ANALYSIS AND DESIGN OF (G+4) EARTHQUAKE RESISTANT BUILDING USING STAAD.Pro IN DIFFERENT SEISMIC ZONES

Dissertation submitted to

Shri Ramdeobaba College of Engineering & Management, Nagpur

in partial fulfillment of requirement for the award of

Degree of

Bachelor of Engineering

In

CIVIL ENGINEERING

Byz

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SHRI RAMDEOBABA COLLEGE OF ENGINEERING & MANAGEMENT, NAGPUR

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Department of Civil Engineering

CERTIFICATE

This is to certify that the Project Report on **"Analysis and Design of (G+4) Earthquake Resistant Building using STAAD.Pro in different Seismic Zones"** is a bonafide work of **Sakshi Watas, Nandini Dange, Shraddha Malve, Tanmay Bhansali** submitted to the Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur in partial fulfillment of the award of a Bachelor of Engineering, in Civil has been carried out at the Department of Civil Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur during the academic year 2018-19.

Date:

Place: Nagpur

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DECLARATION

We, hereby declare that the thesis titled **"Analysis and Design of (G+4) Earthquake Resistant Building using STAAD.Pro in different Seismic Zones."** submitted herein, has been carried out in the Department of Civil Engineering of Shri Ramdeobaba College of Engineering & Management, Nagpur. The work is original and has not been submitted earlier as a whole or part for the award of any degree / diploma at this or any other institution / University.

Date:

Place: Nagpur

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This thesis/dissertation/ project report entitled Analysis and Design of (G+4) Earthquake Resistant Building using STAAD.Pro in different Seismic Zones submitted by Sakshi Watas, Nandini Dange, Shraddha Malve, Tanmay Bhansali is approved for the degree of Bachelor of Engineering (Civil).

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Date: / / 2019

Place: Nagpur

ACKNOWLEDGEMENT

Being new in the field of structural engineering, our project topic needed studying of various topics that were useful for the analysis and design of (G + 4) earthquake resistant building.

We would respectfully like to thank our guide **Dr P. D. Hiwase**, who explained us the intricacies of our scope of work. He ensured that we were never short of data and relevant notes. His unconditional support and motivation helped us tremendously in retrieving the goal which we had set.

We would like to thank our **H.O.D. Dr. P. D. Pachpor** and other faculty members of the civil engineering department ensured that this project be conducted properly with utmost care. This project gave us the opportunity to test our capability in research work with regards to design of civil engineering structures.

We would like to express our gratitude towards our **Principal Dr. R. S. Pande** and the entire management for providing us the facilities to work in the department. We are also thankful to all our friends who helped us in completing our project and for their valuable support.

ABSTRACT

Earthquake resistant design of structures has grown into a true multi-disciplinary field of engineering wherein many exciting developments are possible in near future. Considering the field of structural designing, the basic requirement is the analysis of structures with seismic analysis prior to the construction. Earthquake causes vibratory ground motions at the base of structure and the structure actively responds to these motions. Response of a structure subjected to such motions due to the effect of earthquake is the seismic analysis. In this paper, a G + 4 residential building with ground floor as partial parking for analysis by using STAAD.PRO software has been considered. The calculation of base shear has been done manually and it has been compared to the results given by software. Various load combinations as per IS 1893-2002 were analyzed and designed on the basis of the worst combination. The quantity of steel and concrete has been compared with and without the effect of seismic forces pertaining to different earthquake zones.

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CHAPTER 1

INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1AIM

The aim of this project is to analyze and design an Earthquake Resistant (G+4) building.

1.2 SCOPE OF THE PROJECT:

A (G+4) residential building is to be designed to resist seismic loads and which can withstand an Earthquake with minimum damage following Indian Standard guidelines. Standard worldwide software, STAAD.Pro shall be used for analyzing and designing the building using Indian standard criteria and performing stability checks. The desired goal of the project is provision of better seismic protection through new and/ or improved design methods efficiently using software, thus acquainting us with the newer technologies and methods for design. The Provisions and the building codes in Indian Standards based on its recommendations are technical documents used primarily in the design and analysis of the residential buildings.

Furthermore, the design will consist the modern probabilistic approach of seismic design and deduce the shortcomings of the older force-based method of seismic design. However, response spectra won’t be used as it is required for design of high-rise buildings of G+12 and higher.

1.3 Introduction to Structural design:

Structural design is the methodical investigation of the stability, strength and rigidity of` structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life. The primary purpose of a structure is to transmit or support loads. If the structure is improperly designed or fabricated, or if the actual applied loads exceed the design specifications, the device will probably fail to perform its intended function, with possible serious consequences. A well engineered structure greatly minimizes the possibility of costly failures.

Structural design process:

There are three phases of structural design process, planning, design and construction.

1) Planning: It involves consideration of the various factors affecting the general layout and dimensions of the structure and results in the choice of one or perhaps several alternative types of structure, which offer the best general solution.
2) Design: The alternative solutions defined in the planning phase are considered in detail in the design of a structure. This results in the determination of the most suitable proportions, dimensions and details of the structural elements and connections for constructing each alternative structural arrangement being considered.
3) Construction: This includes mobilization of personnel; procurement of materials and equipment including their transportation to the site, and actual on-site erection. During construction, if unforeseen difficulties occur, some redesign may be required such as unavailability of specified materials or foundation problems.

1.4 INTRODUCTION TO STAAD.Pro

STAAD.Pro is a general purpose program for performing the analysis and design of a wide variety of types of structures. The basic three activities which are to be carried achieve that goal - a) model generation b) the calculations to obtain the analytical results c) result verification - are all facilitated by tools contained in the program's

In 21st century due to huge population the number of dwelling areas in units is decreasing day by day. Few years ago, the population was not so vast so the civil engineers used to stay in horizontal system (due to large area available per person).

Column and reinforcement shall be good enough to counteract these forces successfully. And the soil shall be good enough to pass the superstructure load successfully to the foundation. For loose soil it has been preferred to use deep foundation. If they do so much calculation for a high-rise building, manually then it will take more time as well as human errors may occur. This type of problem can be solved by STAAD.Pro along with IS-Codes. Moreover STAAD.Pro has a greater advantage than the manual technique as it gives more accurate and precise result than the manual technique.

1. Graphical model generation utilities as well as text editor-based commands for creating the mathematical model. Beam and column members are represented using lines. Walls, slabs and panel type entities are represented using triangular and quadrilateral finite elements. Solid blocks are represented using brick elements. These utilities allow you to create the geometry, assign properties, orient cross sections as desired, assign materials like steel, concrete, timber, aluminium, specify supports, apply loads explicitly as well as have the program generate loads, design parameters, etc.

2. Analysis engines for performing linear elastic and p-delta analysis, finite element analysis, frequency extraction, and dynamic response (spectrum, time history, steady state, etc.).

3. Design engines for code checking and optimization of steel, aluminium and timber members. Reinforcement calculations for concrete beams, columns, slabs and shear walls. Design of shear and moment connections for steel members.

4. Result viewing, result verification and report generation tools for examining displacement diagrams, bending moment and shear force diagrams, beam, plate and solid stress contours, etc.

5. Peripheral tools for activities like import and export of data from and to other widely accepted formats, links with other popular software for niche areas like reinforced and pre-stressed concrete slab design, footing design, steel connection design, etc.

6. A library of exposed functions called Open-STAAD which allows you to access STAAD.Pro’s internal functions and routines as well as its graphical commands to tap into STAAD‟s database and link input and output data to third-party software written using languages like C, C++, VB, VBA, FORTRAN, Java, Delphi, etc. Thus, Open-STAAD can be used to link in-house or third-party applications with STAAD.Pro

EARTHQUAKE

An earthquake is a sudden tremor or movement of the Earth's Crust which originates at or below the surface.

1.5 CAUSES OF EARTHQUAKE

1.5.1 THE EARTH AND ITS INTERIOR

The earth consists of following components

1) Inner core

2) Outer Core

3) The Mantle

4) The Crust

The Inner core is solid and comprises of heavy metals example Nickel, Andiron etc. Some light materials like Basalt, Granite, etc form the crust. The outer core is in liquid form and the Mantle has capability to flow.

