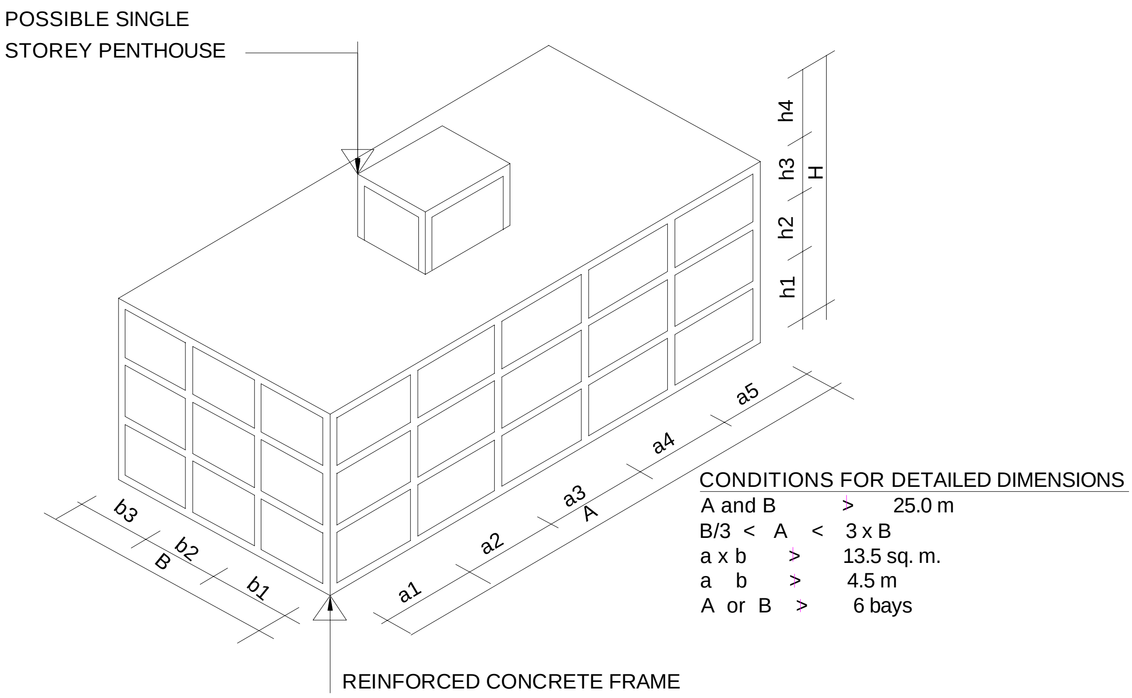
(a) Neither *A* nor *B* shall exceed 6 bays in length nor 25 metres. Each bay shall not exceed 4.5 m, as shown in **Figure 4.1**.

(b) *A* shall be not greater than 3 *B* nor less than *B*/3.

(c) Neither *H/A* nor *H/B* shall exceed 3.

(d) The area of a slab panel shall not be more than 13.5 square metres.

(e) The maximum height of a structure is 11 m or 3 storeys, whichever is less. Within an 11 m height, there may be an additional storey of smaller plan area. The area of this shall not exceed 25 % of the area of a typical floor. If this limit is exceeded, it shall be considered as an additional storey and not permitted.

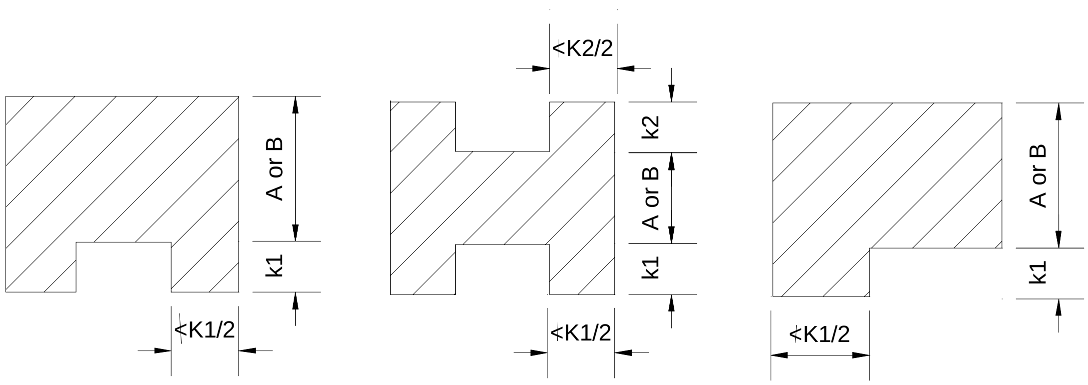


[Note: 1. Openings in structural infills walls restricted, in others as per functional/architectural requirements.

2. Foundation is not shown.]

Figure 4.1 : Reinforced Concrete Frame

(f) The length of wings on the structure shall be restricted such that K_1 and K_2 shall be less than the lesser of 0.25 *A* or 0.25 *B*. The width of the wings shall be restricted as shown in **Figure 4.2**. The plan shape of the building excluding wings shall be rectangular.



K1, K2 < 0.25 A or 0.25 B, whichever is less.

Figure 4.2 : Restrictions on Plan Projections

(g) All walls and columns resisting lateral load shall be vertical and shall continue on the same centreline down to foundation level. The top storey may, however, be smaller or have a different geometry subject to the provisions of subparagraph (e) above.

(h) All infill walls resisting lateral load shall be constructed from the same grade of masonry and shall have the same quality of plaster finish.

(i) Only infill wall panels with openings having a total area less than 10 % of the gross panel area shall be considered as resisting seismic loads. Such openings shall be located outside the middle two-thirds of the panel and the restricted zone, as shown in **Figure 4.3**.

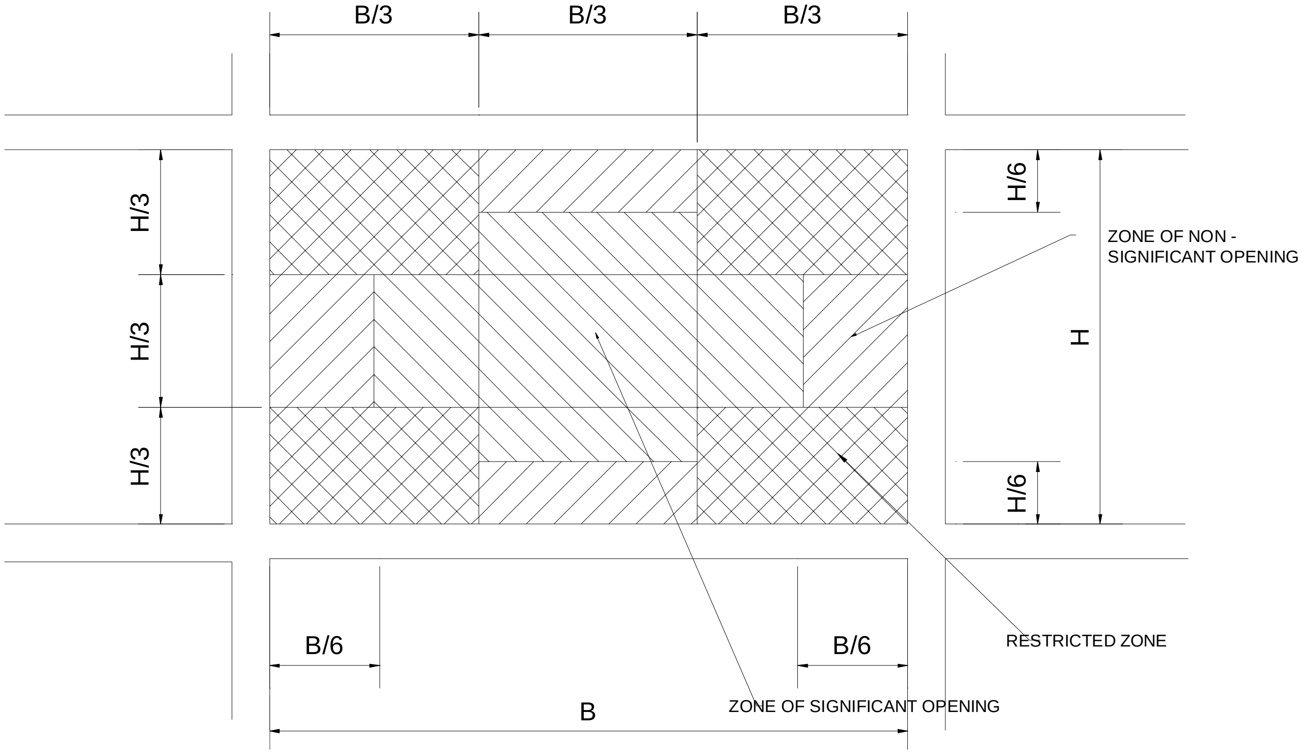


Figure 4.3 : Possible Location of Openings in Load-Bearing Infill Wall

(j) Any infill wall not meeting the requirements of (i) shall have framed openings as explained in **Clause 8.1.2**. However, in no case shall the opening be more than 10 % of the gross panel area and be in the restricted zone.

(k) No walls except a parapet wall shall be built on a cantilevered slab. Such walls shall be constructed only if the cantilevered slab is framed with beams.

(l) At each particular level in the direction under consideration, the wall thickness must be such that :

$$\Sigma\, t_{ei} \; > \; 125 \;\; \Sigma\, (I_i \,/\, H_i^3) \qquad (4\text{-}1)$$

where :

t_{ei} is the effective wall thickness including plaster stiffness at level i given by

$$t_{ei} = t_i\,(1 + t_{pi}\,E_p\,/(t_i\,E_b)) \qquad (4\text{-}2)$$

Σ indicates the summation for all lateral load-resisting elements at level *i*

t_i is the thicknesses of the lateral load-resisting masonry walls at level *i*

t_{pi} is the total thickness of plaster acting with the wall at level *i*

E_b is the modulus of elasticity of brick masonry

E_p is the modulus of elasticity of the plaster

I_i is the column moment of inertia in the plane of the lateral load

H_i is the height of the i^{th} storey

Note : E_b and E_p should be determined by testing specimens at 28 days. In the absence of test data, the following values may be assumed (unit brick strength taken as 7.5 N/mm²) :

E_b = 2400 N/mm², E_p = 10 000 N/mm² for 1:6 cement-sand mortar

E_p = 3000 N/mm², E_p = 15 000 N/mm² for 1:4 cement-sand mortar

(m) At any level the placement of lateral load-resisting walls shall comply with the following **(see Figure 4.4)** :

- At least two lateral resisting walls shall be used in each direction X and Y.

