Earthquake Resistance Emergency School Reconstruction Project

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ABSTRACT: **Most of the Structural buildings such as school, residential, industrial and commercial buildings are suffering from earthquake due to inadequate of structures stabilities and lack of construction techniques/methods, specifications and supervision guideline. We can take the example of, on April 25,2015 an earthquake with magnitude of 7.8(according to Geological Survey) struck many districts of Nepal, the main earthquake and aftershocks caused widespread devastation, killing 8,702 people, wounding 22,303 others and demolishing 498,852 houses.**

The objective of this project is to improve the education environment with earthquake resistance schools which will be safe shelters against future earthquake is the priority for the safeguard of children based on the Build Back Better (BBB) concept. Thereby contributing to sustainable socioeconomic development.

IndexTerms **- safe shelters against future earthquake, BBB concept, socioeconomic development, Quality control.**

INTRODUCTION

1.1 Background

The proposed project is "An Institutional Building" located at Tarkeshwor Rural municipality-6, (Former: Khadga-2), Nuwakot. The soil bearing capacity can be tested as per location but as per our site soil is granular type. Since the temperature is moderate there is no possibility of snow. .The studies related to earthquake is so important, as the earthquake, being inevitable natural catastrophe, safe design should hold the paramount important as loss of lives and properties are unpleasant because of worst scenario it can create.

Nepal is located between the Indian and Tibetan plate, along which a relative strain of about 2cm per year has been estimated. The Indian plate is also sub ducting at the rate through to be about 3cm per year. As a result, Nepal is very active seismically. So there is higher demand for the earthquake resistance design of the building for saving from these devastating disasters.

The structure, which is assemblage of smaller elements members also called elements, such as beam, column, slab etc. must be safe and stable against vertical loads such as dead load & live load and lateral loads ,those due to nature i.e. wind loads, earthquake loads etc. besides fulfilling the fundamental requirements as specified by the codes of practice. Hence, our project building is designed for earthquake loads, functional live and dead loads. The project report has been prepared in complete conformity with various stipulations in Indian standards as well as Nepal Building Code(NBC), code of practice for plain and reinforced concrete IS:456-2000, design aids for reinforced concrete to IS 456-1978 , criteria earthquake resistant design structure IS:1893-2002, ductile detailing of concrete structures subjected to seismic forces IS:13920-1993.

1.2 Objective

The aim of reinforced concrete design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety they should sustain the entire load and the deformation of normal construction and use and have adequate durability and adequate resistance to the effect of earthquake and other natural calamities.

Structure and structural elements are normally designed by limit state method. Proper account is taken of accepted theories, experiment and experience and the need to design for durability. Calculation alone does not produce safe, serviceable and durable structures. Suitable materials, quality control, adequate detailing and good supervision are equally important.

The above project has been assigned to me to achieve the subsequent main objective:

- To improve the education environment with earthquake resistance schools which will be safe shelters against future earthquake.
- Contributing to sustainable socioeconomic development through Build Back Better (BBB) concept.
- To provide the design which will be less prone towards the earthquake hazard.

The project deals with the various structural members of Institutional building. Design of various structural members such as slab, beam, column, footing and staircase are done in sequential manner in this project work.

1.4 Building Descriptions

Building type : 2 storied RCC framed
Structural system : OMRF
Plinth area covered : 142.75 sq.m
Type of footing : Isolated Footing
No. of storey : Two
Floor height : 10’
Type of soil : Granular
Seismic zone : Zone I

1.5 METHODOLOGY

The study has been done in two stages:

i) Design aid and Quality control
ii) Construction Supervision

Planning includes book reviews, site visits etc. which forms a basis of our studies and investigative visit is done to few existing institutional building, to get acquainted with the functional requirements. Feasibility of the project is studied through site visits and geological investigations at the site.

The second phase comprises of developing a functional plan in accordance with the latest standards and the functional requirements of the building. A thorough study of NBC is done before the initiation of the design.

2.0 REVIEW OF LITERATURE

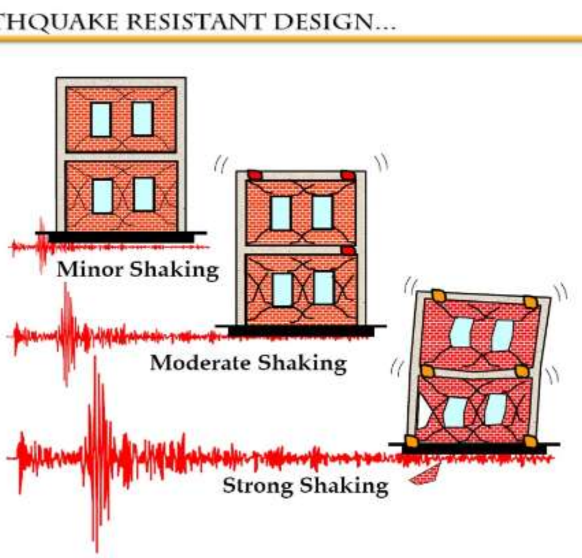
2.1 Background

We are mainly dealing with seismic analysis and structural design of RCC framed concrete structure. Our main focus will be on obtaining design output by limit state method on basis of structural design incorporating seismic considerations.

Earthquake is the natural phenomena caused by release of seismic wave (p-wave and s-wave) from the earth surface from a faint tremor to a wild motion due to sudden release of energy stored to the rocks beneath the earth surface. Most of the earthquake are minor and go un-noticed but the major ones, though occasional are responsible for huge loss of life and property.

The theoretical development of earthquake forces in structure reveals that the maximum elastic response acceleration during earthquake (range for which structure is designed) would be several times larger than the design acceleration i.e. the seismic coefficient specified in most of the codes. This situation is quite different to the approach made in codes for loads such as design loads are usually higher than the actual ones. It is based on the probability of the in-frequent occurrence of large earthquakes and the energy absorption capacity of the structure.

It is assumed that the structure will respond in a nonlinear manner in severe earthquakes and there by dissipate the energy of motion using material and structural ductility. It is clear that, to achieve ductile behaviors, brittle modes of failure due to shear, anchorage and bond should be avoided. This concept is derived from a basic philosophy that damage of the building is permissible as long as the structure doesn’t collapse catastrophically during a severe earthquake. This fact guides concept that vertical load-bearing member providing basic support of structure should be strong and can achieved by applying strong column- weak beam concept.



2.2 Design Philosophy

There are three philosophies for the design of reinforced concrete viz.

1. Working Stress Method

2. Ultimate Load Method
3. Limit State Method

Among above, the Limit state method has been adopted for the design of the structural elements.

2.2.1 The Limit State Method

Limit state design has originated from ultimate or plastic design. The object of design based on the limit state concept is to achieve an acceptable probability that a structure will not become unserviceable in its life time for the use for which it is intended, i.e. it will not reach a limit state. A structure with appropriate degrees of reliability should be able to withstand safely all the loads that are liable to act on it through-out its life and it should satisfy the serviceability requirements. All relevant limit states must be considered in design to ensure an adequate degree of safety and serviceability.

Assumptions for the limit state of collapse in flexure:

a. The plane section normal to the axis of member remains plane after bending.
b. The maximum strain in concrete at the outermost compression fiber is 0.0035.
c. The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola or any other shape.

For design purpose, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor γm =1.5 shall be applied.

d. The tensile strength of concrete is ignored.
e. The stresses in the reinforcement are derived from the representative stress-strain curve for the type of steel used. For design purpose the partial safety factor γm =1.15 shall be applied.
f. The maximum strain in the tension reinforcement in the section at failure shall not be less than:

$$(Fy/1.15Es)+0.002$$

Where, f_y= characteristics strength
E_s = modulus of elasticity of steel.

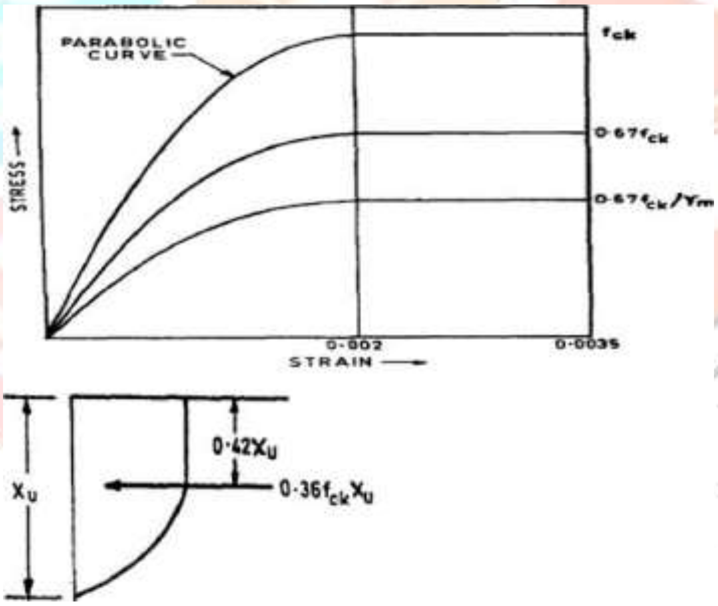


Fig2.1 Stress-Strain curve for concrete and Fig2.2. Blocks parameters. (Source **IS: 456- 2000)**

Assumptions for the limit state of collapse in compression:

In addition to the assumptions for limit state of collapse in flexure from 1 to 5, the following shall be assumed:
a. The maximum compressive strain in concrete in axial compression is taken as 0.002.
b. The maximum compressive strain at the highly compressed extreme fiber in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at least compressed extreme fiber.