The temperature is around 2500 degree Celsius at the core, pressure is around 4 million atmosphere and density is 13.5 gm/cc while on the surface of the earth, the temperature is 25 degree Celsius, pressure is 1 atm and density is around 1.5 gm/cc.

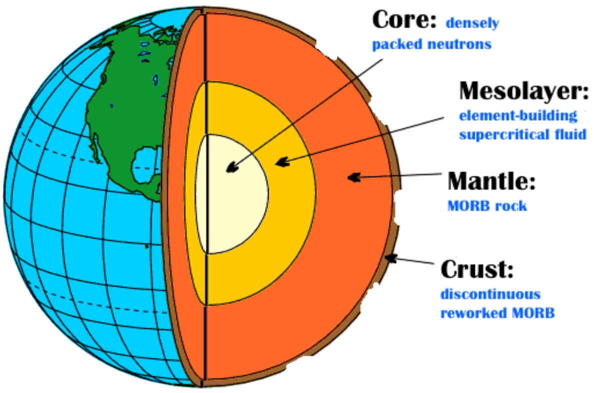


Figure 1.1 Interior Earth's Structure
(Source: Google)

1.5.2 TECTONIC PLATES

A piece of lithosphere that means like a rigid block without internal deformation on the Earth's atmosphere is called a tectonic plate. The structure and dynamics of Earth atmosphere is explained by Plate Tectonics theory. According to this theory, the lithosphere is fragmented into a series of plates that move over asthenosphere.

The motion of the plates, their addresses and interactions is also described by this theory. The lithosphere of earth consists of large plates, smaller plates or micro plates. There is concentrated seismic activity, volcanic and tectonic activity at the edges of plates. This results in formation of large chains and basins.

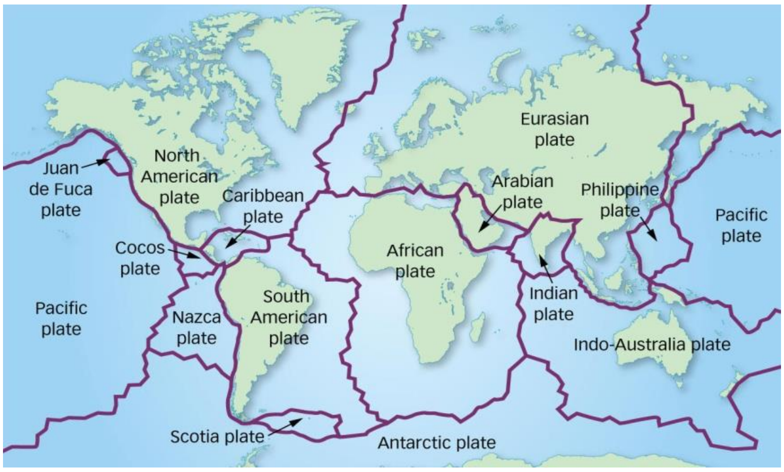


Figure 1.2 Tectonic plates of the Earth
(Source: Google)

There are two types of lithosphere plates and it depends on the kind of crust that forms the surface.

The two types of crust are

(1) Oceanic

(2) Continental

Oceanic plates: - Oceanic plates are completely covered with oceanic crust thin basic composition. Except presence of intra plate volcanic structures, oceanic plates appear immersed in its entirely. Emerged are highlighted by high island arcs in any of its edges. Some examples are located in the Pacific.

Mixed plates: -

These plates are of such characteristics that they are partly covered by Continental crust and partially by oceanic crust. This is because there would be lack of divergent type of edges in contour in a full continental plate.

The different boundaries of plates are as follows: -

(1) Divergent boundaries: -

These are formed where new crust is formed to fill the gap of plates to separate.

(2) Convergent boundaries: -

At the plate sinking another, the crust is destroyed and there comes convergent boundaries.

(3) Transform boundaries: -

It is present where the plates slide horizontally only with each other.

1.6 EFFECTS OF EARTHQUAKE

Shaking is main cause of damage by earthquake. Collapse of numerous objects, buildings and structures is caused by this shock. Due to this collapse of buildings, its inhabitants are trapped in rubble, often perish by being crushed.
Very heavy objects falling during an earthquake like furniture, suspended ceiling etc often causes a number of injuries and even death casualties reported differ depending upon intensity of earthquake

1.6.1 EFFECTS ON BUILDINGS AND INFRASTRUCTURE:

Serious damage:
Collapse of poor-quality building and no earthquake resistant features. Falling from ceiling, walls, partitions, balconies, exterior walls, cracks in the walls etc comes under partial collapse of building which causes serious damage. Also, fire caused by short and flammable materials, flooding from broken dams, water pipes etc.

- Slight damage:

This includes cracks in walls, chimney, tiles, pots etc. Also fall of ceramic tiling and broken glass causes damage especially when the fall from upper floor.

- Damage to infrastructure:

Damage to important supply systems including damage done to electricity, water, gas, etc and its installations. Due to settlements, landslides and mudslides, partial damage is done to the roads, bridges, tunnels, rails etc

1.6.2 EFFECTS ON HUMAN ACTION ANDREACTION:

The terrified people, especially children and the sick face psychological and physiological alterations. People might face panic assaults, they escape and actions caused by uncontrolled crowds, jumping from windows etc.
Consequences of improper actions on damaged buildings and affected people

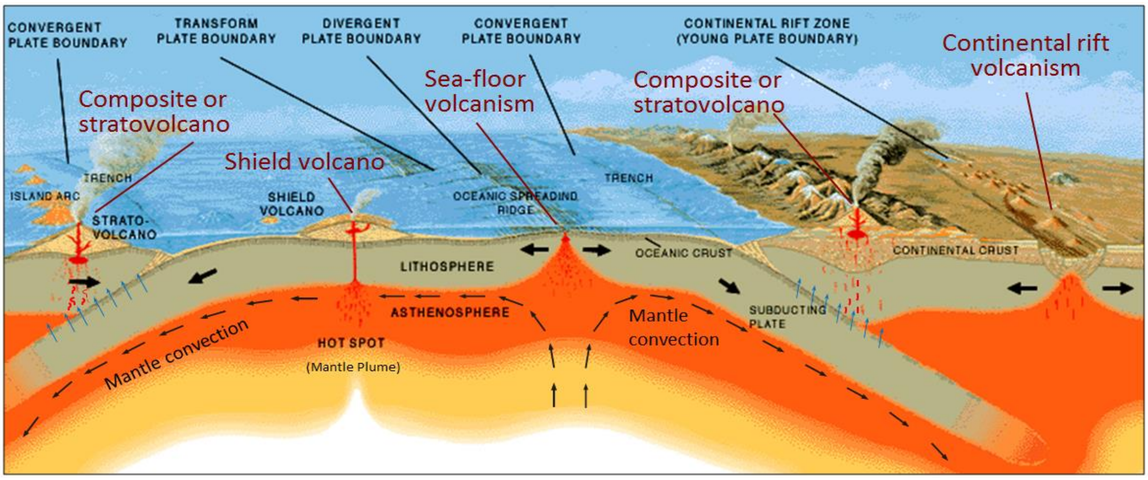


Figure 1.3 Effects of Continental Drift (Source: - Google)

1.7 DESIGN OF BUILDING TO RESIST EARTHQUAKEFORCES

1.7.1 CONFIGURATION OFBUILDING

We call configuration a set of features it has any structure, and according as designed will be the performance of the building to the gravity loads or dynamic loads. The configuration refers to the shape of the building as a whole, their size, nature and location of the resistant elements and non-structural.

1.7.2 SYMMETRY

The term symmetry describes a geometric property of the configuration of the building. A building is symmetric about two axes if the geometry is identical on either side of the axes in the horizontal or vertical plane.

There is structural symmetry if the center of mass and center of rigidity coincide on the ground.