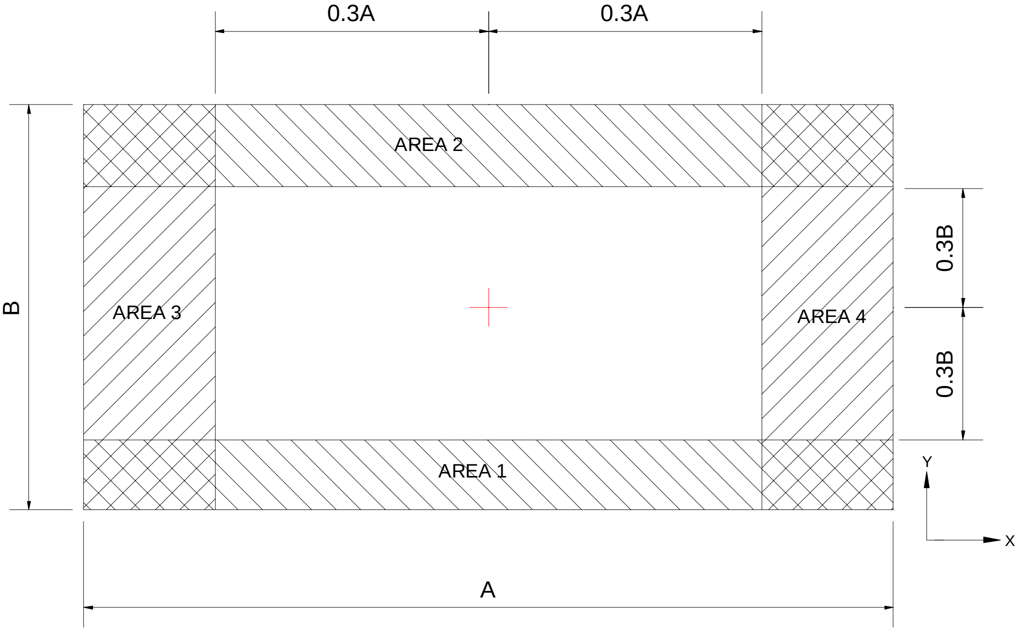


Figure 4.4 : Preferred Infill Locations

- At least 20 % of the total length of walls resisting lateral load in the X-direction shall be in each area 1, and area 2, and in the Y-direction in each area 3 and 4.

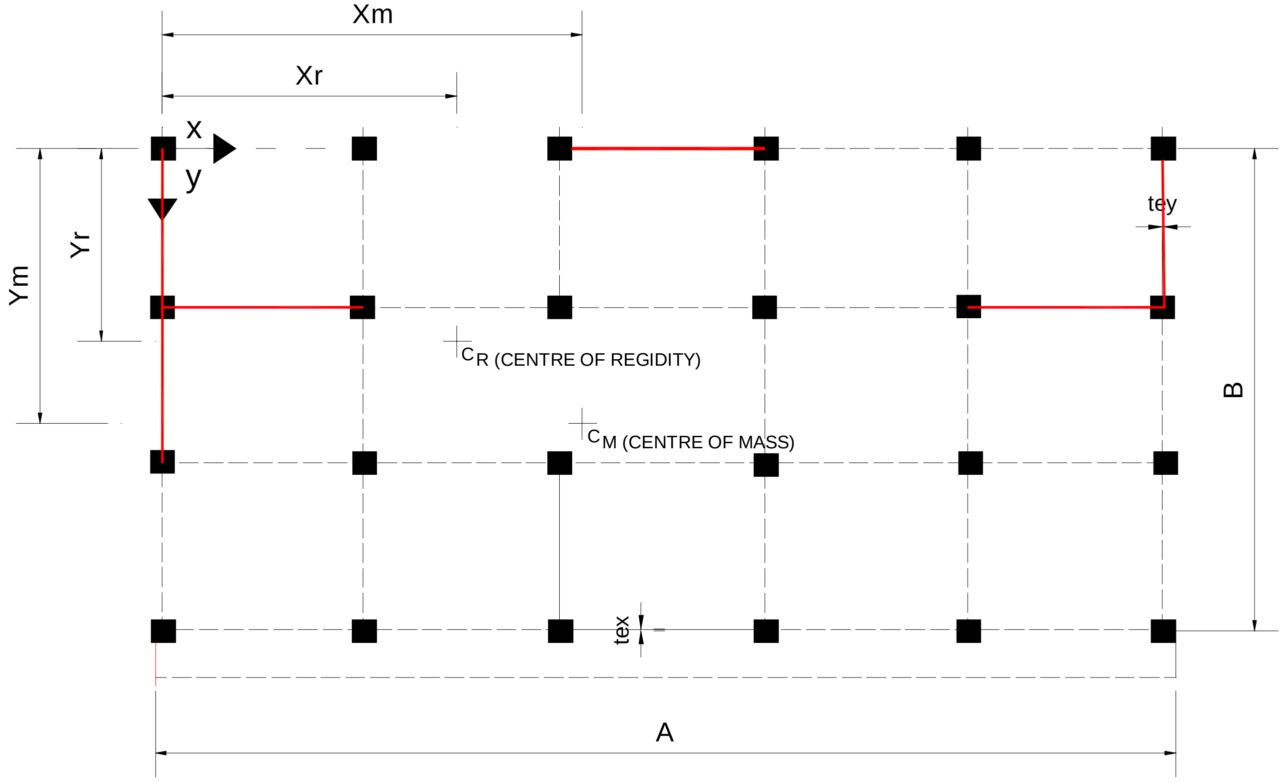
(n) In each principal direction, the lumped mass of each individual floor divided by the sum of the thicknesses of the walls resisting the lateral load including plaster finish shall not be more than 125 % of the same ratio for any higher floor. The structure at roof level need not comply with this requirement.

(o) Following limitations shall be complied with as given in **Figure 4.5**:

$$(X_m - X_r) \leq \pm\ 0.1\, A \qquad (4\text{-}3a)$$

and $$(Y_m - Y_r) \leq \pm\ 0.1\, B \qquad (4\text{-}3b)$$

Adjust wall thicknesses, if necessary, to satisfy this condition.



C_R = Centre of rigidity, C_M = Centre of mass,
t_{ex}, t_{ey} = Effective thickness of infill wall along x and y axes respectively

Figure 4.5 : Infill Walls in Plan

[Note: 1. Calculate the centre of rigidity for each floor as follows:

$$X_R = \Sigma x\, t_{ey} / \Sigma t_{ey} \qquad (4\text{-}3a)$$

$$Y_R = \Sigma y\, t_{ex} / \Sigma t_{ex} \qquad (4\text{-}3b)$$

where :

X is the distance to the particular wall capable of resisting lateral load in the y-direction :

Y is the distance to the particular wall capable of resisting lateral load in the x-direction.

t_{ex} *is the wall thickness including plaster in the x-direction.*

t_{ey} *is the wall thickness including plaster in the y-direction.*

2. Calculate the centre of mass of the floor including the mass of all the dead as well as appropriate live loads supported laterally at that level]

(p) The foundation shall be at a uniform level.

5 Construction Materials

5.1 Concrete

The concrete to be used in footings, columns, beams and slabs, etc., shall have a minimum crushing strength of 15 N/mm² at 28 days for a 150 mm cube.

Cement: Cement shall be as fresh as possible. Any cement stored for more than two months from the date of receipt from the factory should either be avoided or tested and used only if the test results are found to be satisfactory. Any cement which has deteriorated or hardened shall not be used. All cement used shall be Ordinary Portland Cement meeting the requirements of NS : 049-2041. It is advisable to use cement which has obtained the NS mark if independent tests are not carried out.

Coarse Aggregates: Coarse aggregates shall consist of crushed or broken stone and shall be hard, strong, dense, durable, clean, of proper grading and free from any coating likely to prevent the adhesion of mortar. The aggregate shall be generally angular in shape. As far as possible, flaky, elongated pieces shall be avoided. The aggregates shall conform to the requirements of IS : 383-1970 and IS : 515-1959.

The coarse aggregates shall be of following sizes :

(a) Normal cement concrete with a thickness of 100 mm and above graded from 20 mm downwards

(b) Cement concrete from 40 mm to 100 mm thick graded from 12 mm downwards

Sand: Sand shall consist of a siliceous material having hard strong, durable, uncoated particles. It shall be free from undesirable amounts of dust lumps, soft or flaky particles, shale, salts, organic matter, loam, mica or other deleterious substances. In no case shall the total of all the undesirable substances exceed five percent by weight.

Note : Refer to the construction guidelines.

5.2 Brickwork

The brick masonry shall be built with the usually specified care regarding pre-soaking of bricks in water, level bedding of planes fully covered with mortar, vertical joints broken from course to course and their filling with mortar fully.

Bricks : The bricks shall be of a standard rectangular shape, burnt red, hand-formed or machine-made, and of crushing strength not less than 3.5 N/mm². The higher the density and the strength, the better they will be. The standard brick size of 240 x 115 x 57 mm with 10 mm thick horizontal and vertical mortar joints is preferable. Tolerances of -10 mm on length, -5 mm on width and ±3 mm on thickness shall be acceptable for the purpose of thick walls in this MRT.

Wall Thickness : A minimum thickness of one half-brick and a maximum thickness of one brick shall be used.

Mortar : Cement-sand mixes of 1:6 and 1:4 shall be adopted for one-brick and a half-brick thick walls, respectively. The addition to the mortars of small quantities of freshly hydrated lime in a ratio of ¼ to ½ of the cement will greatly increase their plasticity without reducing their strength. Hence, the addition of lime within these limits is encouraged.

Plaster : All plasters should have a cement-sand mix not leaner than 1:6. They shall have a minimum 28 days cube crushing strength of 3 N/mm².

5.3 Reinforcing Steel Bars

Reinforcing steel shall be clean and free of loose mill-scale, dust, loose rust and coats of paints, oil, grease or other coatings, which may impair or reduce bond. It shall conform to the following NS specifications.

Mild steel bars conforming to NS:84-2042 or IS:432 (Part)-1966 with f_y = 250 N/mm², or high-strength deformed bars conforming tom IS:1139-1966 or NS :191-2046 with f_y = 415 N/mm² or f_y=550 N/mm² shall be used for reinforcing all masonry and concrete.

[Note: 1. *In the presentation of this MRT, f_y = 415 N/mm² steel is assumed for main bars in beams and columns. For using any other steel with lower values of f_y,, the steel area shall be correspondingly increased.*

2. *High-strength steel bars having f_y= 550 N/mm² may only be used as reinforcement in slabs.*

3. *7 ϕ bars steel grade Fe550 can be replaced by 8 ϕ bars of steel grade Fe415. Similarly, 5 ϕ bars of steel grade Fe550 can be replaced by 6 ϕ bars of steel grade Fe250.*

6 Design Procedure

6.1 Procedure Outline

The simplified design procedure comprises the following stages :

(a) Confirm that the building plan meets the structural layout restrictions (**Clause 4.2**).

(b) Calculate the total horizontal seismic base shear on the building (**Clause 6.2**).

(c) Distribute the total horizontal seismic base up the height of the building (**Clause 6.3**).

(d) Distribute the total horizontal seismic load to the individual load-resisting elements (**Clause 6.4**).

(e) Design and detail the structural elements :

(i) The frame (**Clause 7.1 and 7.2**)

(ii) Columns with abutting walls in one direction only (**Clause 7.3**)

(f) Reinforcing of infill wall panels and non load-bearing walls. (**Clause 8.1 and 8.2**).

(g) Reinforcing of parapets (**Clause 9.1**).

6.2 Total Horizontal Seismic Base Shear

The structure shall be designed to withstand a total horizontal seismic base shear, *V*, calculated in accordance with the formula :

$$V = C_d \text{ x } W_t$$

where : W_t is the combination of the total vertical dead load and 25 % of the live loads above the level of lateral restraint provided by the ground.

6.2.1 Design Seismic Coefficient

[1]The design seismic coefficients, C_d for the design of frames with masonry infills in the zones shown in **Figure 1.1** are:

[2]Zone A = 0.128, Zone B = 0.115, Zone C = 0.102

Where a building location lies close to a zone boundary so that its particular zone is uncertain, then the building shall be assumed to fall in the zone requiring the higher value of basic seismic coefficient.