*** The most important of these limit states which must be examined in design are as follows**:

2.2.1.1 Limit state of collapse

This state corresponds to the maximum load carrying capacity. Violation of collapse limit state implies failure in sense that a clearly defined limit state of structural usefulness has been exceeded. However, it does not mean a complete collapse. This limit state may correspond to:
a. Flexure
b. Compression

c. Shear, and
d. Torsion.

2.2.1.2 Limit state of serviceability

This state corresponds to development of the excessive deformation and is used for checking members in which magnitude of deformation may limit the use of the structure or its components. This state may correspond to:
a. Deflection
b. Cracking, and
c. Vibration.

a. Control of deflection:

The deflection of a structure or part there of shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. Two methods are given in code for checking the deflections. These are:

- Calculation of deflection given in Appendix C of code to be followed in special cases.
- In all normal cases, the deflection of flexural member will not be excessive if the ratio of its span to its effective depth is not greater than appropriate ratios given in the IS 456:2000 Clause 23.2.1

b. Control of cracking:

Cracking is a very complex phenomenon. Design considerations for crack control would require the following.

• Expression for crack width and spacing, and (**Annex F of IS: 456-2000**).

• Allowable crack widths under different service conditions with due considerations to corrosion and durability of concrete (**clause no 35.3.2 of IS: 456-2000).**

• Unless the calculation of crack widths shows that a greater spacing is acceptable, for the flexural members in normal internal or external conditions of exposure, the maximum distance between bars in tension shall not exceed the value as given in **IS: 456-2000,clause no 26.3.3**.

• Cracks due to bending in compression member subjected to design axial load >0.2fck*Ac, need not be checked. For flexural members (A member which is subjected to design load <0.2fck*Ac) if greater spacing of reinforcements as given in **clause 26.3.2, IS456-2000** is required, the expected crack width should be checked by formula given in **Annex F of IS456-2000**.

c. Control of Vibration:

A dynamic load is any load of which the magnitude, direction or position varies with the time and almost any RCC structural system may be subjected to one form or another loading during its life-time. Similarly structural response i.e. resulting stresses or deflections is also time-varying or dynamic and is expressed in terms of displacements.

The limit state concept of design of reinforced concrete structures takes into account the probabilistically and structurally variation in the material properties, loads and safety factors

2.3 Design Criteria for Loads

• Dead loads are calculated as per IS: 875 (Part 1) – 1987
• Imposed loads according to IS: 875 (Part 2) - 1987
• Seismic load according to IS: 1893 (Part 1): 2002 considering Nuwakot located at Zone I

2.4 Codes of Practices

Following codes of practices developed by Bureau of Indian Standards were followed in the analysis and design of building.

• **IS 456:2000** (Code of practice for reinforced concrete)
• **IS 1893(part 1):2002** (Criteria for earthquake resistant design of structures)
• **IS 13920:1993** (Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces)
• **IS 875(part 1):1987** (To access dead loads)
• **IS 875(part 2):1987** (To access live loads)
• **IS 875(part 5):1987** (For load combinations)
• **SP** 16 and **SP 34** (Design aids and hand books)

2.5 Idealization and Assumption in Analysis and Design

Various assumptions have been made in analysis and design of the structures, for consideration of simplicity and economy, viz.:

• Tensile strength of the concrete is ignored.
• Shrinkage and temperature strength are negligible.
• Adhesion between concrete and steel is adequate to develop full strength.
• Seismic and wind load do not occur simultaneously.
• Centerlines of beam, column and shear walls are concurrent everywhere.

2.7 Design

The following materials are adopted for the design of the elements:

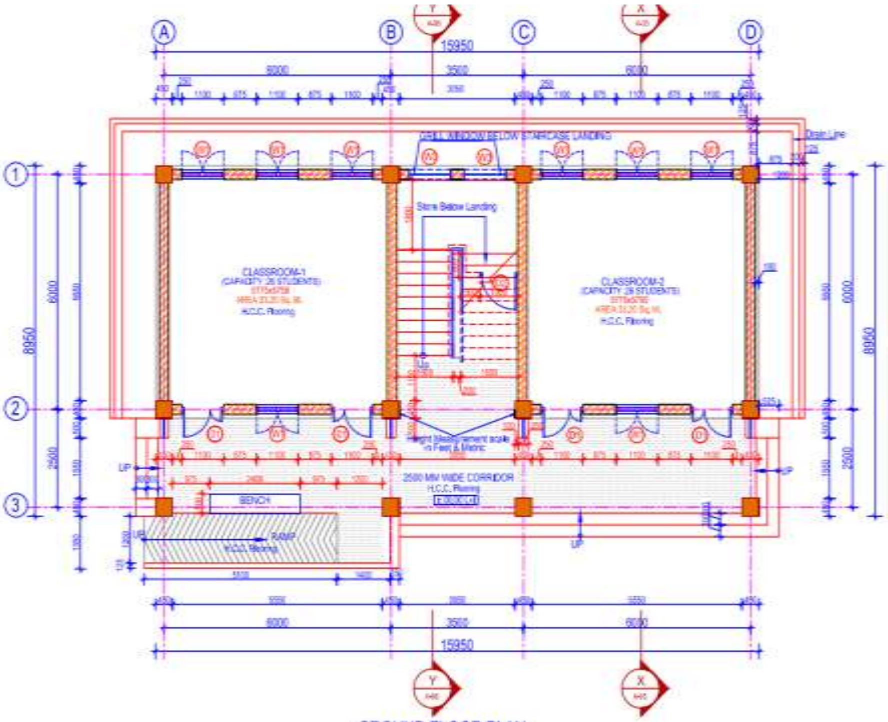
• Concrete Grade: M20
: M20 for Beam , slab and columns
• Reinforcement Steel: Fe 415
: Fe 415 for longitudinal as well as for lateral bar

Limit state method is used for the design of RC elements. The design is based on **IS:456- 2000**, **SP-16**, **IS:1893-2002** are extensively used in the progress of design.

The design moments, shear forces, axial forces are taken as computed by computer software program "**SAP2000 V15**" for the worst possible combination and a number of hand calculations are done so as to verify the reliability of the design results suggested by the software.

2.8 Detailing The structure is designed with due consideration to provide ductile behavior and comply with the requirements given in IS 13920:1993.

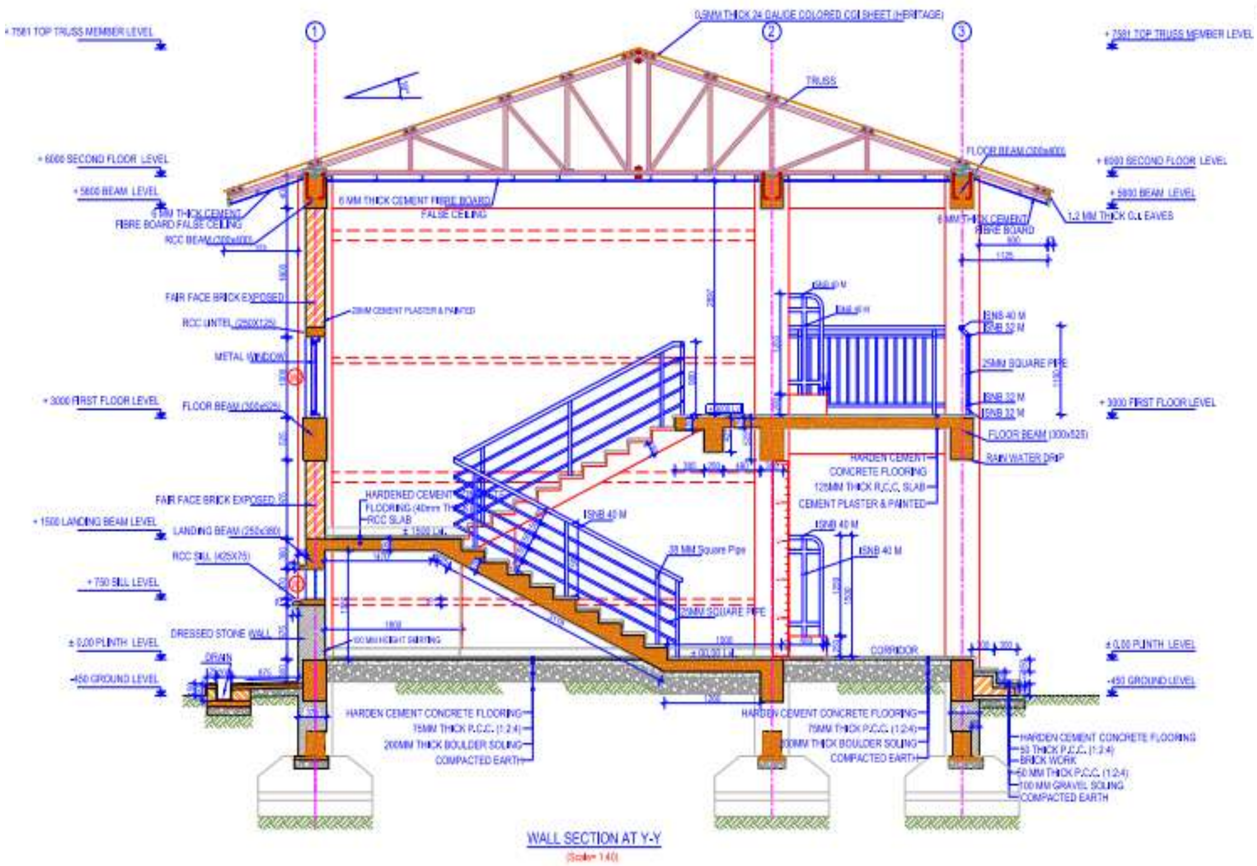
ARCHRTICTURAL DRAWINGS



GROUND FLOOR PLAN

Area = 142.75 Sq. M.