1.7.3 MASS DISTRIBUTION AND CONCENTRATION

The distribution of masses must be as uniform as possible. It is desirable that the variation of the floor to floor mass accompanying the variation in stiffness. If the mass- stiffness varies sharply from one floor to another stress concentration occurs. It is desirable to solve the water supply system which avoids the construction of the voluminous water reserve at the highest level of the building.

1.7.4 DENSITY STRUCTURE INPLAN

The most efficient seismic configuration is which has the largest number of vertical elements at the base, that's where most needed.

A statistical measure may be the "density of the structure on the ground" at ground level, defined as the total area of all vertical structural elements divided by the gross floor area.in a modern building that area is 1%, in buildings with porticoes and walls amounts to 2%.

1.7.5 STIFFNESS

Stiffness is confused with resistance, but they are two different concepts, while resistance is the load capacity that can withstand before collapsing structural element, the stiffness measured the ability of a structural element has to resist being deformed. It is said that a body is more rigid the greater the load must be applied to achieve a given deformation. Analytically the stiffness of an element is expressed by the ratio between the load and strain it produces.

CHAPTER 2

LITERATURE REVIEW

LITERATURE SURVEY

1. EARTHQUAKE RESISTANT DESIGN OF MULTISTOREY STRUCTURE:

(Nishant Rathi, Birla Institute of Technology and Science, Pilani)

- Various examples, guidelines and commentary on codes by IIT Kanpur under sponsorship from Gujarat state disaster management authority (GSDMA) are helpful so as to understand seismic force calculation, there application and effect on structure, and design of frame for gravity and seismic loads.

- Design Example of a Six Storey Building- IITK-GSDMA-EQ26-V3.0, describes the detailed procedure for calculation of lateral forces, analysis of frame for gravity and lateral loads Explanatory Examples for Ductile Detailing of RC Buildings Document No. :: IITK-GSDMA-EQ22-V3.0 provides suitable reference for ductile detailing structural components such as beam column and joints.

- Design for lateral loads is an important aspect of multi-storey design. In this project major emphasis has been given in design of structural members considering earthquake load according to IS 1893 and then earthquake resistant design using IS 13920.

- This paper describes the use of analysis and design of RCC building with the help of standard software package STAAD Pro and Excel spread sheets considering earthquake load.

- Its easy to optimize the sections with the use of software package and to do the reanalysis and redesign of the whole structure with a greater speed.

2.STUDY ON EARTHQUAKE RESISTANT CONSTRUCTION TECHNIQUES.

(By Mohammad Adil Dar, Prof. (Dr.) A.R. Dar, Asim Qureshi, Jayalakshmi Raju, American Journal of Engineering Research (AJER), 2013)

- Apart from the modern techniques, there are some other old traditional earthquake resistant techniques which are effective for resisting earthquake loads and are also cost effective with easy constructability.

- Technology is available to drastically mitigate the earthquake related disasters. This is confirmed by minimal damage generally without any loss of life when moderate to severe earthquake strikes developed countries, whereas even a moderate earthquake causes huge devastation in developing countries as has been observed in recent earthquakes.

- The reason being that earthquake resistant measures are strictly followed in these countries where as such guidelines are miserably violated in developing countries.

- The administration system is 13 efficient and effective in developed countries, and its not the same in developing countries – so the government should ensure the implementation of earthquake resistant design guidelines. So it is here that civil engineers in general and structural engineers in particular have a great role to play in mitigating the sufferings.

3. FUTURE TRENDS IN EARTHQUAKE-RESISTANT DESIGN OF STRUCTURES.

(Durgesh C. Rai, Department of Earthquake Engineering, University of Roorkee)

- Whenever there is an earthquake-related disaster in the news with pictures of collapsed buildings and other structures strewn all over the place, one may probably think that earthquake-resistant design (EQRD) of structures is still in the dark ages. But over the years we have learned about building structures that will behave predictably and within acceptable damage limit and there is a bright future in this field

- Developments of new techniques and shifting to new materials, which are not traditionally used in civil engineering structures, offer significant promise in reducing seismic risk.

- Notable improvements have been made in our understanding of earthquakes and the response of structures. Advances in modelling ground motions; development of more involved and complex analysis

- In the coming years, the field of EQRD of structures is most likely to witness the following significant developments:
  (1) A complete probabilistic analysis and design approach that rationally accounts fort in the structural system will gradually replace deterministic approaches, especially in the characterization of the loading environment.
  (2) Performance-based design processes will take center stage, making conventional descriptive codes.
  (3) The acceptable risk criterion for design purposes will be prescribed in terms of performance adjectives and hazard levels.

4. SEISMIC ANALYSIS & DESIGN OF G+5 RESIDENTIAL BUILDING:

(K Aparna Srivastav, Prasad V Potluri, Department of Civil Engineering, Siddhartha Institute of Technology, Kanuru, Vijayawada, AP, India)

- In this paper the design of various building elements such as beam, column, slab & stairs by using software STAAD.Pro is shown.

- After designing & analyzing the structure on STAAD.Pro results are concluded. In this design of structure, the seismic loads dominate the wind loads.

- Wind pressure is high for high rise buildings.
  The storey drift condition under the structure consideration says that it is safe.

5. SUSTAINABLE EARTHQUAKE RESISTING SYSTEM:

(Mark Grigorian, Ph.D., S.E.1; and Carl E. Grigorian, Ph.D., S.E.2)

- A new design philosophy that leads to efficient earthquake-resisting systems is presented. Commercially available technologies are used to propose an archetype that is capable of damage control, elimination or reduction of residual stresses, collapse prevention (CP), and post-earthquake realignment and repairs (PERR).

- The new approach was inspired by the current state of knowledge and the need to develop sustainable earthquake-resisting systems. As a result, design-led analysis (DLA) was synthesized to develop repairable, earthquake-resistant rocking wall-moment frames .

- DLA is a displacement-based method of approach with built-in results.

6. PROBABILISTIC DESIGN OF EARTHQUAKE-RESISTANT STRUCTURES:
(By M. A. Austin,1 K. S. Pister/ and S. A. Mahin)

- This paper has described the significant sources of uncertainty and variation in the seismic environment, and a design methodology for accounting for these sources of uncertainty has been proposed.

- It has been demonstrated that the dissatisfaction function models effectively the relationship between response scatter and the corresponding level of frame response required to attain a target level of reliability.

- Preference pair parameters can be set to model situations in which the designer cannot define a problem with accuracy. Extra conservatism for important structures can be enforced without adjustment of the lateral loads.

- One simply decreases the values in the [HIGH, LOW] preference pair. The ability to designate HARD and SOFT constraint attributes is seen as a desirable feature, because it allows the designer to impart a solution strategy to solving a problem in much the same way as would be done in a manual design procedure.

- Finally, the proposed methodology is amenable to implementation in an interactive computing environment.

7. EARTHQUAKE BEHAVIOUR OF BUILDINGS:
(C. V. R. Murty, Rupen Goswami, A. R. Vijayanarayanan, Vipul V. Mehta)

In earthquake-resistant design of new buildings, design development process involves:

- Analyzing the building to capture desired seismic behaviour, i.e., performing suitable analyses of building to ensure the limited expected behavioural actions ALONE are realised in building during earthquake shaking.

- Designing the building to reflect that all assumptions made in analysis are honoured, and thereby controlling desired seismic behaviour through design of the new building

- Observing the building (during the next earthquake in the region where the building is built) to gain confidence in the design process or understand deficiencies in it.

- In assessment of earthquake resistance of existing buildings, safety assessment process involves marginally separate steps depending on whether the assessment is done after an earthquake or before it.

8. EARTHQUAKE TIPS:
(C. V. R. Murty)

- Dynamic actions are caused on buildings by both *wind* and *earthquakes*. But, design for wind forces and for earthquake effects are distinctly different.

- The intuitive philosophy of structural design uses *force* as the basis, which is consistent in wind design, wherein the building is subjected to a *pressure* on its exposed surface area; this is *force-type* loading.