6.3 Distributing Total Horizontal Seismic Base Shear

The total horizontal base shear, *V*, shall be distributed up the height of the building in accordance with the formula (**refer Figure 6.1**) :

$$F_i = V \times \frac{W_i h_i}{\Sigma W_i h_i} \qquad \textbf{(6-2)}$$

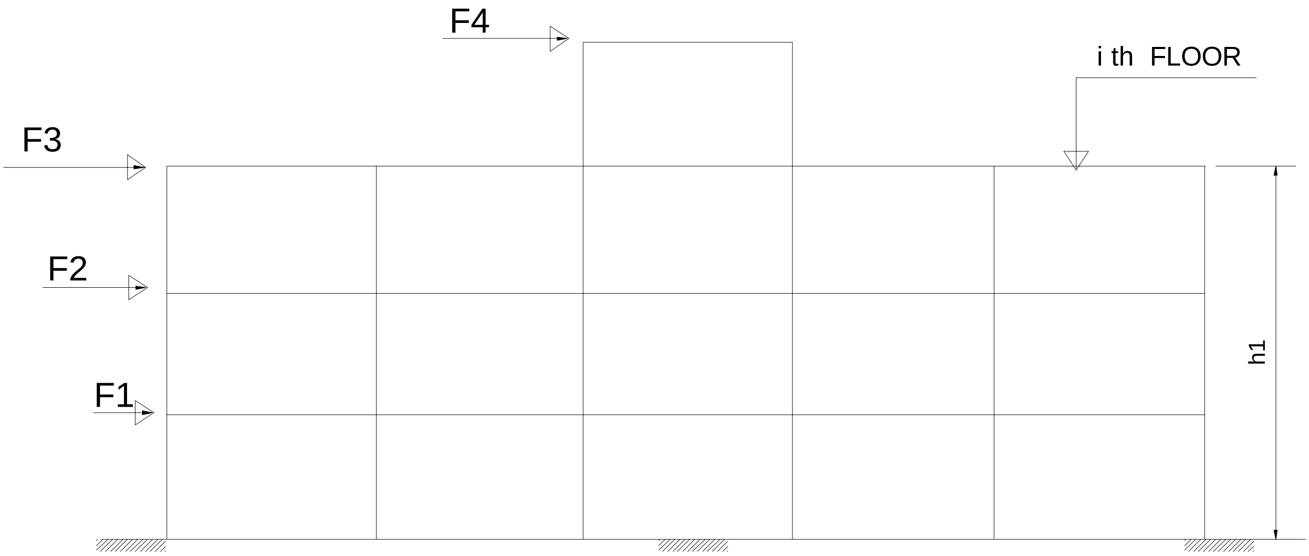


Figure 6.1 : Floor Level Lateral Forces

where :

---

1 Seismic coefficients are in accordance with NBC 105 for stiff buildings on a medium grade of soil.

2 Seismic coefficients adopted for the guideline is 1.028 which is base on the most server seismic zone under IS 1893-1895. At the time of preparation of this guideline NBC 105 was not ready for use. Capable designers are therefore, encouraged to undertake design using NBC 105.

F_i is the load applied at the level designated as i

W_i is the proportion of W_t at i^{th} level

h_i is the height of level i above the level of lateral restraint imposed by the ground.

6.4 Distribution of the Seismic Shear to the Individual Walls

At a particular level i the shear force V_{ij} resisted by an individual load resisting wall j shall be determined from the formula :

$$V_{ij} = \frac{t_{eij}}{\sum_{j} t_{eij}} \times \sum_{i}^{Roof} F_i \qquad \textbf{(6-3)}$$

where :

$\sum_{i}^{Roof} F_i$ is the sum of floor loads above the particular level i.

t_{eij} is the effective thickness of the particular lateral load resisting wall j at level i.

$\Sigma\, t_{eij}$ is the sum of the effective thicknesses of the j lateral load resisting walls j in level i.

The walls capable of resisting lateral loads are defined in **Clause 5.2 (h)**.

7 Design of the Frames

7.1 Frames

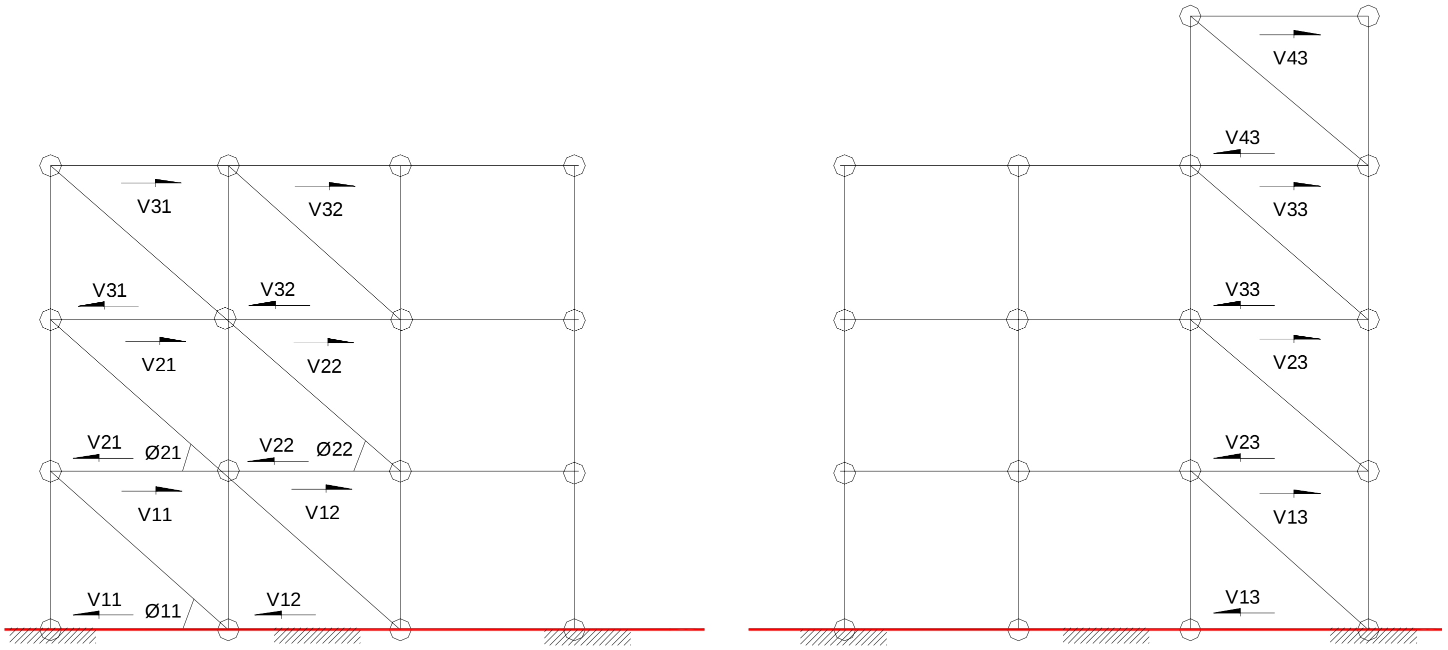
All frames shall be designed :

(a) to support the applied vertical gravity loads (including the weight of the infill walls) without assistance from the infill walls, and

(b) for seismic conditions using forces as per **Clause 6.1**, but using a seismic coefficient equal to $C_d/4$ only without any assistance from the infill walls.

7.2 Frames Surrounding Lateral Load-Resisting Walls

(a) The frame immediately abutting a lateral load-resisting wall shall be designed for the axial loads arising from the composite action of the frame and walls under the seismic condition with 90 % of the force F_i. These loads may be assessed assuming a pin-jointed frame, as shown in **Figure 7.1**, with the influence of the infill walls in resisting lateral loads represented by diagonal struts. If the wall does not resist lateral load, a compression strut is not included in that bay. The load acting at each individual beam-column intersection at the top and bottom of individual wall panels j is V_{ij} (see **Clause 6.4**).



a) 3-storey, 3-bay frame infill panel in two bays, j=1,2.

b) 4-storey, 3-bay frame infill panel in one bay only, j=3.

Figure 7.1 : Strut Action of Infill Panels Acting with Frames (Frames assumed pin-jointed)

Diagonal compression in a wall strut is given by

$$V_{ij} \sec \Theta_{ij}$$

Where :

Θ_{ij} is the angle of the strut from the horizontal, as shown in **Figure 7.1**.

The axial load induced in a column by the diagonal compression strut of the masonry panel which reacts V_{ij} shall be determined separately for wall panels in the direction of the two orthogonal building axes.

(b) These results shall be superposed on the vertical load and moments determined under **Clause 7.1 (b).**

(c) The design shear force in a column abutting a lateral load-resisting wall shall be taken as $V_{ij}/2$, whereas the shear force in the wall shall be V_{ij}.

7.3 Columns with Abutting Walls in One Direction Only

(a) Where any wall, whether or not it resists lateral load, abuts a column along one axis, only the column shall be designed to resist by bending action the load at right angles to the wall arising from seismic load on the wall.

(b) Where the column is required to resist the lateral loads by cantilever action from a foundation or lower floor, it shall be designed for the lateral loads on the appropriate tributary area.

7.4 Frame Design

The recommendations for member sizes and minimum reinforcement in all frames are shown in **Figures 7.2 to 7.6**. The reinforcement shall also comply with all applicable sections.

7.4.1 Basis of Recommendations

The recommended sizes of members and the reinforcement are based on sample calculations using the following data :

Building Occupancy	:	residential
Column Plan	:	4.5 x 3.0 m bays
Number of Storeys	:	three
Storey Height		
1st storey	:	3.2 m floor-to-floor
Upper storey	:	2.8 m floor-to-floor
Wall Thicknesses	:	up to 115 mm or equivalent for all internal walls (but infill walls 230 or 240 mm) and 240 mm or equivalent for all external walls
Cantilever Floor Projection	:	1.0 m (from centre-line of the beam)
Number of Solid Infill Panels	:	A minimum two infill panels in each direction for : (a) 100 m² of column plan area (b) 60 m² of column plan area

Concrete mix	:	M15 (15 N/mm²) cube crushing strength at 28 days) minimum
Reinforcement	:	Fe250 (minimum f_y = 250 N/mm²), Fe415 (minimum f_y = 415 N/mm²), Fe 550 (minimum f_y = 550 N/mm²)
Mortar	:	Minimum 1:6 cement-sand mortar in one-brick thick wall and 1:4 cement-sand mortar in half-brick thick walls.
Bricks	:	Minimum crushing strength : 7.5 N/mm² for infill walls and 3.5 N/mm² for other walls.
Seismic coefficient	:	C_d = 0.08 x 1.6 = 0.128 (for infill frame on medium grade of soil)

7.4.2 Recommended Members Sizes and Minimum Reinforcement

Slab

Roof and Floors

Thickness : 100 mm
Steel : T08 and M06 bars as shown in **Figure 7.2**.

Beams

Roof and floors (both directions)

Width : 230 or 240 mm
Depth : 325 mm (overall including slab).