FRONT ELEVATION
0.5MM THICK 24 GAUGE COLORED CGI SHEET (HERITAGE)
FAIR-FACED BRICK WORK WITH CEMENT POINTING
DRESSED STONE WALL WITH CEMENT POINTING
SIDE ELEVATION
SIDE ELEVATION


0.5MM THICK 24 GAUGE COLORED CGI SHEET (HERITAGE)
TRUSS
+ 6000 SECOND FLOOR LEVEL
+ 5800 BEAM LEVEL
FAIR FACE BRICK EXPOSED
RCC LINTEL (250X125)
METAL WINDOW
+ 3000 FIRST FLOOR LEVEL
FLOOR BEAM (300x525)
+ 1500 LANDING BEAM LEVEL
LANDING BEAM (250x380)
RCC SILL (425X75)
+ 750 SILL LEVEL
± 0.00 PLINTH LEVEL
DRESSED STONE WALL
DRAIN
-450 GROUND LEVEL
HARDEN CEMENT CONCRETE FLOORING
75MM THICK P.C.C. (1:2:4)
200MM THICK BOULDER SOLING
COMPACTED EARTH
CORRIDOR
RAIN WATER DRIP
25MM SQUARE PIPE
1.2 MM THICK G.I. EAVES
WALL SECTION AT Y-Y

3.0 STRUCTURAL SYSTEM

3.1 Structural System

Any structure is made up of structural elements (load carrying, such as beams and columns) and non- structural elements (such as partitions, false ceilings, doors). The structural elements put together constitute the structural systems. Its function is to resist effectively the action of gravitational and environmental loads, and to transmit the resulting forces to the supporting ground without significantly disturbing the geometry, integrity and serviceability of the structure.

3.3 Guidelines

The following guidelines will be helpful in design of building:

1. Functional Design

• Provide happy environment inside as well as outside.
• Proper arrangements of room/halls.
• Good ventilation, lighting, acoustics, unobstructed view.

2. Structural Design

• Structural design is an art and science of understanding the behaviour of structural members subjected to loads and designing them with economy and elegance to give a safe, serviceable and durable structure.

3. Footings

The type of footing depends on the load carrying capacity of soil, type of loads, purpose of building etc. We have opted to make use of isolated footing design considerations and hence made the calculations as the code specified for the design.

At the preliminary design stage, calculation of reinforcement may be excessive, but it will be good to know the maximum steel required to check that it lies within a reasonable percentage of the concrete section and can be located in it without congestion. The approximate dimensions of structural element were determined in preliminary design so, that they act as guidelines in analysis and aid to make final design safe and economical.

4. Column

• Selecting the position of columns so as to reduce bending moments in beams.
• Avoid larger spans of beams.
• Maximum spans of beams carrying live load up to 5 KN/m2.
• Avoid larger center to center distance between columns.
• Avoid the projection of column outside the wall.
• Orient the column so that the depth of column is contained in the major plane of the bending or is perpendicular to the major axis of bending.
• Orient the column in grid pattern to resist the lateral force as per stiffness.

4. Beams

• Normally provided under walls.
• Below a heavy concentrated load to avoid these loads directly coming on slabs.
• Avoid the larger spacing of beams from deflection and cracking criteria.
• In building with live load less than 5KN/m2, the maximum spacing of beams may be limited to the value of maximum spans of slabs.

Foundation tie beam

It is beam which reduces slenderness of columns by acting as stiffener and it ties the footings at the foundation level.

- It is to reduce and to avoid overturning of footings.
- It is not to carry the slab load but just to act as a stiffener to the columns and thereby reduce the long columns effect.
- It keeps the footings in their positions during seismic events.

Plinth tie beam

It is a reinforced concrete beam constructed between the wall and its foundation as shown in below Figure-1

- Plinth beam is provided to prevent the extension or propagation of cracks from the foundation into the wall above when the foundation suffers from settlement.
- It distributes the loads of the wall over the foundation evenly.

• So it is mandatory to provide plinth beam in areas that prone to earthquake and construction of plinth beam above the natural ground is another application of this type of beam.

5. **Staircase**

• The rise R should not be more than 200mm and trade T not less than 200mm.
• For residential building the riser (R) may be between 150mm to 180mm and tread (T) between 220mm to 250mm.
• For public building the riser (R) may be kept between 120mm to 150mm and tread (T) between 250mm to 300mm.
• The sum of tread plus twice the rise (T+2R) should be between 500mm to 650mm.
• The width of stairs for residential building = 0.8m to 1m.
• The width of stairs for public building =1.8m to 2m.
• The width of landing should not be less than width of stairs.
• For comfortable ascend on stairs, the number of steps in each flight should not be greater than 38 degree.
• The head room measured vertically above any step or below mid-landing shall not be less than 2.1m.

6. **Slabs**

• A slab normally acts as a one way slab when the aspect ratio **Ly/Lx>2.**

•A two-way slab having aspect ratio **Ly/Lx<2** is generally economical compared to one-way slab because steel along both the spans acts as main steel and transfers the load to all its four corners.

• Spanning of slab is decided by the necessity of continuity to adjacent slab.

• Decide type of slab.

• Corner Balconies

3.4 Preliminary Design

For analysis of the building, it requires the rough idea on the member sizes used in the building as beam, column and slab. According to which the contributed dead load of the member to the structure could be estimated.

The size of the members is dependent on the limit state of serviceability on deflection and cracking. For this, the **IS code 456-2000** is referred to make sure.

4.0 LOAD ASSESMENT

4.1 Introduction

Structurally speaking, buildings are built to support loads. There are different types of loads which come across and have to be dealt with in the analysis and design of any structure. The proposed building is a RCC framed structure, located at Pokhara. Thus, wind loads, snow loads, and other special types of loads described by **IS: 875 (part 5):1987** can be taken as negligible as compared to the dead, live and seismic loads.

4.1.1 Dead Loads

According to the **IS 875:1987(Part I**),the dead load in a building shall comprise the weights of all walls, partitions, beam, column, floors and roofs and shall include the weights of all other permanent features in the building.

The correct thickness/size of the structural member (i.e. slab, beams and columns) cannot be ascertained before the structural analysis and design are finalized, thus some sizes need to assigned by experience and architectural consideration to begin with, checked and modified during preliminary design and finalized during detailed analysis and checking.

<u>Eccentricity of vertical loads:</u>

When transferring the loads from parapets, partition walls, cladding walls and façade walls etc. to the supporting beams or columns, the eccentricity with these loads should be properly considered in the case of rigid frames of reinforced concrete. Such eccentricities will produce externally-applied joint moments similar to these arising from projecting cantilevers and these should be included in frame design.

4.1.2 Live Loads

It means the load assumed or known resulting from the occupancy or use of a building and includes the load on balustrades and loads from movable goods, machinery and plant that are not an integral part of the building. These are to be chosen from codes as **IS:875-1987(Part 2**) for various occupancies where required. These codes permit certain modifications in the load intensities where large contributory areas are involved, or when the building consists of many stories.

Severe Catastrophic	No collapse of system which could cause loss of life.	Allow structure to enter into in-elastic range and absorb energy by providing ductility.

Table 4.1:Seismic Design Criteria

An earthquake-res

4.1.3 Earthquake loads

This load on a structure is function of the site-dependent probable maximum earthquake intensity or strong ground-motion on the local soil, the stiffness, damping the strength and energy-dissipation characteristics of the building, and its orientation in the relation to the incident seismic waves. These are the load resulting from the vibration of the ground underneath the super-structure during an earthquake. The earthquake is an unpredictable natural phenomenon. Nobody knows the exact timing and magnitude of such loads. Seismic loads are to be determined essentially to produce an earthquake resistant design. For design purpose, the resultant effects are usually represented by the horizontal and vertical seismic coefficient, α_x and α_y respectively.