- However, in earthquake design, the building is subjected to random motion of the ground at its base, which induces inertia forces in the building that in turn cause stresses; this is *displacement-type* loading.

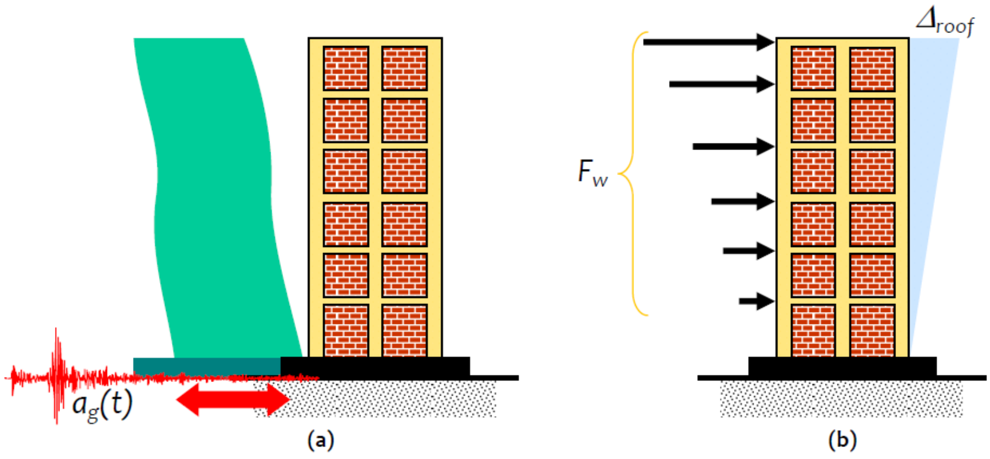


Fig. 2.1 Earthquake ground movement at the base and wind pressure on the exposed area

- The *mass* of the building being designed controls seismic design in addition to the building *stiffness*, because earthquake induces *inertia forces* that are proportional to the building mass.
- Designing buildings to behave elastically during earthquakes without damage may render the project economically unviable. As a consequence, it may be necessary for the structure to undergo damage and thereby dissipate the energy input to it during the earthquake.
- Therefore, the traditional *earthquake-resistant design* philosophy requires that normal buildings should be able to resist
  (a) ***Minor** (and frequent) shaking* with no damage to structural and non-structural elements;
  (b) ***Moderate** shaking* with minor damage to structural elements, and some damage to non-structural elements; and
  (c) ***Severe** (and infrequent) shaking* with damage to structural elements, but with NO collapse (to save life and property inside/adjoining the building).

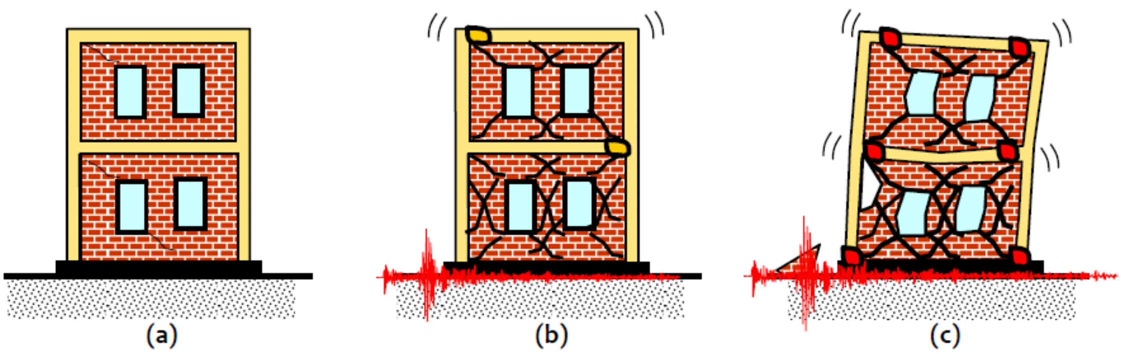


Figure 2.2: Earthquake-Resistant Design Philosophy for buildings: (a) Minor (Frequent) Shaking – No/Hardly any damage, (b) Moderate Shaking – Minor structural damage, and some non-structural damage, and (c) Severe (Infrequent) Shaking – Structural damage, but NO collapse

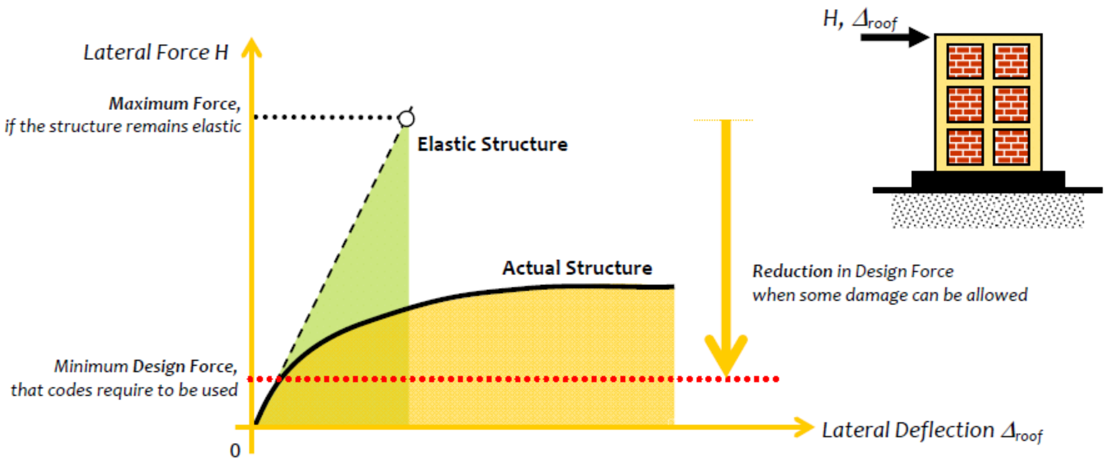


Figure 2.3: Basic strategy of earthquake design: Calculate maximum elastic forces and reduce by a factor to obtain design forces.

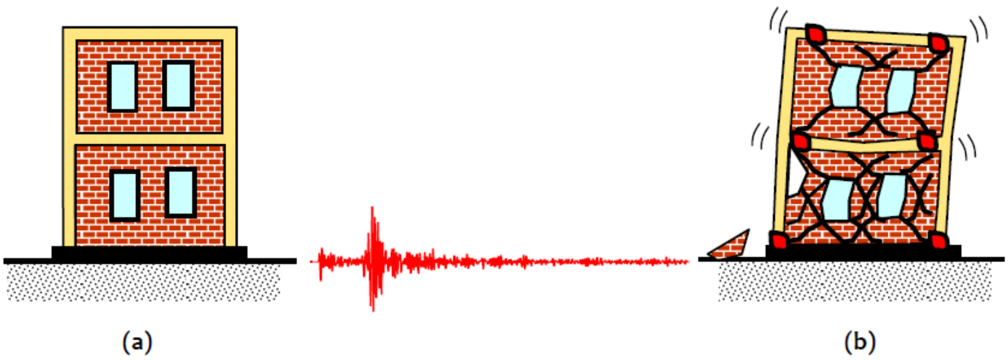


Figure 2.4 : Earthquake-Resistant and NOT Earthquake-Proof: Damage is expected during an earthquake in normal constructions (a) undamaged building, and (b) damaged building.

The design for only a fraction of the elastic level of seismic forces is possible, only if the building can stably withstand large displacement demand through structural damage without collapse and undue loss of strength. This property is called *ductility*. It is relatively simple to design structures to possess certain lateral strength and initial stiffness by appropriately proportioning the size and material of the members. But, achieving sufficient ductility is more involved and requires extensive laboratory tests on full-scale specimen to identify preferable methods of detailing.