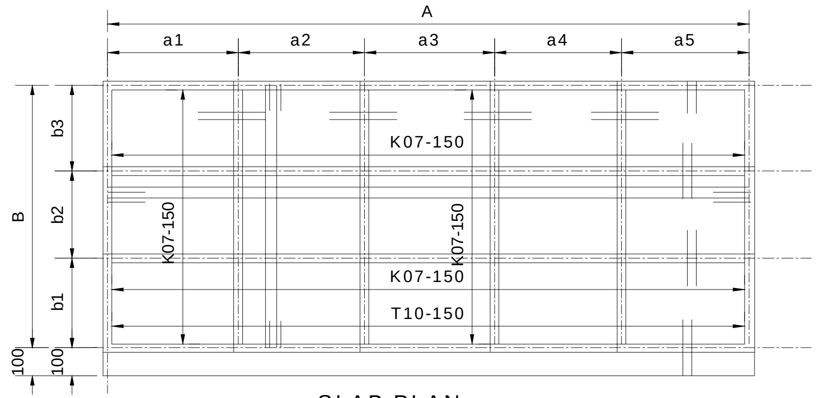
Plinth (both directions)

Width : 230 or 240 mm
Depth : 200 mm over all

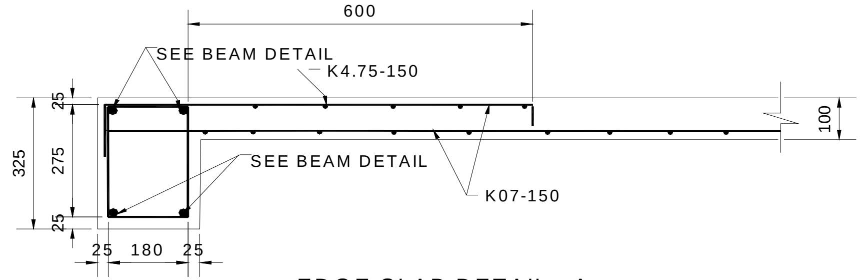
Longitudinal Steel

Longitudinal bars are presented for different spans for :

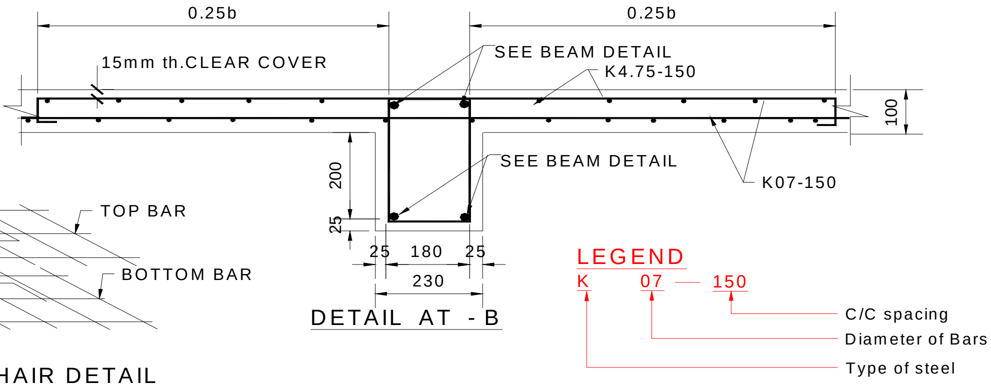
(a) two walls each way per 100 m² of column plan area and
(b) two walls each way per 60 m² of column plan area.



SLAB PLAN



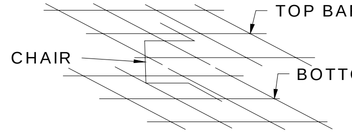
EDGE SLAB DETAIL - A



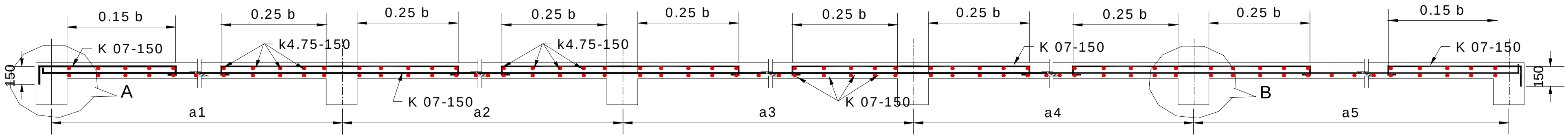
DETAIL AT - B

NOTE:

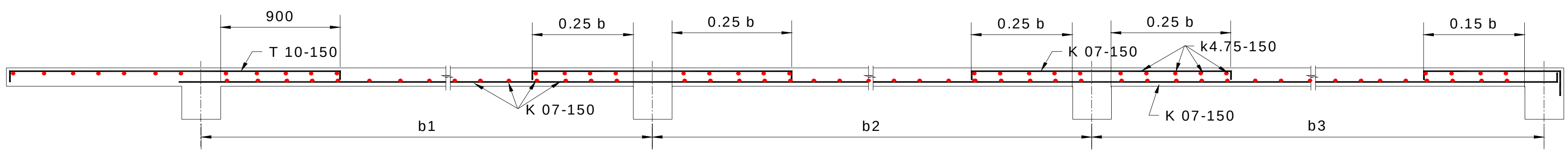
1. K07 bars can be replaced by T08 & k4.75 can be replaced by M06 bars.
2. Top bars could be curtailed at 0.25 of short span from edge of support.
3. Cut for stairwell can be made any where as desired with slab edge detail as in detail A.
4. No wall other than parapet shall be built on cantilever slab.
5. 15mm clear cover shall be maintained for bars.
6. The bars externding through adjacent apans to any span less than 2 m shall not be curtailed.
7. Exposed surfaces of concrete shall be kept condtinuously wet or damp at least for one week.
8. In normal circumstances, formwork can be removed only after two weeks of concreting.



CHAIR DETAIL



SECTION AT X - X



SECTION AT Y - Y

Figure 7.2 : Slab Details

The steel for free-span beams presented in **Table 7.1** shall govern for both categories. The steel in beams abutting infill walls for category (a) and (b) are presented in **Tables 7.2a and 7.2b**, respectively. The placing of the bars shall be as specified in **Figures 7.3a and 7.3b.**

Transverse Steel

The transverse stirrups are presented for free-span beams and beams abutting infill walls in **Table 7.3**. The spacing and size of stirrups are applicable for two walls each way for :

(a) 100 m² of column plan area, as well as

(b) 60 m² of column plan area.

TABLE 7.1 : LONGITUDINAL STEEL IN FREE-SPAN BEAMS

SPAN	4.5 ≥ *l* > 4.0				4.0 ≥ *l* > 3.5				3.5 ≥ l > 3.0				l ≤ 3.0			
Bar Type	Regular		Additional		Regular		Additional		Regular		Additional		Regular		Additional	
Level	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot
Roof and Pent- House	2T12	2T12	1T12	1T12	2T12	2T12	1T12	1T12	2T12	2T12	1T10	1T10	2T12	2T12	1T10	1T10
II	2T16	2T16	1T12	1T10	2T12	2T12	1T16	2T10	2T12	2T12	1T12	1T12	2T12	2T12	1T12	1T12
I	2T16	2T16	1T12	1T10	2T12	2T12	1T16	2T10	2T12	2T12	1T12	1T12	2T12	2T12	1T12	1T12
Plinth	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-

TABLE 7.2A : LONGITUDINAL STEEL IN BEAMS ABUTTING INFILL WALLS
(for two walls each way per 100 m² of column plan area)

SPAN	4.5 ≥ *l* > 4.0				4.0 ≥ *l* > 3.5				3.5 ≥ *l* >3.0				*l* ≤ 3.0			
Bar Type	Regular		Additional		Regular		Additional		Regular		Additional		Regular		Additional	
Level	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot
ROOF AND PENT HOUSE	3T12	3T12	-	-	3T12	3T12	-	-	3T12	3T12	-	-	3T12	3T12	-	-
II	2T16 + 2T10	2T16 + 2T10	-	-	2T16 + 2T10	2T16 + 2T10	-	-	2T16 + 1T12	2T16 + 1T12	-	-	2T16 + 1T12	2T16 + 1T12	-	-
I	2T16 + 2T12	2T16 + 2T12	-	-	2T16 + 2T12	2T16 + 2T12	-	-	2T16 + 2T12	2T16 + 2T12	-	-	3T16	3T16	-	-
PLINTH	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-

TABLE 7.2B : LONGITUDINAL STEEL IN BEAMS ABUTTING INFILL WALLS (for two walls each way per 60 m² of column plan area)

SPAN	4.5 ≥ *l* > 4.0				4.0 ≥ *l* > 3.5				3.5 ≥ *l* > 3.0				*l* ≤ 3.0			
Bar Type	Regular		Additional		Regular		Additional		Regular		Additional		Regular		Additional	
Level	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot
Roof and Pent-House	3T12	3T12	-	-	3T12	3T12	-	-	2T12 + 1T10	2T12 + 1T10	-	-	2T12 + 1T10	2T12 + 1T10	-	-
II	2T16 + 1T12	2T16 + 1T12	-	-	4T12	4T12	-	-	2T12 + 1T10	2T12 + 2T10	-	-	2T12 + 2T10	2T12 + 2T10	-	-
I	2T16 + 1T12	2T16 + 1T12	-	-	4T12	4T12	-	-	4T12	4T12	-	-	2T12 + 2T10	2T12 + 2T10	-	-
Plinth	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-	2T12	2T12	-	-

[Note: 1 2T12 Stands for 2 number of 12 mm ϕ Fe415 (eg., `Torsteel' or equivalent) steel bars.

2 Additional top bars coming from adjacent spans if the span under question is less than 2 metre.

3 Incase of adjacent beams of different spans, top bars of longer span shall govern.

4 Bars of beam abutting infill wall shall not be curtailed and shall be continued at least 56 ϕ away from face of the column.]

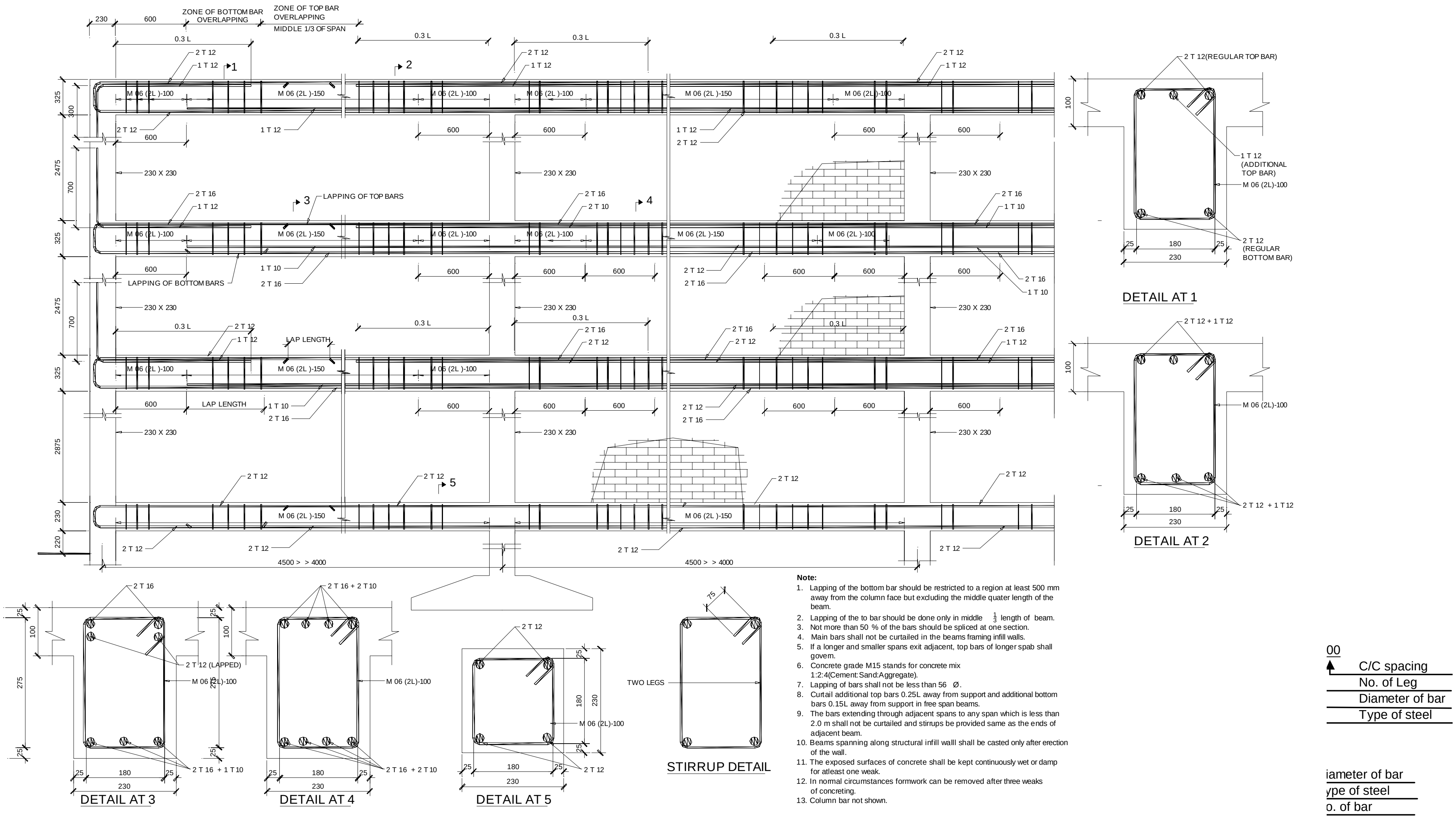


Figure 7.3a : Beam Detail (two walls each way / 100 m^2)