Since the **probable maximum earthquake occurrence is not frequent, designing building for such earthquake isn't practical as well as economically prudent**. Instead, reliance is placed on kinetic dissipation in the structure through plastic deformation of elements and joints and the design forces are reduced accordingly. Thus, the philosophy of seismic design is **to obtain a no-collapse structure rather than no-damage structure. This is a sound economic proposition for not only the poor and undeveloped countries, but even for the developed ones as well**. To achieve the great degree of protection, the critical and important building are designed for higher seismic factor by using **IS:1893(part I)-2002. Since the total height of the structure is less than 40 m, <u>Seismic Coefficient Method as defined in clause 10.1 NBC 105:1994</u>** is used to calculate lateral load.

<u>Seismic Design Criteria:</u>

From **IS:1893(Part I)-2002** the criteria for seismic load is as follow;

Earthquake	**Desired Behaviour**	**Controlling Parameter**
Minor	No damage to non-structural Components.	Controlling deflection by providing adequate member size Stiffness.

Moderate	No significant structural damage, minor cracks in beams and column should be pre-dominantly elastic.	Avoid yielding of members or permanent damage by providing strength.

istant building has four virtues in it, namely:

i. Good Structural Configuration:

Its size, shape and structural system carrying loads are such that they ensure a direct and smooth flow of inertia forces to the ground.

ii. Lateral Strength:

The maximum lateral (horizontal) force that it can resist is such that the damage induced in it does not result in collapse.

iii. Adequate Stiffness:

Its lateral load resisting system is such that the earthquake-induced deformations in it do not damage its contents under low-to-moderate shaking.

iv. Good Ductility:

Its capacity to undergo large deformations under severe earthquake shaking even after yielding, is improved by favorable design and detailing strategies.

***Seismic codes cover all these aspects**

4.2 Estimation of Loads

It is most important step in structural design. Proper recording of them required for confusion free analysis.

• Dead loads:

i. Calculate the weight of those elements of building whose dimensions are fixed already from functional considerations and can be worked out carefully. These are generally non-structural elements and of parapets, rooftop, railings etc.

ii. From pre design, calculate weight of structural elements such as beam, column, slab etc.

iii. Put all loads systematically on sketches, say plan wise, showing their gravity lines with reference to column center-lines.

• Live loads:

Select live load intensity occupancy-wise as applicable for slabs and beams from the code and write this on plan. The reduction of live load intensities for the number of storey in the columns and that for calculating earthquake loads may be considered in the calculations later.

4.3 Load Combinations

In the course of analysis, different load cases and combinations are considered to obtain the most critical stresses in the element of the structure. The load cases considered for the structural analysis are:

a. Dead Load (DL)

b. Live Load (LL)

c. Earthquake load in X (EQx) static

d. Earthquake load in Y (EQx) static

e. Earthquake load in X (Rx) response spectrum method

f. Earthquake load in X (Ry) response spectrum method

The analysis was performed for various 13 combinations and time history separately. Following are those 13 combinations as suggested by **NBC.**

1) 1.5(DL + LL)
2) 1.5DL + 1.3 LL + 1.25EQx
3) 1.5 DL +1.3 LL-1.25 EQx
4) 1.5 DL +1.3 LL+1.25 EQy
5) 1.5 DL +1.3 LL-1.25 EQy
6) 1.0 DL +1.25 EQx
7) 1.0 DL -1.25 EQx
8) 1.0 DL +1.25 EQy
9) 1.0 DL - 1.25 EQy
10) 0.9 DL + 1.25 EQx
11) 0.9 DL - 1.25 EQx
12) 0.9 DL + 1.25 EQy
13) 0.9 DL - 1.25 EQy

6.0 DESIGN OF STRUCTURAL ELEMENT AND THEIR DETAILING

6.1 Design Procedure

Altogether, detailed designs have been done for five structural elements namely slab, beam, column, foundation and staircase.

6.1.4 Foundation

Foundations are the structural elements that transfer loads from the buildings or individual columns to the earth. If these loads are to be properly transmitted, foundations must be designed to prevent excessive settlement or rotation, to minimize differential settlement and to provide adequate safety against sliding and overturning.

Most foundations may be classified as:

- Isolated footings
- Strip foundation and wall footings
- Combined footings
- Raft or mat foundation
- Pile foundation

The choice of type of foundations to be used in any given situation depends on a number of factors, such as:

- Soil strata
- Type of structure
- Type of loads
- Economy
- Bearing capacity and standard penetration test value N of soil.
- Permissible differential settlement, etc.

The choice is usually made from experience but it is advisable to carry out a comparative study of different designs to determine the most economical.

Depth of foundation:

Depth of foundation governs the following factors:

- To penetrate below the zone where seasonal weather changes are likely to cause significant movement due to swelling and shrinkage of soils.
- To secure safe bearing capacity.
- To penetrate below the zone which may get affected by frost.

6.1.3 Column

The design of column is governed by limit state of axial compression and bending moments about two axes. Shear in column is small and shear stress work out to be safe. There are two kinds of reinforcement in column; longitudinal & transverse reinforcement. The purpose of transverse reinforcement is to hold vertical bars in position providing lateral support so that individual bars cannot buckle outwards and split the concrete. They are provided for confinement of concrete and lateral resistance. It should be noted that transverse reinforcement doesn't contribute to the strength of a column.

Moment in column change sign in each storey due to reversal of loads so that we generally provide symmetrical bar arrangement in a column section and steel area is kept constant through-out a given storey.

The following steps are followed in design of axially loaded column with biaxial bending:

i. Size of column.

ii. If slenderness ratio = l_e/LLD <12 , short column.

Where, LLd = Least Later Dimension

iii. Check for eccentricity;

e_{min} = L/500+D/30

And moment due to eccentricity = $P_u * e_{min}$

Reinforcement is equally distributed in two sides.

iv. Axial(P_u), Moments(M_{ux}&M_{uy}) are taken from SAP analysis.

v. Assume Percentage of reinforcement, p and carried out trial for this percentage.

vi. Find p/f_{ck}, d/D, and $P_u/f_{ck}bD$

vii. Find $M_u/F_{ck}bD^2$, Referring to the chart as per data obtain from step vi, from SP-16

viii. Calculation of P_{uz} using,

$P_{uz}= 0.45f_{ck}(A_g-pA_g/100)+0.75*pA_g/100$

ix. Find P_u/P_{uz}, M_{uy}/M_{uy1}, M_{uz}/M_{uz1} and α_n

x. Find $(M_{uy}/M_{uy1})^{\alpha n} + (M_{uz}/M_{uz1})^{\alpha n}$

xi. If $(M_{uy}/M_{uy1})^{\alpha n} + (M_{uz}/M_{uz1})^{\alpha n} <1.0$ O.K , if not next trial with changing p.

xii. Design of diameter and pitch of lateral ties:

- The diameter of lateral ties should not be less than one-fourth diameter of largest longitudinal bar.

  $D_T \geq D_s/4$ and

  ≥ 6 mm

- Pitches of ties;

Pitches of ties ≤ least lateral dimension
≤16D_s
≤300 mm
xiii. Check for ductility criteria

- The spacing of hoops shall not exceed half the LLD of column
- Special confining reinforcement shall be provided over a length l_0 from each joint face.

a. LLD
b. 1/6 of clear span of member.
c. 450 mm

- Lap splices shall be provided only in the central half of the member.

a. Hoops shall be provided over the entire splices spacing of which should be less than 150 mm c/c at splices.

6.1.2 Beam

The design of beam is governed by limit state of moment, shear and deflection. Shear stirrups will be provided to address excess shear beyond shear capacity and longitudinal bars for moments in the concrete section of the beam. Dimensions are adopted from pre-design and beam is designed as T-beam.
Design procedure of beam has followed as follows:

1. Size of beam for preliminary design.
2. Factored bending moment(M_u) and Factored shear force(V_u) SAP analysis.
3. Assuming diameter of reinforcement bars(d) with 40mm clear cover, effective depth is calculated as;
   i. $d = D\text{-}d/2\text{-}40$
4. Determination of limiting bending moment is calculated using following formula;
   i. $X_{ul} = 0.46d$
5. If $X_{ul}<D_f$, N.A lies in flange
   a. $M_{ul} = 0.36*b_f*d^2*f_{ck}*(1\text{-}0.416(X_u/d))$
6. If $X_{ul}>D_f$, N.A lies in flange,
   a. $M_{ul}= 0.36b_fd^2f_{ck}(1\text{-}0.42(X_u/d)) + 0.45f_{ck}(b_f\text{-}b_w)*Y_f(d\text{-}Y_f/2)$

   Where, $Y_f = 0.15X_u+0.65D_f$ or D_f whichever is less
7. If $M_u>M_{lim}$, Doubly reinforced section is designed.
8. If $M_u<M_{lim}$, Singly reinforced section is designed.
9. Assume $X_u = D_f$
   1. $M_{ul} = 0.36*b_f*d^2*f_{ck}*(1\text{-}0.416(X_u/d))$
10. *If* $M_{ul}> M_u$, N.A lies in flange
    i. $X_u/d = 1.2\text{-}(1.446\text{-}6.677*M_u/f_{ck}*b*d^2$
11. Area of tension steel required
    i. $A_{st} = M_u/(0.87f_y(d\text{-}0.416*X_u))$
12. Check for maximum area of tension steel from **IS 456:2000, clause 26.5.1.1(a). p46 & p47**

$A_o/bd = 0.85/f_y$
Check for maximum area of tension steel from **IS 456:2000,clause 26.5.1.1(a). p47**
$A_o = 0.04bD$

13. Check for shear

Permissible shear stress τ_c is taken from **IS 456:2000. Table 19, p79**
For design of P_t , Nominal shear stress , $\tau_v= V_u/bd$
$\tau_{c,max}$ is taken from **IS 456:2000, Table 20, p73** for designed grade of concrete.