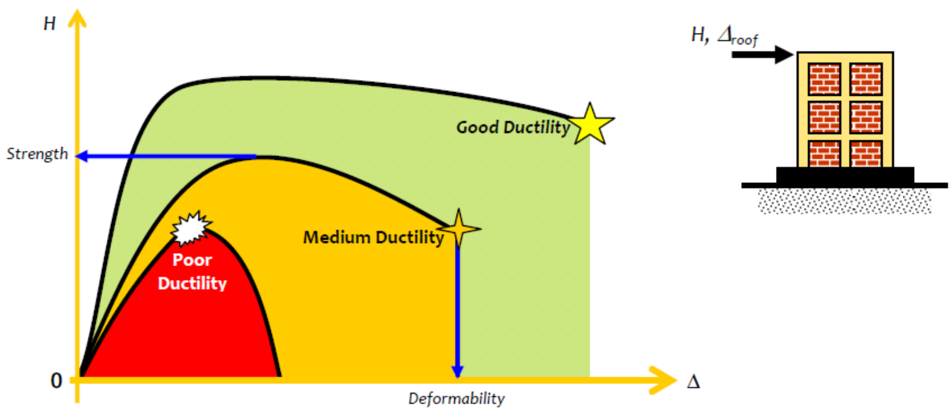


Figure 2.5: Ductility - types

9. **A COMPARATIVE STUDY ON ANALYSIS AND DESIGN OF MULTI-STOREYED (G+6) BUILDING BY STAAD.PRO AND SAP2000:**
(Bhargav Jyoti Borah, Amit Kalita, Manikuntala Sutradhar, Indranuj Pathak)

- The principle objective of this project is the comparative study on analysis and design of multi-storeyed building (G+6) by STAAD.Pro and SAP2000 software. STAAD.Pro is one of the leading software for design of structures.
- In this paper an attempt has been made to analyse a G+6 building for finding the shear forces, bending moments, deflections and reinforcement details for the structural components of the building.
- SAP2000 is also a leading design software in contemporary time used by many structural designers. Here an attempt has been made to analyse the same structure using SAP 2000 software.
- Finally results of analysis and design obtained using both STAAD.Pro AND SAP2000 are compared.

10. **Comparison between Manual and Software Approach towards Design of Structural Elements**
(Dr. P. D. Hiwase, Miss. Aditi Joshi, Mr. Aakash Keshariya)

- The use of various software's and learning of the same has become much easier and important.
- Big construction firms and ventures have switched their approach and have started using them for design purposes.
- This paper mainly ponders upon the comparison of analysis procured from the design of regular multi-storeyed structures using these user-friendly software's.
- In this paper, comparison of software's results with the manual calculations of a sample beam and column of the same structure designed as per IS 456 has been made.

11. **SEISMIC ANALYSIS AND DESIGN OF G+7 RESIDENTIAL BUILDING USING STAAD-PRO**
(BY B. GIREESH BABU)

- Structural designing requires structural analysis and earthquake or seismic analysis of any structure prior to construction. Earthquake or seismic analysis is the calculation of the response of a structure subjected to earthquake excitation.
- Various seismic data are necessary to carry out the seismic analysis of the structures in this study the seismic response of the structures is investigated under earthquake excitation expressed in the form of member forces, joint displacement, support reaction and story drift,
- The response is investigated for g+7 building structures by using STAAD PRO designing software. We observed the response reduction of cases Ordinary moment resisting frame.

- In this case, we have taken earthquake zone 2, response factor 3 for Ordinary moment resisting frame and importance factor 1. Initially, we started with the designing of simple 2-dimensional.

12. COMPARATIVE STUDY FOR SEISMIC ANALYSIS OF BUILDING USING DIFFERENT SOFTWARE
(Sumit Sharma, Ashish Yadav , Mukesh Dubey)

- This paper concern on the seismic analysis of G+12 building which is subjected to live, dead, seismic load as per IS codes.

- Earthquake occurred in any structure shows that if the structures are not designed for earthquake loads then it may lead to the complete collapse of the structures.

- To ensure safety against lateral forces that will act on multi-storied building hence, there is need to study of seismic analysis to design earthquake resistance structures.
  In this paper Base shear, time period and storey displacement is evaluated by using STAAD and Etabs software and the results are compared with IS1893 and this paper building is analyzed for zone IV.

- The study includes the modeling of building having plan areas 20mx20m and the height of storey is 3m. These analysis are carried out by considering zone IV with medium soil and using SMRF type building.

- The results obtained for base shear and other design parameters obtained from STAAD and Etabs software were compared and matched with IS1893:2002

13. Effect of Irregular Configurations on Seismic Vulnerability of RCC Buildings
(Ravikumar C. M., Babu Narayan K. S., Sujith B. V., Venkat Reddy D.)

- Many buildings in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes.

- In case, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one.

- The present paper made an attempt to study two kinds of irregularities in the building models namely plan irregularity with geometric and diaphragm discontinuity and vertical irregularity with setback and sloping ground.
  These irregularities are created as per clause 7.1 of IS 1893 (part1)2002 code.

- In Order to identify the most vulnerable building among the models considered, the various analytical approaches are performed to identify the seismic demands in both linear and nonlinear way.

- It is also examined the effect of three different lateral load patterns on the performance of various irregular buildings in pushover analysis.
  This study creates awareness about seismic vulnerability concept on practicing engineers.

CHAPTER 3

STUDY OF IS CODES

CHAPTER 3

STUDY OF IS CODES

INDIAN STANDARD PLAIN AND REINFORCED CONCRETE CODE OF PRACTICE

IS 456-2000

This Indian standard was adopted by the bureau of Indian standards, after the draft finalized by cement and concrete sectional committee had been approved by civil engineering division council this standard was first published in 1953 under the title "Code of Practice for Plain and Reinforced Concrete for general building construction" and subsequently revised in

1957. The code was further revised in 1964 and published under modified title "Code of practice for plain and reinforced concrete‟, thus enlarging the scope of use of this code to structures other than general building construction also. The third revision was published in 1978, and it included limit state approach to design. This is the fourth revision of the standard. This revision was taken up with a view to keeping abreast with the rapid development in the field of concrete technology and to bring in further modifications/ improvements in the light of experience gained while using the earlier version of the standard.

There are commonly two methods are used for the design of reinforced concrete structure/element:

1. WORKING STRESS METHOD (WSM)

This is the traditional method of design, used not only for reinforced concrete but also for structural steel and timber. This method ensures adequate safety by suitably restricting the stresses in the materials induced by the expected working loads on the structure. The assumption of linear elastic behavior is considered justifiable since the specified permissible stresses are kept well below the ultimate strength of the material. The WSM uses a factor of safety of about 3 with respect to the cube strength of concrete and a factor of safety of about 1.8 with respect to the yield strength of steel.

2. LIMIT STATE METHOD (LSM)

An ideal method is the one which takes into account not only the ultimate strength of the structure but also the serviceability and durability requirements. The newly engineering "limit state method" of design is oriented towards the simultaneous satisfaction of all these requirements. In the limit state method, a structure is designed for safety against collapse and checked for its serviceability at working loads, thus rendering the structure fit for its intended use. Thus, the LSM includes consideration of a structure at both the working and the ultimate load levels with a view to satisfy the requirements of safety and serviceability.