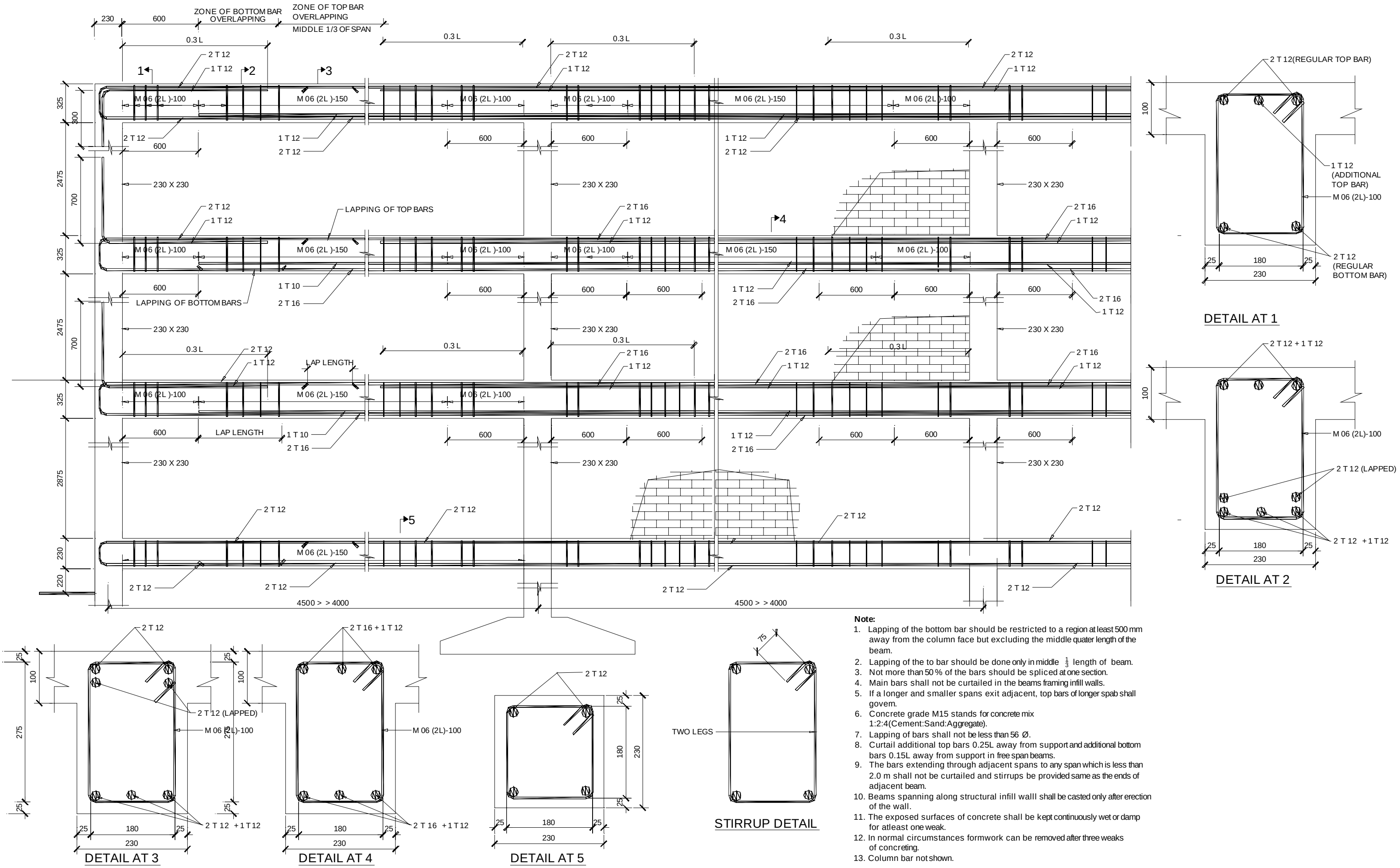


Figure 7.3b : Beam Detail (two walls each way / 60 m^2)

TABLE 7.3 : TRANSVERSE STIRRUPS IN BEAMS
(All stirrups are 2-legged)

Level	Free-Span Beam		Beam in Frames Abutting Infill Walls	
Roof	End 600 mm - M06 @ 100 mm	Remaining length M06 @ 150	End 600 mm - M06 @ 100 mm	Remaining length M06 @ 150
II	End 600 mm - M06 @ 100 mm	Remaining length M06 @ 150	End 600 mm - T08 @ 100 Next 600 mm - M06 @ 100	Remaining length M06 @ 150
I	End 600 mm - M06 @ 100 mm	Remaining length M06 @ 150	End 630 mm - T08 @ 90 Next 600 mm - M06 @ 100	Remaining length M06 @ 150
Plinth	Full length : M06 @ 100 mm		Full length (M06 @ 100)	

[Note: 1. M06 @150 stands for 6 mm ϕ FE250 steel grade stirrups at a spacing of 150 mm].

Columns:

(a) Where two infill walls are used each way per 100 m² of column plan area :

Size :

i) Those in first storey abutting infill wall = 230 (or 240) x 300 mm. (The longer dimension along the plane of the wall)

ii) All other columns 230 x 230 mm (or 240 x 240) as per wall thickness.

Steel :

Longitudinal reinforcement (Fe415)

i) Those abutting infill walls in first storey = 4T16

ii) Those in the interior in first storey (beams on 4 sides) = 8T12 (For column size 230 x 230)

iii) All other columns in all storeys = 4T12

(b) Where two infill walls are used each way per 60 m² of column plan area :

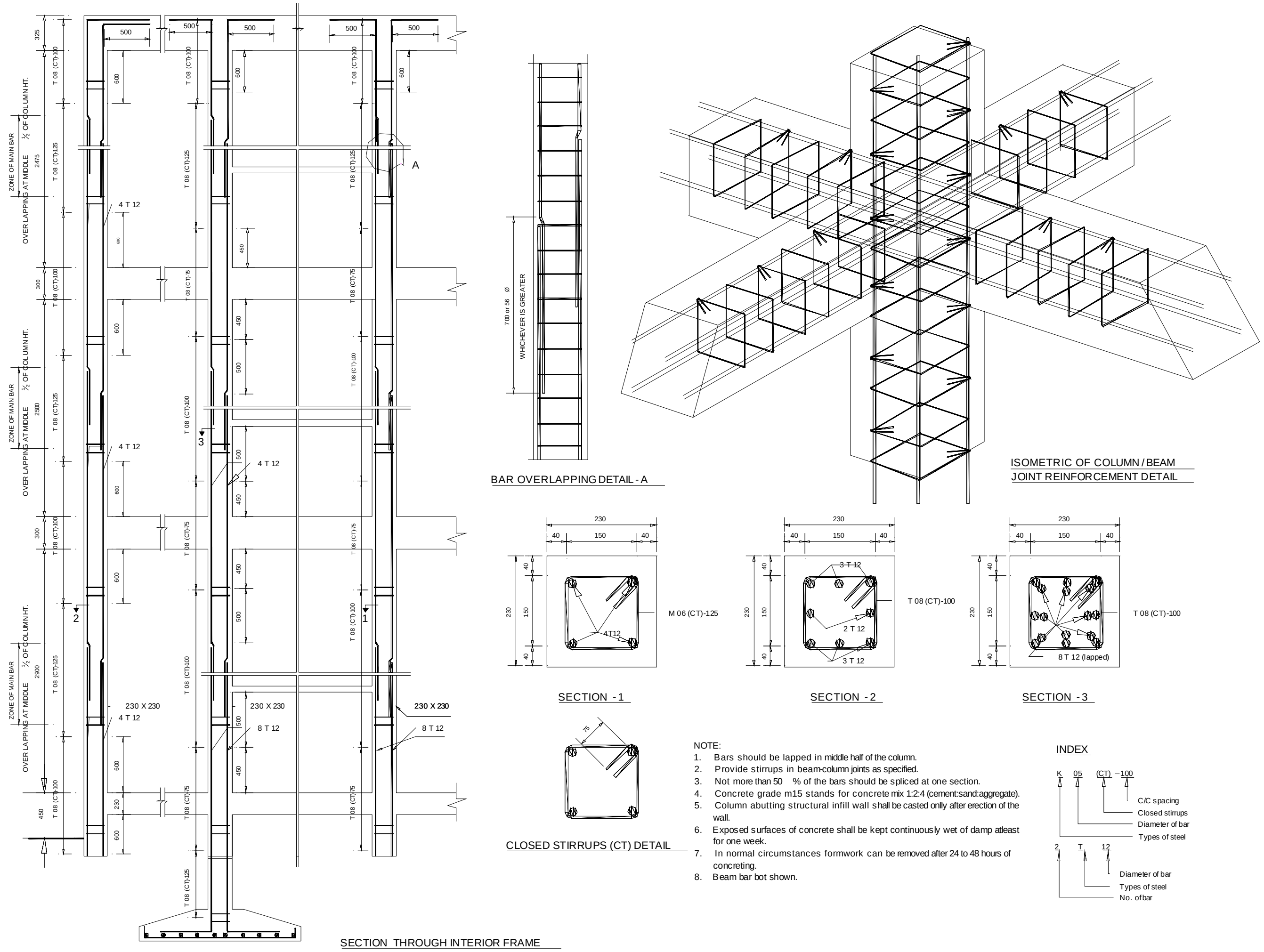


Figure 7.4a : Column Detail (two walls each way / 100 m^2)