14. If $\tau_c<\tau_v<\tau_{c,max}$, shear reinforcement is required.
15. Design shear force, $V_{us} = V_u\text{-}\tau_c bd$

$V_{us} = 0.87f_yA_{sv}d/X$

16. Area and spacing of stirrups is taken considering,

Spacing is minimum of
X ≤ 0.75dand ≤ 300mm.

17. Check for Ductility

We have, percentage of minimum and maximum area of reinforcement according to **IS 13920:1993,**
a. $P_{min}= 0.24(f_{ck})^{0.5}/f_y$ and,
b. $P_{max} = 2.5\%$

18. Ductility check for shear,
    i. Spacing, $x \leq d/4$
    ii. $\leq 8\phi$

iii. *≥100 mm*

6.1.1 Slab

Slab are the most widely used structural element forming floors and roofs of building for supporting loads normal to its surface. Slab may be simply supported or continuous over one or more supports and is classified according to nature of supports as; One-way slabs spanning in one direction, two-way slab spanning in both directions.

Slab panels are to be designed for the limit state of bending moment and deflection. The thickness of slab is governed by deflection, while the steel areas at mid span and support sections depend on the bending moments. The slab is designed for one meter wide strip.

The subsequent steps are followed to design the slab;

1. Clear size L_x and L_y.
2. Effectivedepth is taken from preliminary design.
3. Calculation of effective span:
4. $l_x = L_x + d$

$= L_x + 0.35$

Lesser of above these two value is taken

5. Calculation of load (DL and LL)
6. If $(L_y/L_x) \leq 2$, Two-way slab
7. Calculation of bending moment:

Positive and Negative moment coefficient (α_x and α_y) are taken from **IS 456:2000, table 26, P.91,** according to l_y/l_xratio.

Then, bending moment is calculated using following formula:

$Mx = \alpha_x w l^2_x$

$My = \alpha_y w l^2_y$

Where, M_x and M_y= moments on strips of unit width Spanning l_x and l_y respectively.

$\alpha_x$and α_y = Bending moment coefficient

l_y and l_x = length of short and long span

8. Effective depth from moment criteria is calculated to check the required effective depth for moment criteria using following formula:

- $M_u = 0.36 f_{ck} b x_m (d-0.42x_m)$

9. Area steel required for negative moment at continuous edge and positive moment at mid span:

For short span is calculated using following formula,

- $M_x = 0.87 f_y Ast_x (d-(f_y Ast_x/f_{ck} b))$

For long span is calculated using following formula,

- $M_x = 0.87 f_y Ast_x (d_1-(f_y Ast_x/f_{ck} b))$

Where, $d_1 = d-D_s-D_l/2$

D_s= Diameter of bars along short span

D_l= Diameter of bars along long span

10. Check minimum steel from code:

For Fe415, minimum area of steel = 0.12% of bD

11. Maximum spacing:

Spacing ≤3d

≤300 mm

12. Minimum area of steel required is provided in edge strip.
13. Corner steels (Torsion steel):

a. Area of each layer of steel at A

=75% of area required for maximum mid span moment

b. Area of each layer of steel at B

=50% of area of steel of A

14. Shear is check at the edge of short span;

$V_u = W_u L_x/2$

τ_v= v/bd$_1$

percentage of steel,

p= Ast$_y$/2bd$_1$

- for P & M20 grade of concrete, τ_c is taken from **IS 456:2000 table 19, p73**
- k is taken as per **IS 456:2000, clause 40.2.1.1, p72**
- If ,$\tau_c' = k * \tau_c > \tau_v$ O.K

15. Development length is checked at both short and long edge.

$L_d \leq 1.3M_1/V + L_0$

Or, $(0.87 f_y D_s/4\tau bd) \leq 1.3M_1/V + L_0$

16. Deflection is checked at mid span of short span according **to IS 456:2000, clause 23.2.1, p37**

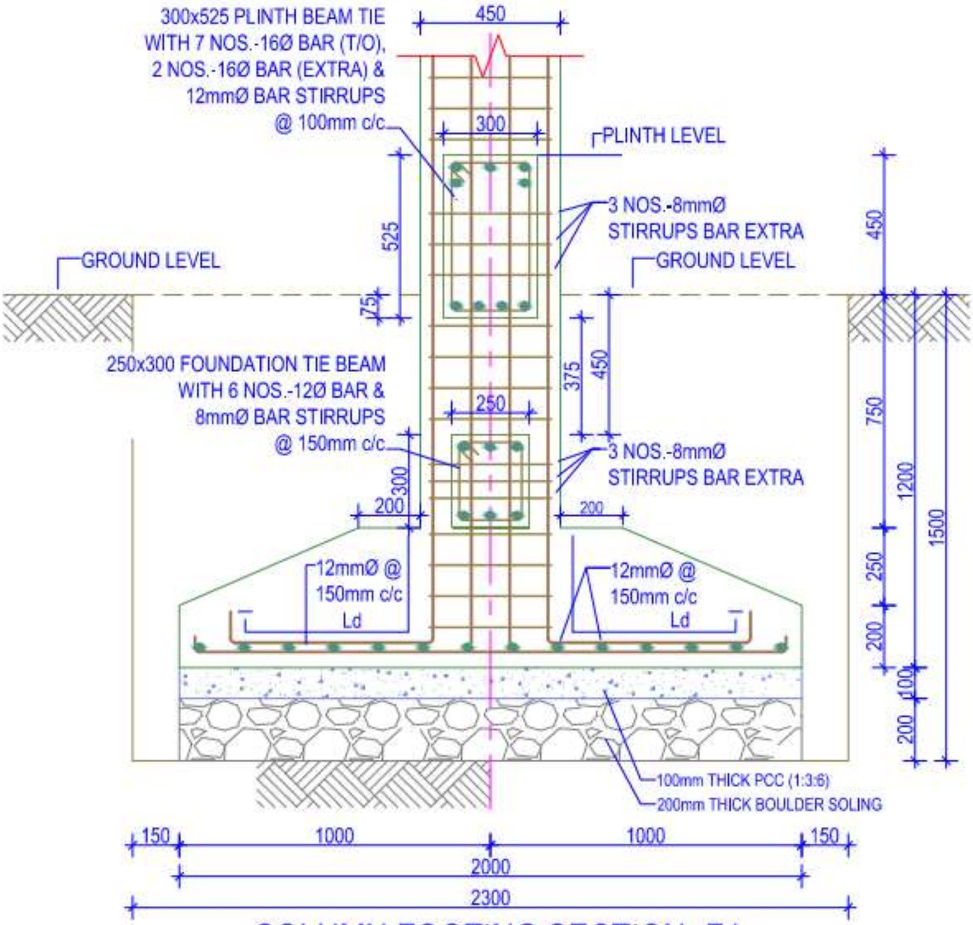
$L/d \leq \alpha\beta\gamma\delta\lambda$

6.2 Detailing of the Structure element

Reinforcement detailing of most of the important structural element has been shown in drawings. They are conformed to relevant section of the IS codes viz. IS: 456-2000, SP-16, SP-34 (S&T) and IS: 13920-1993.

6.2.4 Foundation:

The steel required in both directions should be distributed uniformly across the full width of the footing. Sufficient development length should be provided.