CLAUSES OF IS 456-2000 USED FOR DESIGN OF RCC STRUCTURES

<table>
<tr><td rowspan="2">DESCRIPTION</td><td colspan="2">IS 456 – 2000</td></tr>
<tr><td>CLAUSE</td><td>Contents</td></tr>
<tr><td>Elastic modulus for concrete and steel</td><td>6.2.3.1</td><td>$E_c = 5000\sqrt{f_{ck}}$ N/mm^2
$E_s = 200 \times 10^3$ N/mm^2
{Ec = Elastic Modulus of Concrete
Es = Elastic Modulus of Steel}</td></tr>
<tr><td>Mu limit</td><td>38.1</td><td><table>
<tr><td>GRADE OF CONCRETE</td><td>$M_{u\ lim}$</td></tr>
<tr><td>Fe250</td><td>$0.133 * f_{ck} * bd^2$</td></tr>
<tr><td>Fe415</td><td>$0.138 * f_{ck} * bd^2$</td></tr>
<tr><td>Fe500</td><td>$0.148 * fck * bd^2$</td></tr>
</table></td></tr>
</table>

Span to depth ratio in slab	23.2.1	Cantilever - 7 Simply supported - 20 Continuous – 26
Minimum reinforcement in slab	26.5.2.1	Plain bar - 0.15% High strength bar -0.12%
Nominal cover	26.4	▪ Column: not less than 40mm (When dimension is 200mm or size of bar is 12mm then cover is 25mm) ▪ Beam: not less than 20mm

T beams	23.1.1	For T beams:
		bf = lo/6+bw+6Df
		For L beams:
		bf = lo/12+bw+3Df
		bf = width of flange;
		bw = width of web;
		Df = depth of flange

Torsion	41.4.2	The longitudinal reinforcement shall be designed to resist an equivalent BM. M_{e1} = Mu + Mt $M_t=T_u*((1+D/b)/1.7)$ If $M_t > M_u$, then longitudinal reinforcement shall be provided on flexural compression face, such that beam can also withstand an equivalent M_{e2}, $M_{e2} = M_t - M_u$ M_u=Bending moment at the cross-section, T_u = Torsional moment D = overall depth of beam, b = width of beam

Minimum area of tension reinforcement	26.5.1.1 a	$Ast(min) = \frac{0.85*b*d}{f_y}$ {Ast(min) = minimum area of tension reinforcement; D = effective depth; b = breadth of beam; f_y = characteristic strength of reinforcement in N/mm^2}
Minimum horizontal distance between the bars	26.3.2	Greater of this following 1) larger diameter of the bars 2) Size of the aggregate+5mm Slabs: Main bars – 3d or 300mm Distribution bars – 5d or 450mm not greater than the above
Side face reinforcement	26.5.1.3	When depth > 750mm Total area of reinforcement = 0.1% area of the web and spacing not exceeding 300mm
Shear reinforcement	40.1	$T_v = \frac{Vu}{b*d}$ T_c= taken from table 19. Of IS code using P_t and f_{ck} values When $T_v < T_c$ shear reinforcement is not required.

Column reinforcement	26.5.3.1	0.8 to 6% of gross c/s area Minimum no. of bars rectangular - 4 bars circular - 6 bars Minimum dia.12mm Spacing of bars not greater than 300mm

		Spiral Reinforcement Ratio of volume of helical r/f to volume of core shall not be less than $0.36\ (\frac{Ag}{Ac} - 1)\ \frac{fck}{fy}$ Where, Ag= Gross Area Ac= Area of core of helically reinforced column
Column reinforcement	26.5.3.2 d	Maximum pitch not greater than 75mm LATERAL TIES: Pitch of the transverse reinforcement shall not be more than the least of the following - least lateral dimension - 16* dia. Longitudinal bar - 300mm dia. Of the lateral ties not less than ¼ of the largest longitudinal bar

Column reinforcement	39.3	$P_u = 0.4\, f_{ck} A_c + 0.67\, f_y A_{sc}$ A_c = area of concrete, A_{sc} = area of steel
Foundations Footing thickness	34.1.2	Thickness at the edge Footing on soil not less than 150mm Piles – 300mm
Footing - Critical section for shear	34.2.4.2	D / 2 distance all-round the face of the column
Minimum reinforcement in footings	34.5.2	Nominal reinforcement for concrete thickness greater than 1m shall be 360mm^2.this provision does not supersede the requirement of the min. tensile reinforcement based on depth calculation Longitudinal reinforcement at least 0.5% of the c/s area of the supported column

Development length of bars	26.2.1	τ_{bd} is taken from the table 26.2.1.1 $Ld = \frac{\emptyset * \sigma s}{4\tau bd}$ Where τ_{bd} = design bond stress σ_s = Stress in bar at the section considered at design load Φ = Nominal diameter of bar

INDIAN STANDARD

CRITERIA FOR EARTHQUAKERESISTANT

DESIGN OF STRUCTURES

IS 1893–2002

INTRODUCTION

IS 1893-2002 now revised to IS 1893-2016 was adopted by the Bureau of Indian Standards, after the draft finalized by the Earthquake Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

It is to serve this purpose that IS 1893:1962 Recommendations for earthquake resistant design of structures‟ was published and revised first time in1966.

As a result of additional seismic data collected in India and further knowledge and experience gained since the publication of the first revision of this standard, the sectional committee felt the need to revise the standard again incorporating many changes, such as revision of maps showing seismic zones and epicenters, and adding a more rational approach for design of buildings and sub-structures of bridges. These were covered in the second revision of 1S 1893 brought out in1970.

As a result of the increased use of the standard, considerable amount of suggestions were received for modifying some of the provisions of the standard and, therefore, third revision of the standard was brought out in 1975. The following changes were incorporated in the third revision

a) The standard incorporated seismic zone factors (previously given as multiplying factors in the second revision) on a more rational basis.
b) Importance factors were introduced to account for the varying degrees of importance for various structures.
c) In the clauses for design of multistoried buildings, the coefficient of flexibility was given in the form of a curve with respect to period of buildings.
d) A more rational formula was used to combine modal shear forces.

New clauses were introduced for determination of hydrodynamic pressure.

6.4.2	Design horizontal seismic coefficient Z = Zone factor based on MCE and service life of structure (Table 2) I = Importance factor based on utility or importance of structure (Table 6) R = Response reduction factor based on ductility (Table 7). I/R shall not be greater than 1 Sa/g = Average response acceleration coefficient

6.4.2

TABLE

NO.2

SEISMIC ZONE	I	II	III	IV
SEISMIC INTENSITY	LOW	MODERATE	SEVERE	VERY SEVERE
ZONE FACTOR	0.1	0.16	0.24	0.36

6.4.2

TABLE

NO.3

Damping percent	0	2	5	7	10	15	20	25	30
Factors	3	1.4	1	0.9	0.8	0.7	0.6	0.55	0.5

6.4.2

TABLE

NO.6

STRUCTURE	IMPORTANCE FACTOR
Important structure like hospital, stations, school	1.5
All other buildings	1

7.6	Fundamental natural period • The approximate fundamental natural period of vibration (T'), in seconds, of a moment-resisting frame building without panels may be estimated by the empirical expression: T' = 0.075 $h^{0.75}$ for RC frame building = 0.085 $h^{0.75}$ for steel frame building

CLAUSES OF IS 1893-2002 USED FOR CALCULATION OF SEISMIC FORCE

	• For all other building $T_a = 0.09h/\sqrt{d}$ h = height of building in m. d = Base dimension at plinth level in m along considered direction
6.4.5	Spectral acceleration coefficient (S_a/g) ▪ S_a/g based on foundation strata, natural time period and damping (Refer Figure2) -For rocky or hard soils Sa/g = 1+ 15T 0.0≤ T ≥ 0.1 = 2.5 0.1≤ T ≥ 0.4 = 1/T 0.4≤ T ≥ 4.0 -For medium soils Sa/g = 1+ 15T 0.0≤ T ≥ 0.1 = 2.5 0.1≤ T ≥ 0.55 = 1.36/T 0.55 ≤ T ≥ 4.0 -For soft soil Sa/g = 1+ 15T 0.0 ≤ T ≥ 0.1 = 2.5 0.1 ≤ T ≥ 0.4 = 1.67 0.4 ≤ T ≥ 4.0
7.5	Lateral Force base shear $Qi = Vb \frac{Wihi^2}{\sum_{j=1}^{n} Wjhj^2}$ Where, Qi = Design lateral force at floor Wi = Seismic weight of floor hi = height of floor from base n = number of storey in the building

INDIAN STANDARD CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE)

FOR BUILDINGS AND STRUCTURES

IS 875 (Part 1)–1987

PART 1: DEAD LOADS - UNIT WEIGHTS OF BUILDING MATERIAU AND STORED MATERIALS

INTRODUCTION

This Indian Standard (Part I) (Second Revision) was adopted by the bureau of Indian Standards on 30 October 1987, after the draft finalized by the Structural SafetySectional Committee had been approved by the Civil Engineering Division Council.

A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in this code by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, snow loads and other external loads, the structure would be required to bear.