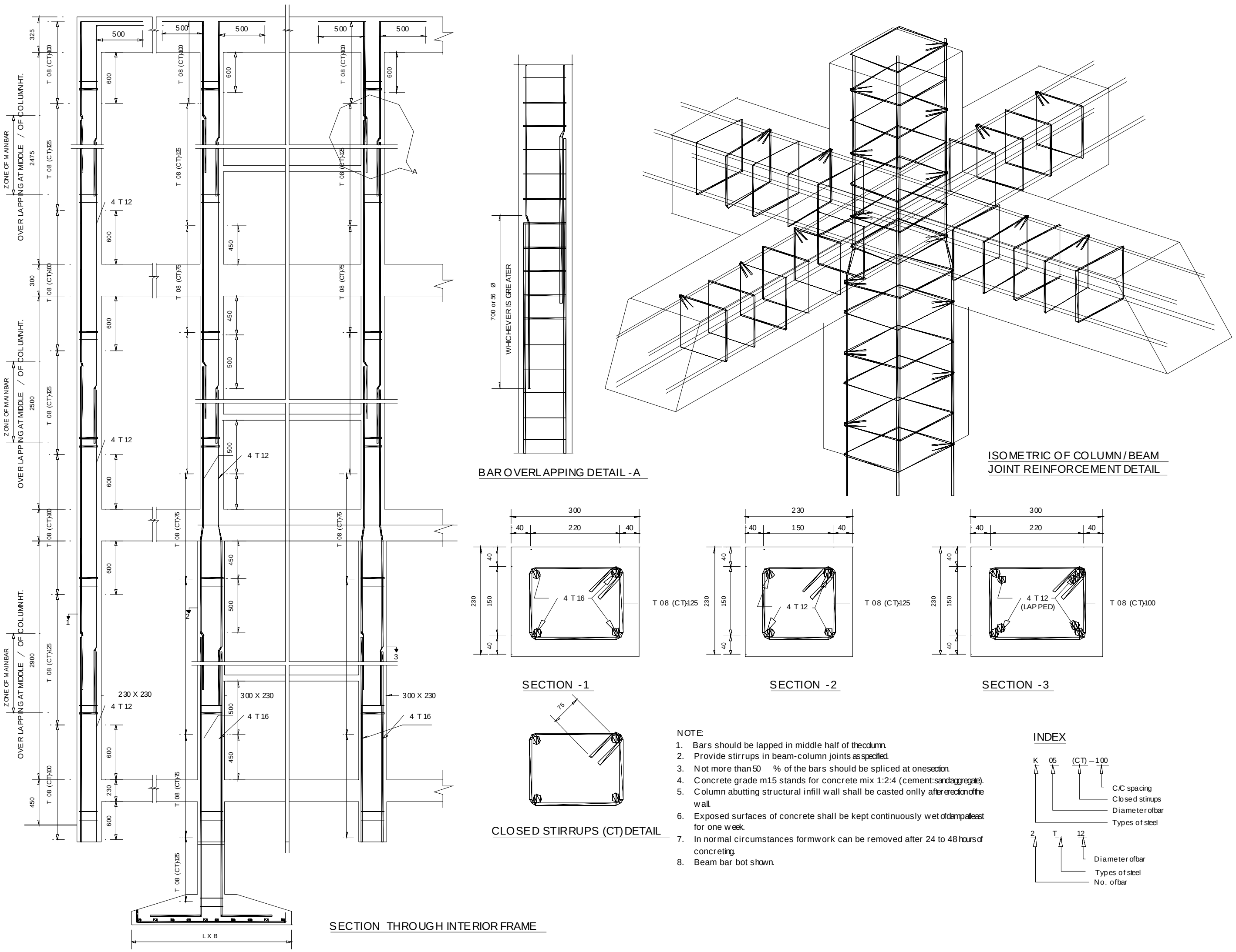


Figure 7.4b : Column Detail (two walls each way / 60 m²)

Size :

All columns 230 x 230 mm (or 240 x 240 mm) as per wall thickness.

Steel :

Longitudinal steel.

i) Interior columns in first storey only = 8T12

ii) All other columns in all storeys = 4T12

Transverse Stirrups :

Transverse stirrups (for both (a) and (b)) shall be as follows :

i) Columns abutting infill walls, only in first and second storeys :

- End 450 mm and in beam-column joint : T08 @ 75 mm
- next 500 mm : T08 @ 100 mm
- Remaining length : M06 @ 100 mm

ii) All other columns except those in (i) :

- End 600 mm and in the beam-column joint : T08 @ 100 mm
- Remaining length : M06@100 mm

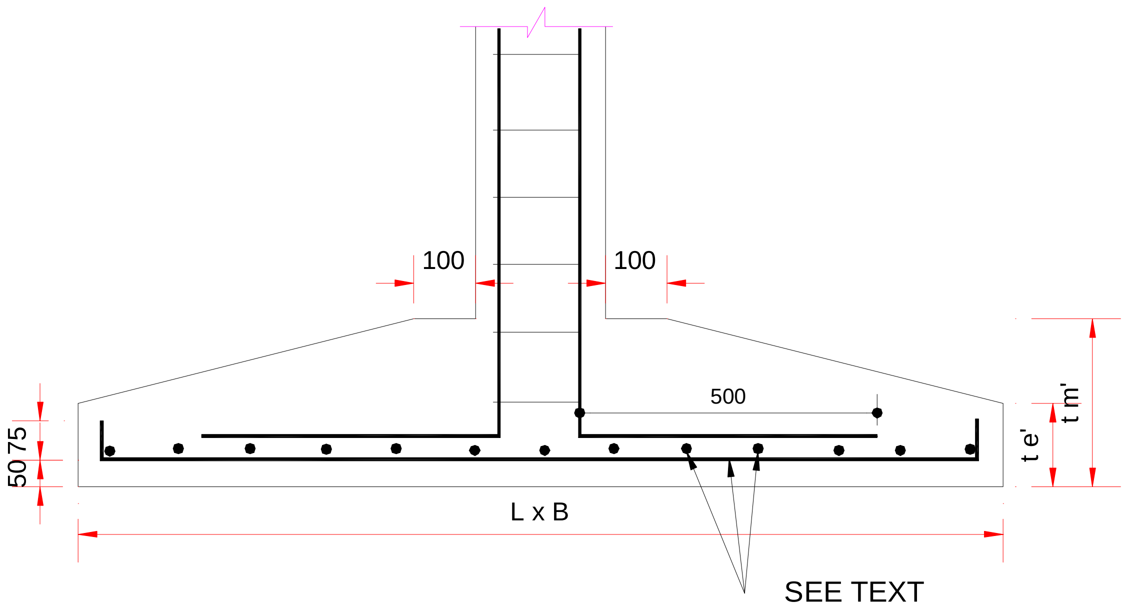
[Note: 1. Continue the column stirrups as specified for the ends if the column is located adjacent to a window or similar opening in order to take care of the short-column effect.

2. T08 @ 75 stands for 8 mm ϕ FE415 steel grade stirrups at a spacing of 75 mm c/c. All stirrups are the closed type.]

The details of each column shall be as specified in **Figures 7.4(a) and 7.4(b).**

<u>Foundations</u>

Sizes and reinforcement are given for independent tapering-type pads for different soil types in **Tables 7.5a to 7.5d**. Details of foundation pads shall be as given in **Figure 7.5**.



Dimensions are given in the text

Figure 7.5 : Pad Foundation Detail

TABLE 7.5A : PAD FOUNDATION SIZE FOR WEAK SOILS
(safe bearing capacity of 50 kN/m²)

Column Type	Column Location			Foundation Plan L x B, (m)	Thickness at Edges t_e, (mm)	Maximum Thickness t_m, (mm)	Rein-forcement each way A_s (mm), Fe415
	Canti-lever Side	Along Long Bay	Abutting Infill Wall				
Corner	No	-	No	1.6 x 1.6	150	300	7 T 10
Corner	Yes	-	No	1.7 x 1.7	150	300	8 T 10
Corner	Yes/No	-	Yes	1.7 x 1.7	150	300	8 T 10
Face	No	No	No	1.9 x 1.9	150	375	7 T 12
Face	No	Yes	No	2.2 x 2.2	150	400	8 T 12
Face	Yes	Yes/No	No	2.2 x 2.2	150	400	8 T 12
Face	Yes	Yes/No	Yes	2.2 x 2.2	150	400	8 T 12
Interior	-	-	No/Yes	2.6 x 2.6	200	500	10 T 12

[Note: 1. 6 T 10 stands for 6 - 10 mm ϕ bars of Fe415 steel grade.]

TABLE 7.5B : PAD FOUNDATION SIZE FOR SOFT SOILS (safe bearing capacity of 100 kN/m²)

Column Type	Column Location			Foundation Plan *L* x *B*, (m)	Thickness at Edges t_e, (mm)	Maximum Thickness t_m, (mm)	Rein-forcement each way
	Canti-lever Side	Along Long Bay	Abutting Infill Wall				
Corner	No	-	No	1.1 x 1.1	150	325	5 T 10
Corner	Yes	-	No	1.2 x 1.2	150	325	6 T 10
Corner	Yes/No	-	Yes	1.4 x 1.4	150	400	8 T 10
Face	No	No	No	1.4 x 1.4	150	400	7 T 12
Face	No	Yes	No	1.6 x 1.6	150	425	7 T 12
Face	Yes	Yes/No	No	1.6 x 1.6	150	425	7 T 12
Face	Yes	Yes/No	Yes	1.6 x 1.6	150	425	7 T 12
Interior	-	-	No/Yes	1.8 x 1.8	200	525	9 T 12

TABLE 7.5C : PAD FOUNDATION SIZE FOR MEDIUM SOIL (safe bearing capacity of 150 kN/m²)

Column Type	Column location			Foundation Plan *L* x *B*, (m)	Thickness at Edges t_e, (mm)	Maximum Thickness t_m, (mm)	Rein-forcement each way
	Canti lever side	Along Long Bay	Abutting Infill Wall				
Corner	No	-	No	1.0 x 1.0	150	325	5 T 10
Corner	Yes	-	No	1.1 x 1.1	150	325	6 T 10
Corner	Yes/No	-	Yes	1.3 x 1.3	150	425	8 T 10
Face	No	No	No	1.2 x 1.2	150	425	8 T 10
Face	No	Yes	No	1.4 x 1.4	175	450	9 T 10
Face	Yes	Yes/No	No	1.4 x 1.4	175	450	9 T 10
Face	Yes	Yes/No	Yes	1.4 x 1.4	175	450	9 T 10
Interior	-	-	No/Yes	1.6 x 1.6	250	550	8 T 12

TABLE 7.5D : PAD FOUNDATION SIZE FOR HARD SOIL
(safe bearing capacity of 200 kN/m²)

Column Type	Column location			Foundation Plan *L* x *B*, (m)	Thickness at Edges t_e, (mm)	Maximum Thickness t_m, (mm)	Rein-forcement each way
	Canti-lever side	Along Long Bay	Abutting Infill Wall				
Corner	No	-	No	0.8 x 0.8	150	350	5 - 10
Corner	Yes	-	No	0.9 x 0.9	150	350	5 - 10
Corner	Yes/No	-	Yes	1.2 x 1.2	200	450	8 - 10
Face	No	No	No	1.0 x 1.0	200	450	7 - 10
Face	No	Yes	No	1.1 x 1.1	200	450	7 - 10
Face	Yes	Yes/No	No	1.1 x 1.1	200	450	7 - 10
Face	Yes	Yes/No	Yes	1.2 x 1.2	200	450	8 - 10
Interior	-	-	No/Yes	1.3 x 1.3	250	550	7 - 12

Toe Wall : All plinth beams shall be constructed on a toe wall below them as given in **Figure 7.6**.