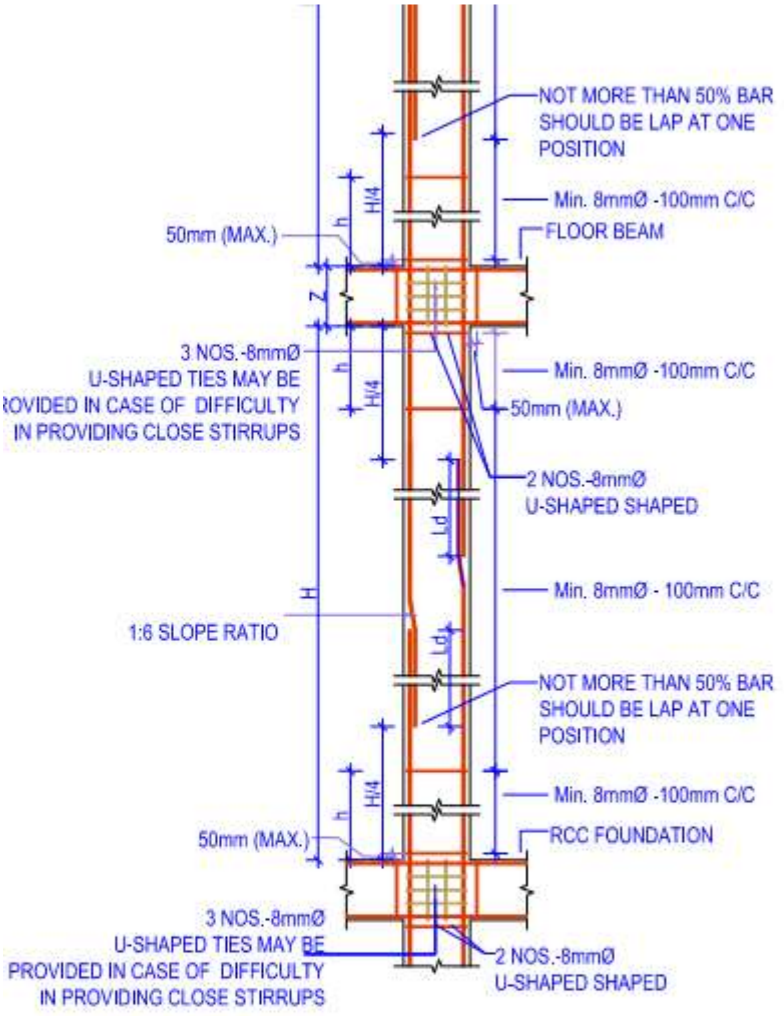


COLUMN FOOTING SECTION -F4

6.2.3 Column:

Column, the vertical member in reinforced concrete building has two sets of steel reinforcement, viz.

- Longitudinal bars, placed vertically along length of column, to resist flexural cracking on side that stretches.
- Lateral ties, closed small loops of small diameter steel bars placed horizontally at regular intervals along its full length.
- Development length(Ld) : 60 times dia of bar



TYP. COLUMN SHEAR REINFORCEMENT DETAIL

Lintel Band and Sill Bands

Horizontal Bands in masonry buildings are seismic bands consisting of reinforced concrete. The demand for masonry buildings is still a prominent method existing for building construction, it is necessary to bring up with additional innovations to make them performed more resistant towards the seismic demands.

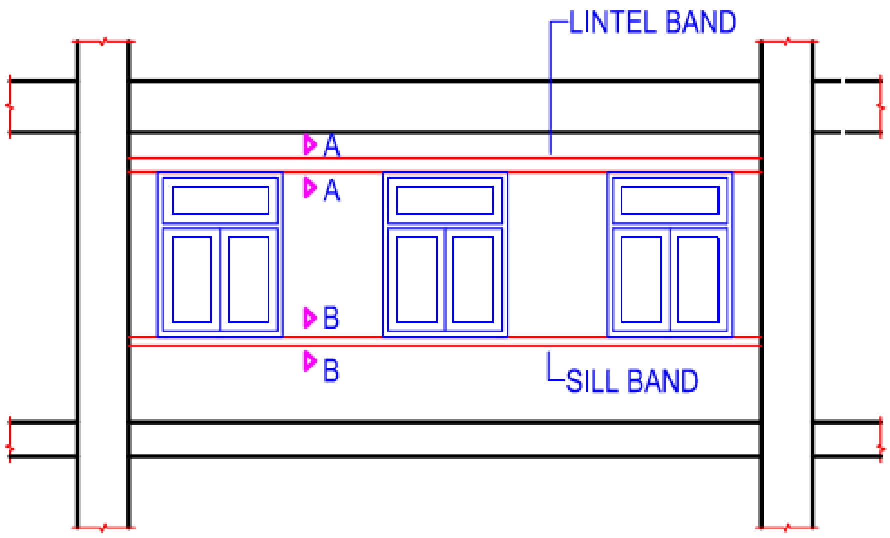
From past records, it has been seen that a higher rate of masonry buildings undergo certain collapse under earthquake motion. This is due to its brittle property that is it has no appreciable ductility stage.

One important methods of increasing seismic resistant of masonry building is by the incorporation of horizontal bands. The use of horizontal bands will help all the elements to be confined together as a single unit. This would have a total resistance from the whole building, other than having an individual contribution.

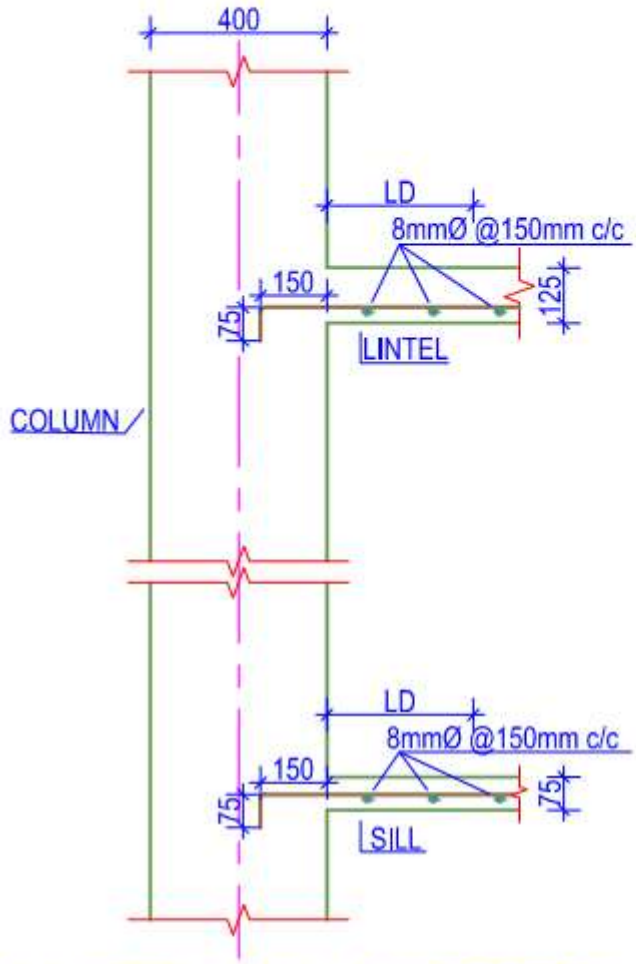
The horizontal Bands can be defined as a method of reinforcing the masonry buildings by providing bands with higher tension strength. This is enabled in areas where two structure elements of a building need, so that connection is formed altogether and they would behave like a single unit.

Horizontal bands are implemented at the following levels:-

- At the plinth level of building.
- At the levels lintels(i.e. at door & windows)
- At the ceiling level



ELEVATION OF WALL WITH LINTEL & SILL BAND



COLUMN ,LINTEL& SILL JOINT DETAIL

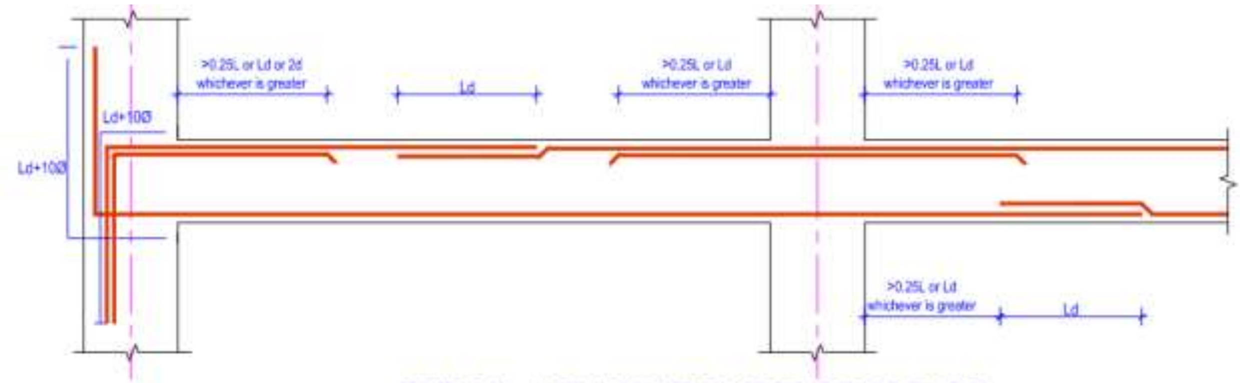
The recommendations on the design of horizontal bands are provided by IS :4326-1996 code of practice.

6.2.2 Beam:

Beam in reinforced concrete building have two sets of steel reinforcement, viz.

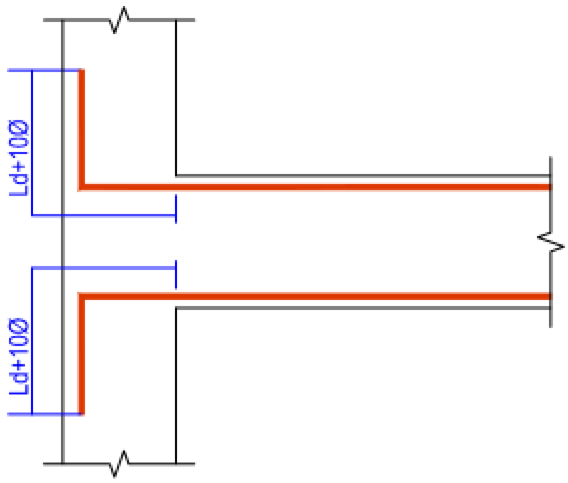
• Longitudinal bars, placed along length of beam, to resist flexural cracking on side that stretches.