This Indian standard code of practice was first published in 1957 for the guidance of civil engineers, designers and architects associated with planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs both curved and sloping, were modified; seismic load provisions were deleted (separate code having 3 been prepared) and metric system of weights and measurements was adopted.

With the increased adoption of the code, a number of comments were received on provisions on live load values adopted for different occupancies. Simultaneously, live load surveys have been carried out in America and Canada to arrive at realistic live loads . Keeping this in view and other developments in the field of wind engineering; the Sectional Committee responsible for the preparation of the standard has decided to prepare the second revision in the following five parts:

Part 1 Dead loads
Part 2 Imposed loads
Part 3 Wind loads
Part 4 Snow loads
Part 5 Special loads and loads combinations

INDIAN STANDARD CODEFOR

DUCTILE DETAILING OF REINFORCED CONCRETE STRUCTURES

SUBJECTED TO SEISMIC FORCES

IS 13920: 1993(Reaffirmed2003)

This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse.

Provisions of this code shall be adopted in all reinforced concrete structures which satisfy one of the following four conditions.

a) The structure is located in seismic zone IV or V;

b) The structure is located in seismic zone III and has the importance factor (I) greater than 1.0;

c) The structure is located in seismic zone III and is an industrial structure and

d) The structure is located in seismic zone III and is more than 5 storey high.

The provisions for reinforced concrete construction given herein apply specifically to monolithic reinforced concrete construction. Precast and/or prestressed concrete members may be used only if they can provide the same level of ductility as that of a monolithic reinforced concrete construction during or after an earthquake.

For the purpose of this standard, the following definitions shall apply.

- Boundary Elements: Portions along the edges of a shear wall that are strengthened by longitudinal and transverse reinforcement. They may have the same thickness as that of the wall web.

- Crosstie: Is a continuous bar having a 135^o hook with a IO-diameter extension (but not < 75 mm) at each end. The hooks shall engage peripheral longitudinal bars.

- Curvature Ductility: Is the ratio of curvature at the ultimate strength of the section to the curvature at first yield of tension steel in the section.

- Heap: Is a closed stirrup having a 135^o hook with a lo-diameter extension (but not < 75 mm) at each end that is embedded in the confined core of the section. It may also be made of two pieces of reinforcement; a U-stirrup with a 135^o hook and a lo-diameter extension (but not < 75 mm) at each end, embedded in the confined core and a crosstie.

- Lateral Force Resisting System: Is that part of the structural system which resists the forces induced by earthquake.
- Shear Wall: A wall that is primarily designed to resist lateral forces in its own plane.
- Space Frame: A three-dimensional structural system composed of interconnected members, without shear or bearing walls, so as to function as a complete 1 IS 13920: 1993 self-contained unit with or without the aid of horizontal diaphragms or floor bracing systems.

CLAUSES OF IS 13920:1993 USED FOR REINFORCEMENT DETAILING

DESCRIPTION	CLAUSE	CONTENT
FLEXURE MEMBER		
Axle load	6.1.1	The factored axle stresses on the member under earthquake loading shall not exceed0.1f_{ck}.
Width to depth ratio	6.1.2	The member shall have width to depth ratio more than 0.3.
Width	6.1.3	The width of member shall not less than 0.2 m.
Depth	6.1.4	The depth of the member shall preferably be not more than one fourth of clear span.
LONGITUDNAL REINFORCEMENT		
Top and bottom r/f	6.2.1(a)	The top and bottom r/f shall contain atleast two bars throughout the length.

Tension steel	6.2.1(b)	The tension steel ratio at any face at any section shall not be less than $p_{min} = 0.24\sqrt{\frac{fck}{fy}}$.
Maximum steel ratio	6.2.2	0.025
Positive steel	6.2.3	Positive steel at the joint face must be equal to half of half of negative steel ate the joint face.
Provision of steel	6.2.4	Steel provided at each of the top and bottom face of the member at any section along its length shall be at least equal to one fourth of maximum negative steel provided at the face of either joints.
External joints	6.2.5	In external joints both top and bottom bars of the beam provided with anchorage length = development length in tension +10times the diameter of bar.
Longitudinal bar	6.2..6	The longitudinal bar shall be spliced only if hoop are provided over the entire splice length at spacing not less than 150mm.
WEB REINFORCEMENT	6.3	
Vertical hoops	6.3.1	Web r/f consist of vertical hoops. Vertical hoop is a closed stirrups having a 135^0 hook with a 10-diameter of extension (but not less than 75mm) at each end that is embedded in confined core.

Minimum diameter of hoop	6.3.2	The minimum diameter of bar forming hoop shall be 6mm. however, in beam with clear span exceeding 5m, the minimum bar diameter shall be 8mm.
Shear force	6.3.3	The shear force to be resisted by the vertical hoops shall be the maximum of (a) calculated factored shear force as per analysis (b) Shear force due to formation of plastic hinge at both ends of beams + factored gravity loads on the span.
	6.3.4	The contribution of bent up bars and inclined hoops to shear resistance of the section shall not considered.
	6.3.5	The spacing of hoops over a length of 2d at either end of a beam shall not exceed (a) d/4 and (b) 8times the diameter of smallest longitudinal bar, however it needs not be less than 100mm.