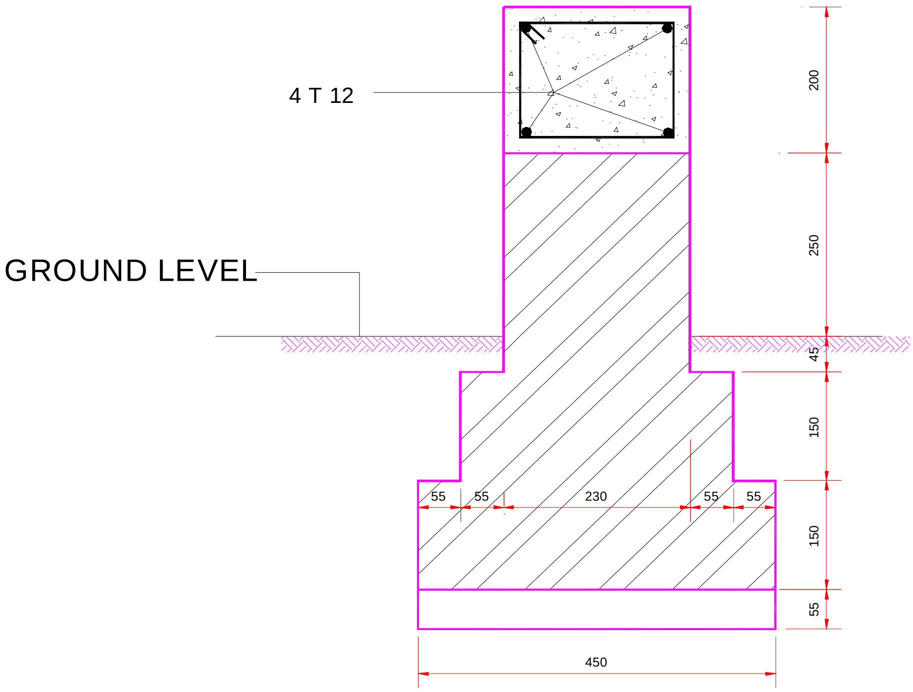


Figure 7.6 : Toe Wall Detail

8 Reinforcing Wall Panels

8.1 Infill Walls Participating in Lateral Load Resistance

8.1.1 With Insignificant Openings

To prevent walls from falling out, these shall be provided with horizontal reinforced concrete (RC) bands through the wall at about one-third and two-thirds of their height above the floor in each storey. The width of the band should be equal to the wall thickness and its thickness equal to that of the masonry unit, or 75 mm, whichever is larger. Reinforcement details shall be as given in **Figure 8.1.**

<u>Reinforcement</u> :

(a) Longitudinal - two bars 8 mm ϕ (Fe415) anchored fully in the RC column abutting the wall.

(b) Transverse - links 6 mm ϕ (Fe250) stirrups at every 150 mm.

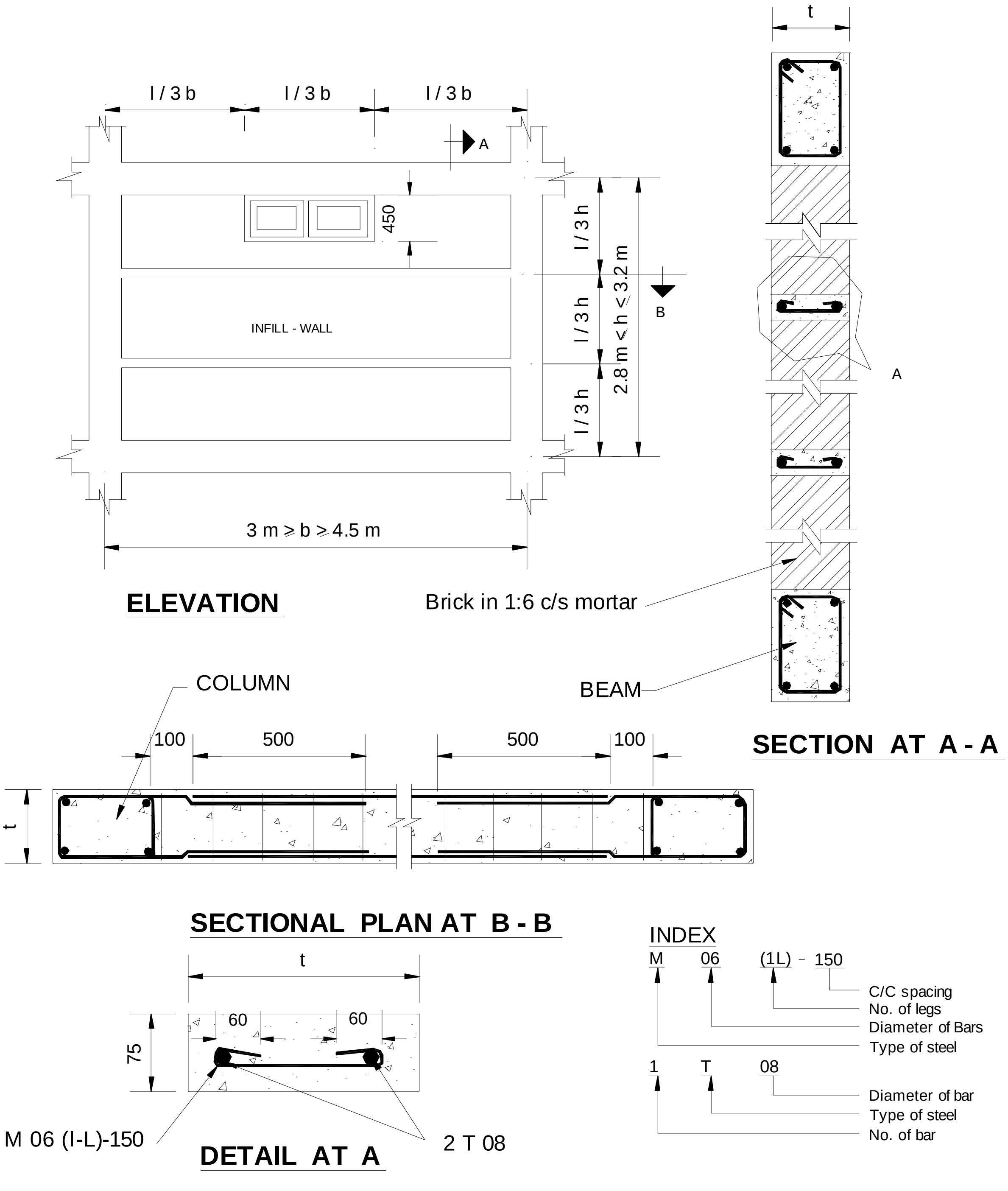


Figure 8.1 : Tie-Band Detail for Infill (Structural) Walls

8.1.2 With Significant Openings

Any opening inside the middle $^2/_3$ of a panel, but not inside the restricted zone, having an area not more than 10 % of the panel can be provided in the wall resisting lateral load. However, such openings shall be framed by RC framing components. The wall should be provided with two tie beams as in **Clause 8.1.1**. Details of the bands shall be as given in **Figure 8.2**.

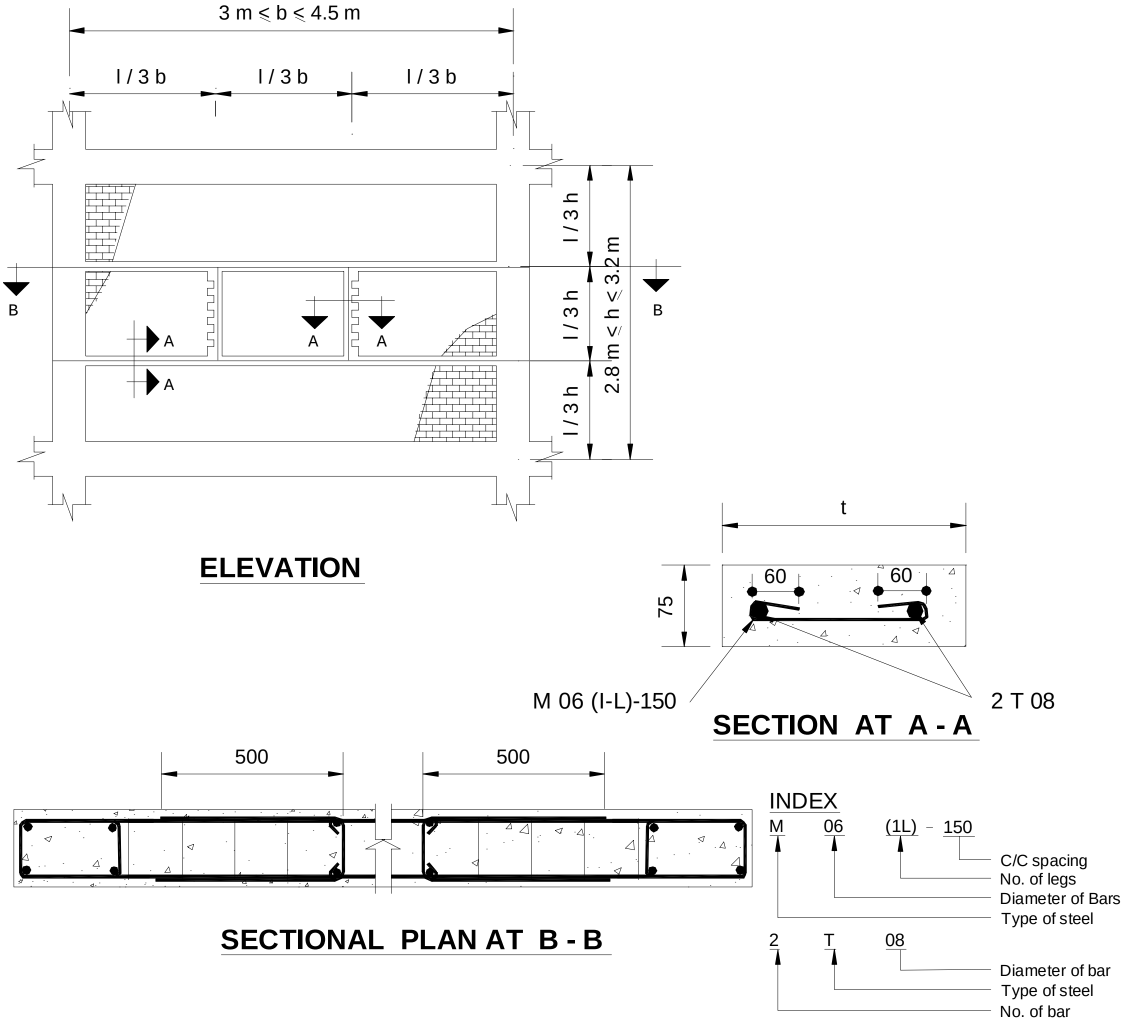


Figure 8.2 : Details for Opening Stiffening of Infill Wall

8.2 Non Load-Bearing Walls

8.2.1 Between Framing Columns

Horizontal RC bands shall be provided through all walls - one at window-sill level, and the other at lintel-level. Their section size and reinforcement shall be as given in **Clause 8.1.1**. For details, refer to **Figure 8.3**.