• Stirrups, closed small loops of small diameter steel bars placed vertically at regular intervals along its full length.

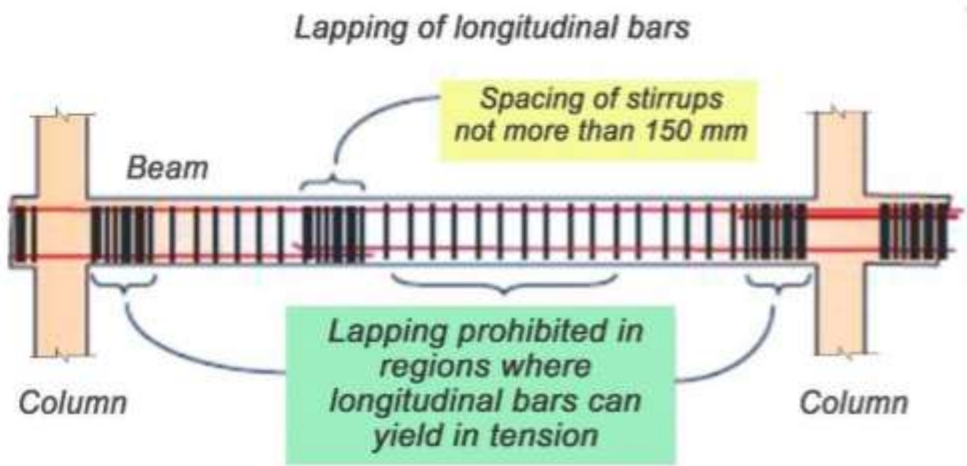


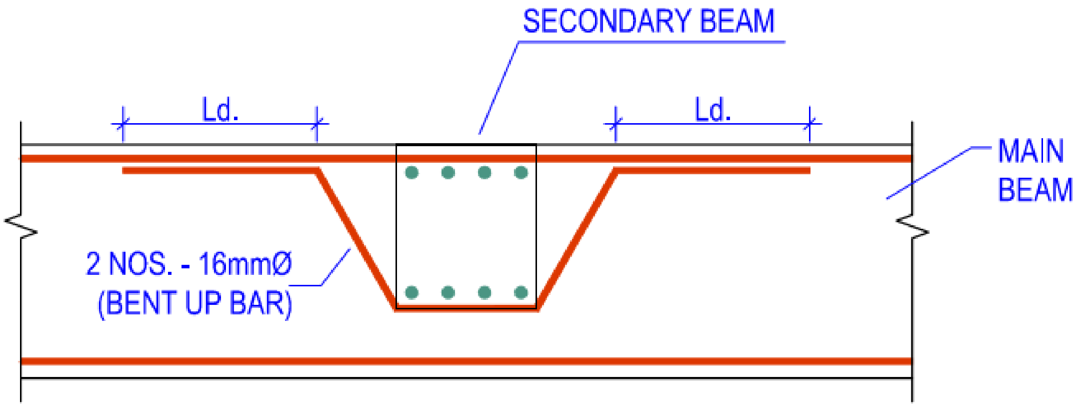
TYPICAL LAP LOCATION FOR BEAM BARS

6.2.3 Connection between Main Beam and Secondary Beam



CONNECTION DETAIL
BETWEEN
MAIN & SECONDARY BEAM
(PLAN)

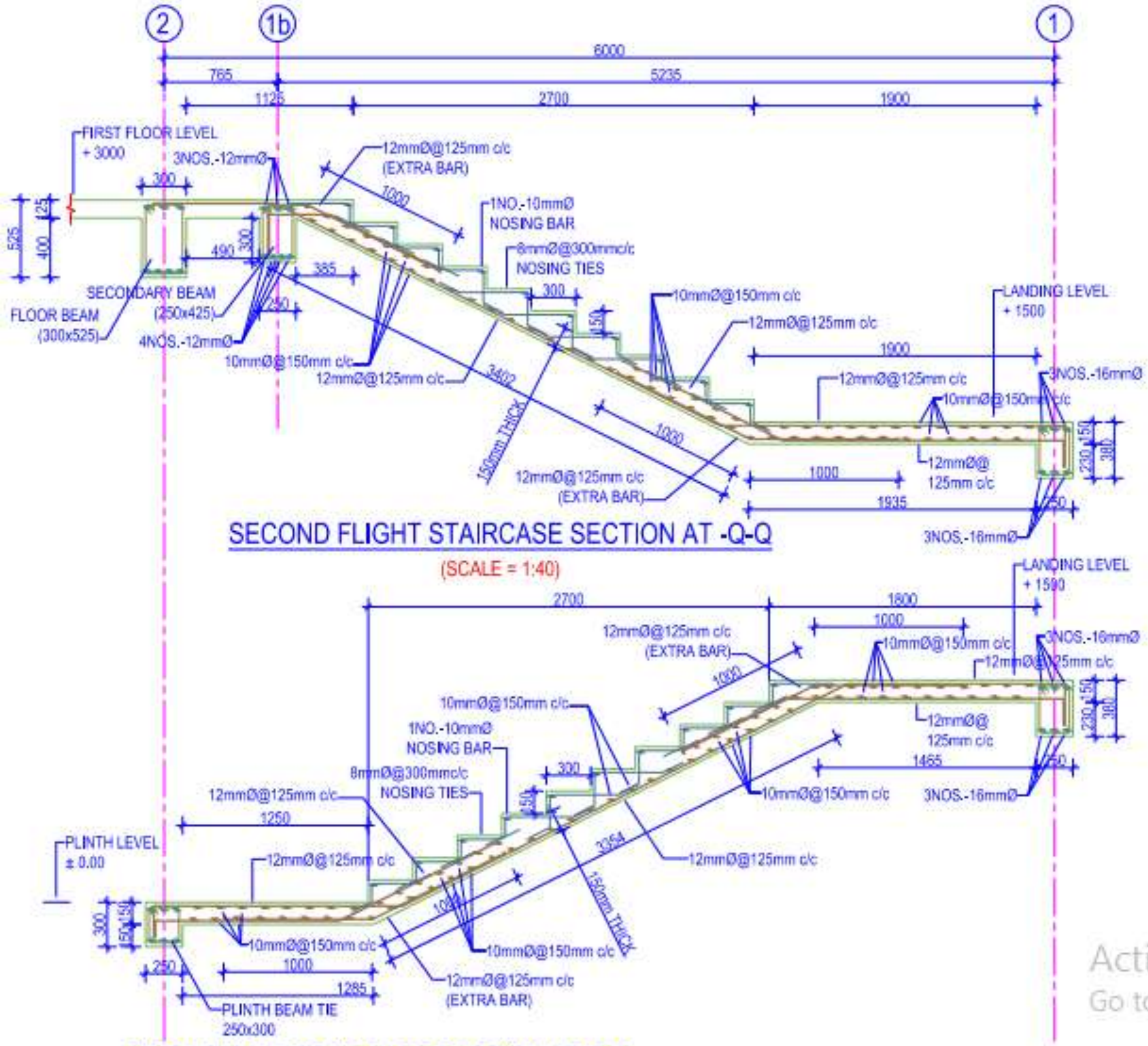




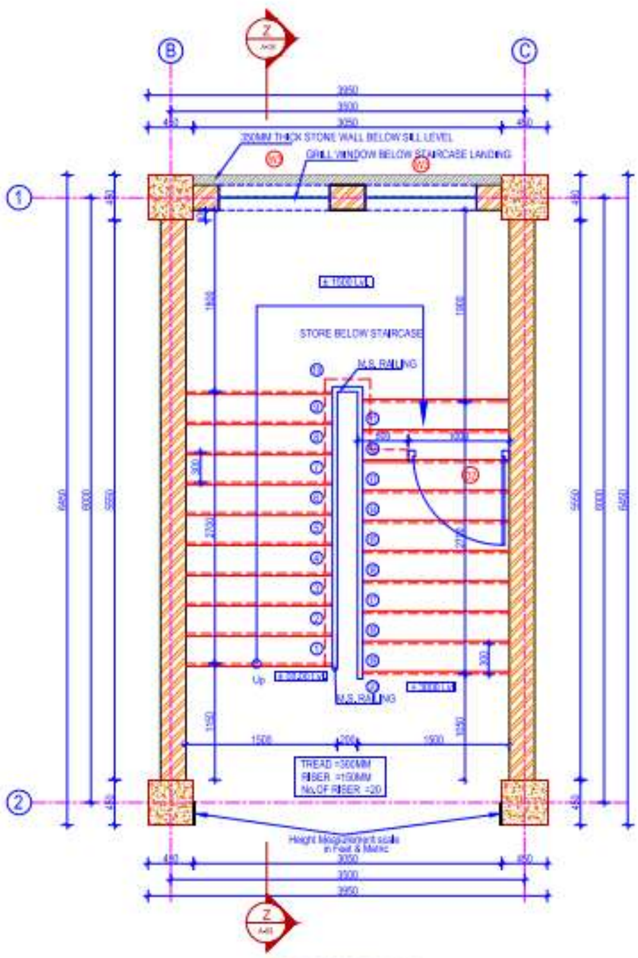
CONNECTION DETAIL BETWEEN
MAIN & SECONDARY BEAM

6.2.5 Staircase:

Care should be taken while detailing of corners such that the steel when pulled in tension does not tend to pull out the concrete over the reinforcement.



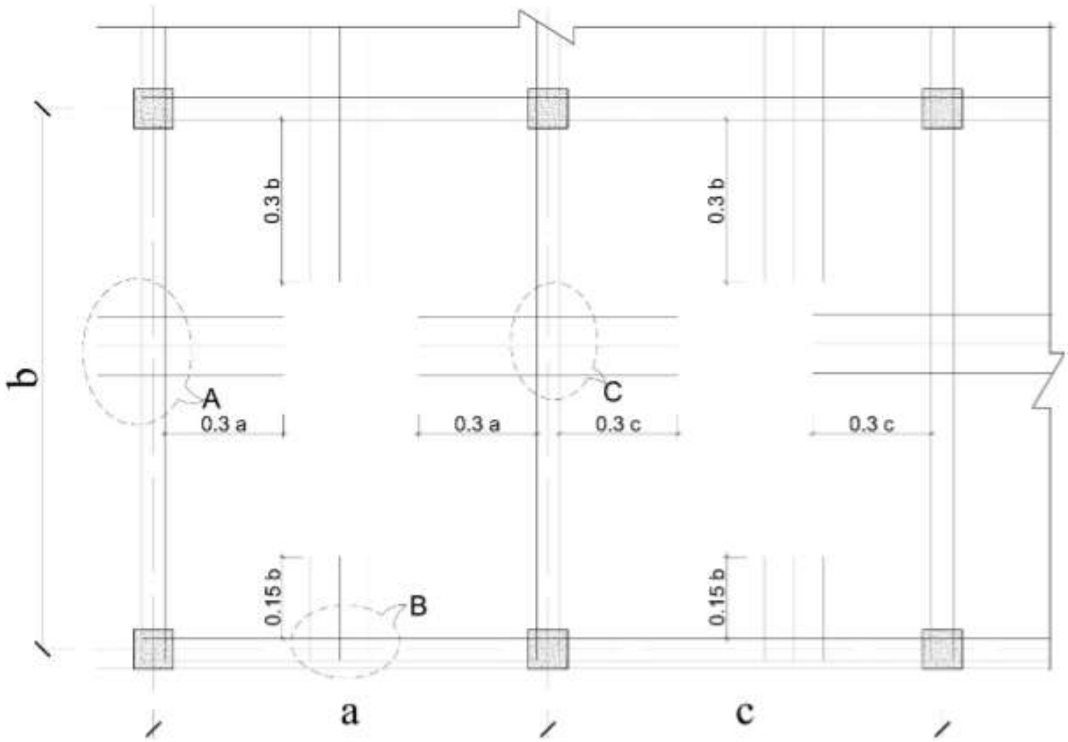
FIRST FLIGHT STAIRCASE SECTION AT -P-P



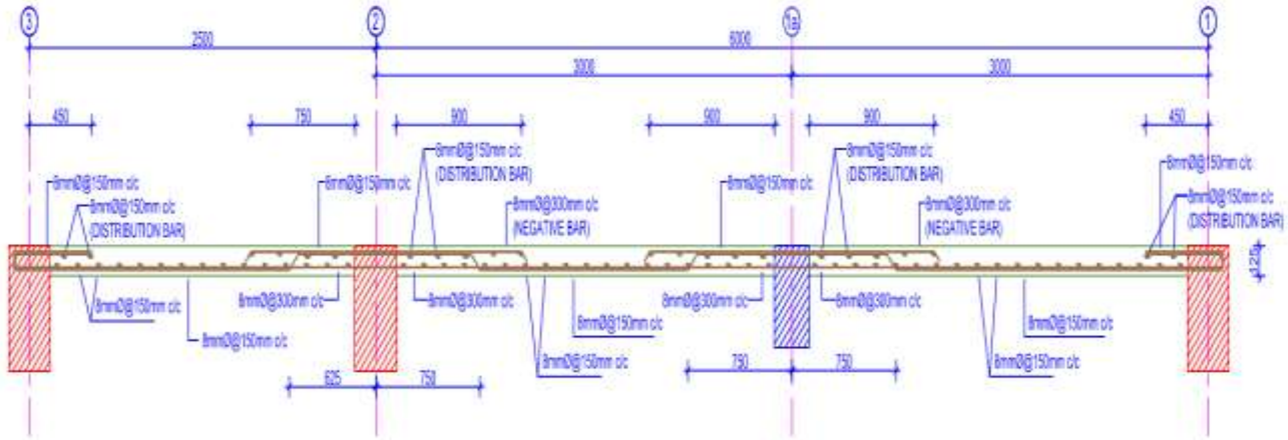
STAIRCASE PLAN

6.2.1 Slab:

While using design of two-way slabs with the help of coefficients, restrained slab are considered to be divided in each direction into middle and edge strips. The moments apply only to the middle strip and no further redistribution is allowed for these moments. The edge strips have to be reinforced only with nominal minimum steel for crack control. In addition, corner steel to resist the torsion stresses produced in these slabs are provided at dis-continuous edges.



Slab top extra reinforcement detail in x and y direction



SLAB SECTION -X-X

(SCALE = 1:30)

***Ductile detailing code IS: 13920-1993 should be strictly followed during detailing of structural elements.**

6.3 Ductility and Ductile Detailing

A ductile material is the one that can undergo larder strains while resisting loads. When applied to reinforced concrete members and structures, the term ductility implies the ability to sustain significant in-elastic deformations prior to collapse. It is the ratio of absolute maximum deformation or curvature or rotation to the corresponding yield deformation. Under reinforced section shows ductile deformation whereas over-reinforced section shows brittle deformation, so, ORS should be avoided while designing structural elements.

6.3.1 Significance of Ductility

While a ductile structure is subjected to overloading it will tend to deform in-elastically and in doing so, will re-distribute the excess load to elastic parts of the structure. This concept can be utilized in several ways:

1. If a structure is ductile, it can be expected to adapt to unexpected overloads, load reversals, impact and structural movements due to foundation settlement and volume changes. These items are generally ignored in analysis and design but assumed to have been taken care of by the presence of some ductility in the structure.
2. If a structure is ductile, its occupant will have sufficient warning of the impending failure thus reducing the probability of loss of life in the event of collapse.
3. The limit state design procedure assumes that all the critical section in the structure will reach their maximum capacities at design load for the structure. For this to occur, all joints and splices must be able to withstand forces and deformations corresponding to yielding of the reinforcement.

6.3.2 Variables Affecting Ductility

a. Tension steel ratio p
b. Compression steel ratio p
c. Shape of cross-section
d. Lateral reinforcement

6.3.3 Design for Ductility

Selection of cross-section having adequate strength is rather easy but it's more difficult to achieve desired strength as well as ductility. For this the designer should pay attention to detailing of reinforcement, bar cut-offs, splicing and joint details. Sufficient ductility can be ensured by following certain simple design details:

1. The structural layout should be simple and regular avoiding offsets of beam to columns, or offsets of column from floor to floor. Changes in stiffness should be gradual from floor to floor.
2. The amount of tensile reinforcement in beams should be restricted and more compression reinforcement should be provided. The later should be enclosed by stirrups to prevent it from buckling.
3. Beams and columns in a reinforced concrete frame should be designed in such a manner that inelasticity is confined to beams only and column remains elastic. To ensure this,
4. The shear reinforcement should be adequate to ensure that the strength in shear exceeds the strength in flexure and thus prevent from non-ductile failure.
5. Splices and anchorages must be sufficient to prevent bond failures.
6. Beam-column connections should be made monolithic.
7. The reversal of stresses in beam and column due to reversal of earthquake force must be taken into account in the design by appropriate reinforcement.

6.3.4 Detailing for Ductility (Based on IS 13920:1993)

1. At least two bars should be provided continuously both at top and bottom.
2. The positive moment resistance at the face of a joint should not be less than one-half of the negative moment resistance provided at that face of the joint.
3. Neither the negative nor the positive moment resistance at any section along the member length should be less than one-fourth of the maximum moment resistance provided at the face of either joint.

6.3.5 Nominal Cover

A reinforcing bar must be surrounded by concrete for the following principle reasons:

1. To develop the desired strength of a bar by ensuring proper bond between concrete and steel through-out its perimeter.
2. To provide protection against corrosion and fire.

Exposure	**Cover in mm**
Mild	20
Moderate	30
Severe	45
Very Severe	50
Extreme	75

Table 6.5: IS code 456-2000 Table-16 Nominal cover

FINAL BUILDING

Multipurpose Hall

2-4c(s)

If good designs are badly constructed they are not safe for school children.