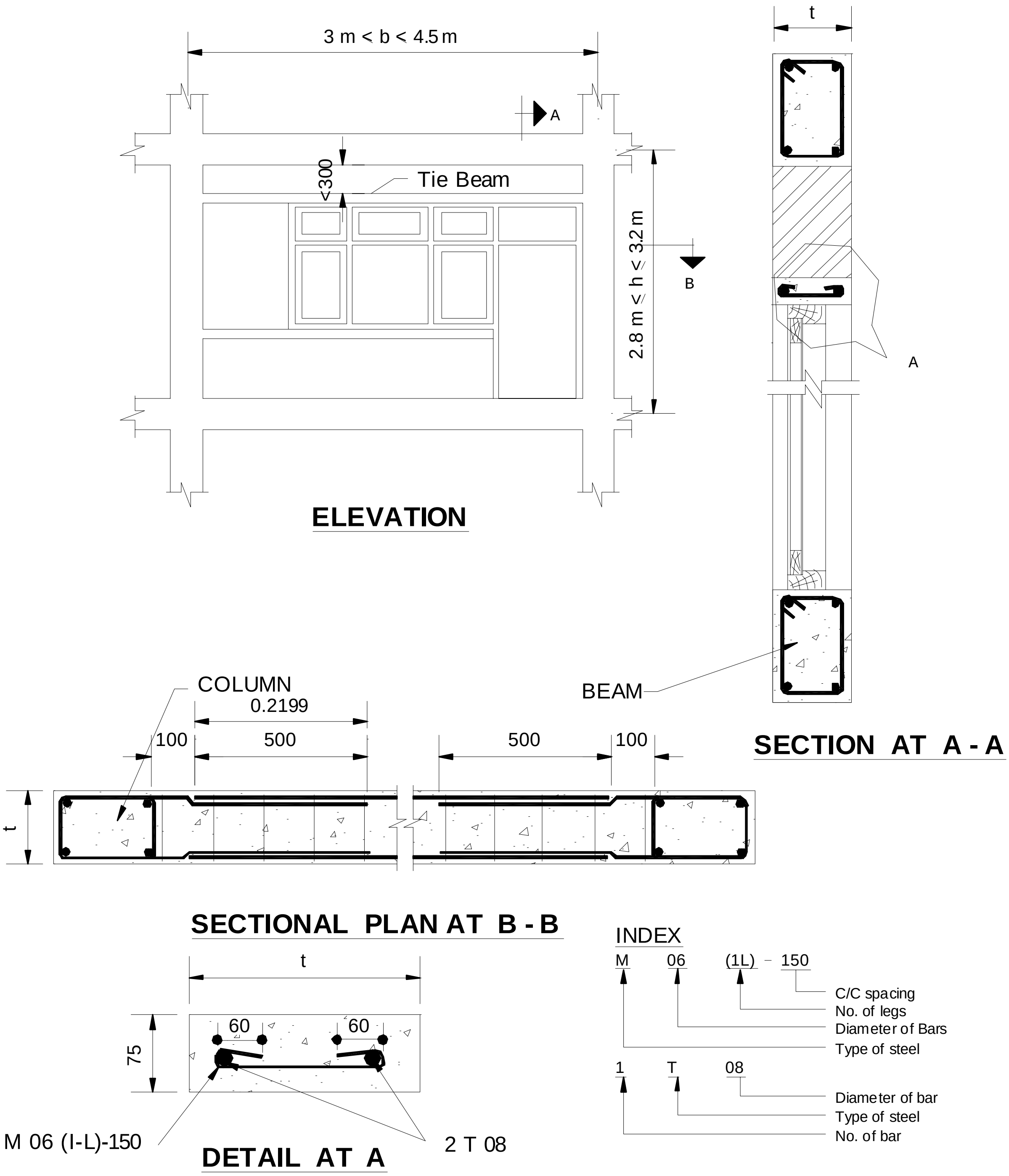


Figure 8.3 : Tie-Band Details for a Non-Structural Wall

8.3 Outside Framing Columns

A horizontal RC band shall be provided through all walls - one at window-sill level and the other at lintel-level. All details shall be the same as in **Clause 0**. The reinforcement of bands shall be taken through the cross-walls into the RC columns as detailed in **Figure 8.4**.

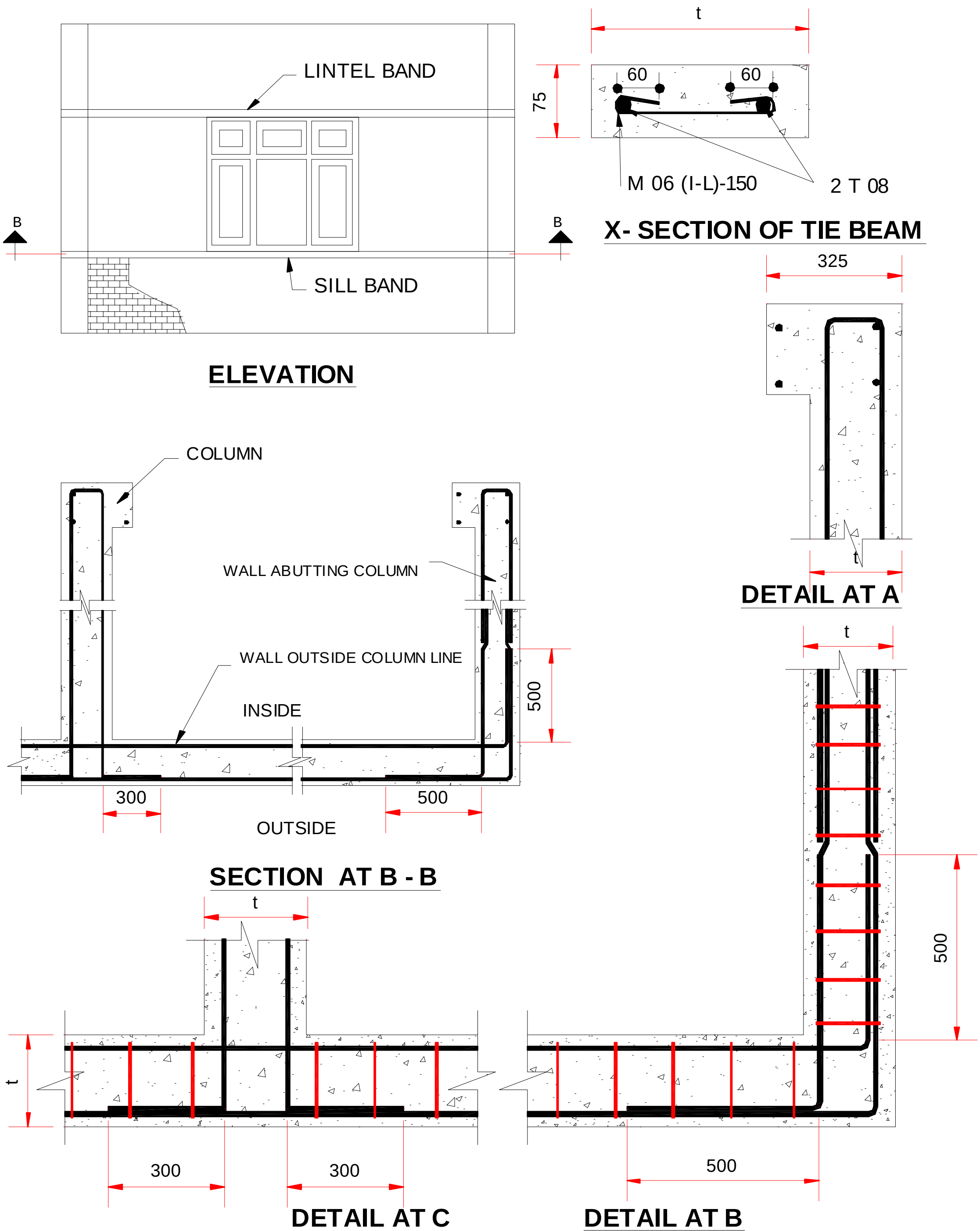


Figure 8.4 : Wall Outside the Frame

9 Parapets

9.1 General

Parapets above roofs and at the edges of balconies should not be taller than one metre. They should either be constructed in reinforced concrete or be reinforced with vertical RC elements spaced not more than 1.5 m apart. The section of the vertical RC post may be kept to *b* x 75 mm, where *b* is the thickness of the parapet. Such RC elements should be reinforced with two vertical bars of 8 mm diameter steel (grade Fe415) with transverse links of 6 mm diameter steel (grade Fe250) @ 150 mm centres. The vertical reinforcement shall be tied into the steel of the slab or beam below with a minimum embedment of 300 mm. Also, a handrail should be provided at the top with a section size and reinforcing as explained in **Clause 8.1.1**. For details, refer to **Figure 9.1**.

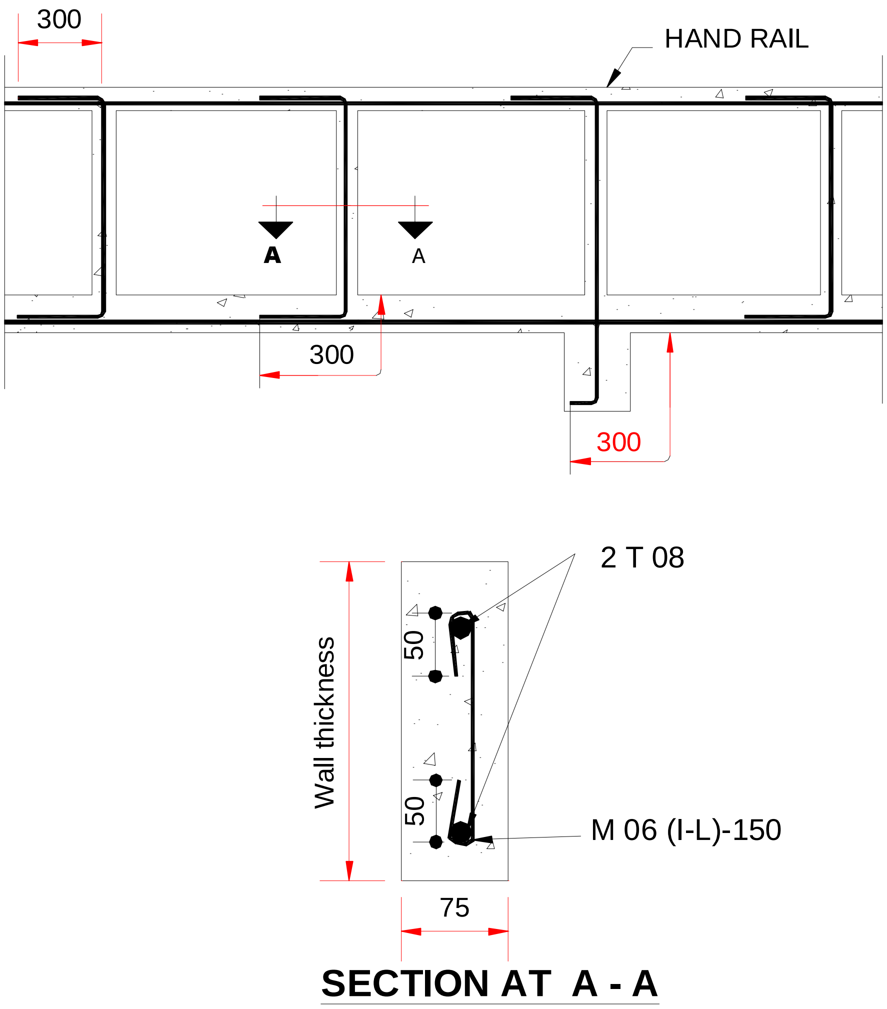


Figure 9.1 : Parapet Wall Tie-Up Details

9.2 Flower Pots

Flower pots should not normally be placed on parapets. However, if it is desired that they be placed there, they shall be adequately wired and held to the parapet through pre-fixed steel hooks/anchors so that they will not be dislodged in severe earthquake shaking.