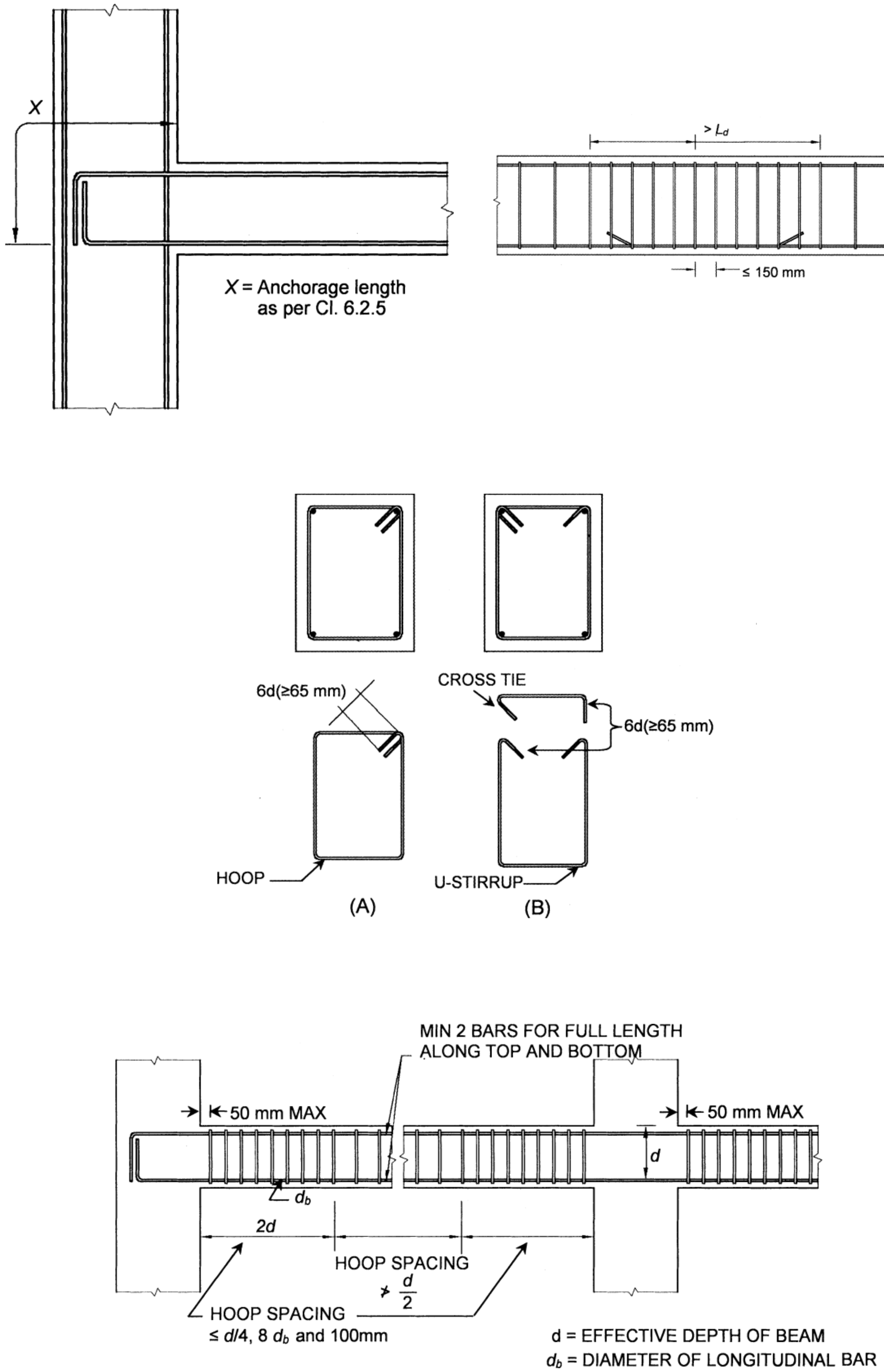


FIG. 3.1 BEAM REINFORCEMENT

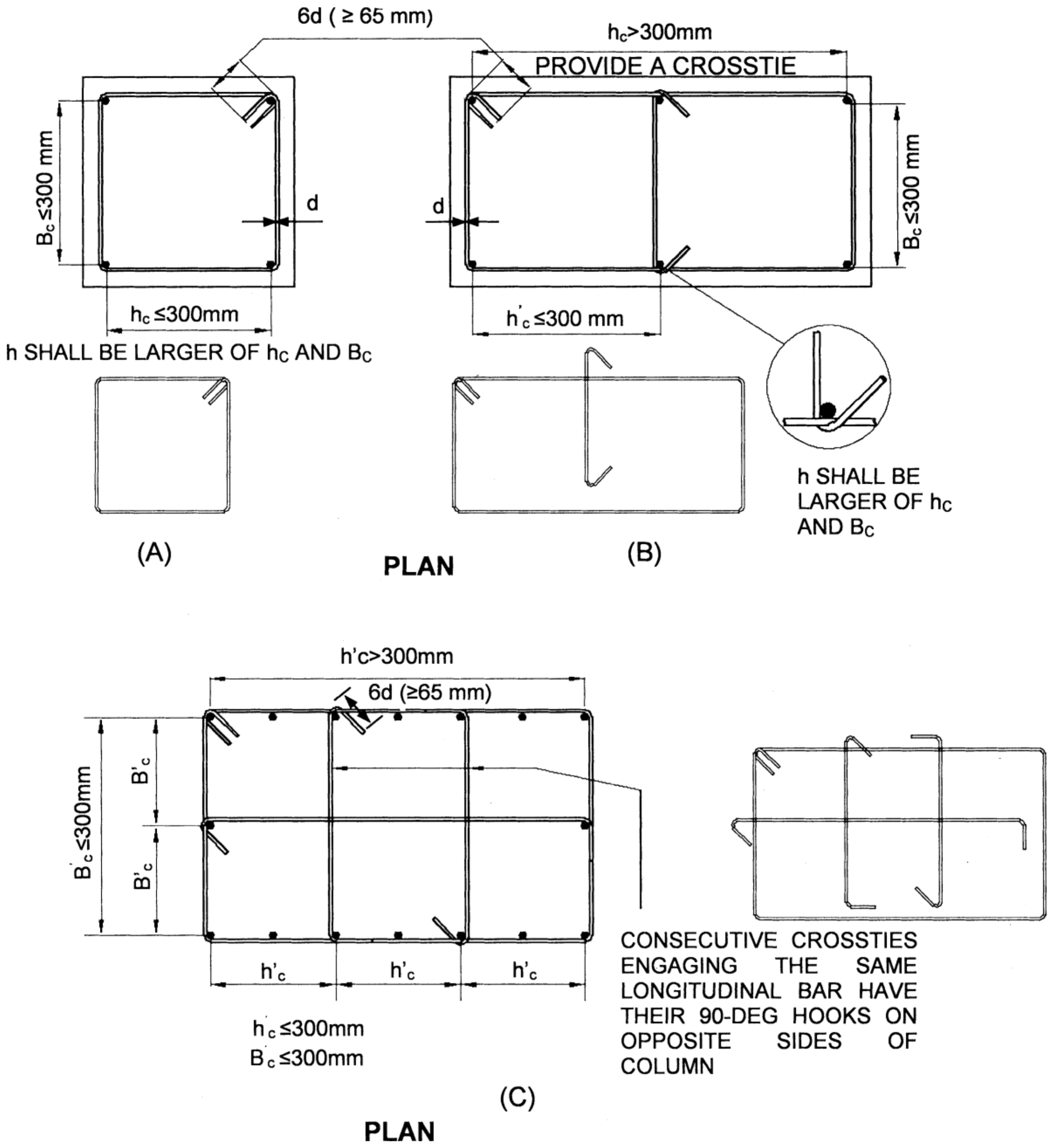


Fig. 3.2 Transverse reinforcement in Column

3.5 ABBREVIATIONS

A_e = Effective cross-sectional area of a joint
A_{ej} = Effective shear area of a joint
A_g = Gross cross-sectional area of column, wall
A_h = Horizontal reinforcement area within spacing S_v
A_k = Area of concrete core of column
A_{sd} = Reinforcement along each diagonal of coupling beam
A_{sh} = Area of cross section of bar forming spiral or link
A_{st} = Area of uniformly distributed vertical reinforcement
A_v = Vertical reinforcement at a joint
b_b = Width of beam
B_c, b_c = Width of column
b_j = Effective width of a joint
D = Overall depth of beam
D_k = Diameter of column core measured to the outside of spiral or link
d = Effective depth of member
d_b = Diameter of longitudinal bar d_w = Effective depth of wall section
E_s = Elastic modulus of steel
f_{ck} = Characteristic compressive strength of concrete cube
f_y = Yield stress of steel reinforcing bars, or 0.2 percent proof strength of reinforcing
h = Longer dimension of rectangular confining link measured to its outer face
h_c = Depth of column
L = Dimension of a building in a considered direction
M_k = Modal mass of mode k
N = Number of storeys or floors
N = Corrected SPT value for soil
N_m = Number of modes to be considered as per 7.7.5.2
P_k = Mode participation factor of mode
Q_i = Lateral force at floor i
Q_{ik} = Design lateral force at floor in mode
R = Response reduction factor
S_a/g = Design / Response acceleration coefficient for rock or soil sites on natural period
S_i = Lateral shear strength of storey
T = Undamped natural period of oscillation of the structure (in second)
T_a = Approximate fundamental period (in second)
T_k = Undamped natural period of mode k of oscillation (in second)
T_1 = Fundamental natural period of oscillation (in second)
V_B = Design seismic base shear
V_B = Design base shear calculated using the approximate fundamental period T_a
B.M = bending moment
M_u = factored bending moment
M_d = design moment
M_f = modification factor
M_x = mid span bending moment along short span

M_y = mid span bending moment along longer span
M''_x = support bending moment along short span
M''_y = support bending moment along longer span
P_t = percentage of steel
W = total design load
W_d = factored load
T_{cmax} = maximum shear stress in concrete
T_y = shear stress in concrete
T_v = nominal shear stress
ǿ = diameter of bar
P_u = factored Axial load
M_{ulim} = limiting moment of resistance of a section without compression reinforcement
M_{ux}, M_{uy} = moment about X and Y axis respectively
A_c = area of concrete
A_{sc} = area of longitudinal reinforcement for column
A = Area
A_{st} = Area of steel
b = Breadth of beam or shorter dimension of rectangular column
d_1 = Effective depth of slab or beam
D = Overall depth of beam or slab
M_{umax} = moment of resistance factor
L_d = Development Length
LL = Live load
L_x = Length of shorter span of slab
L_y = Length of longer span of slab
b_{ef} = Effective width of slab
b_f = Effective width of flange
b_w = Breadth of web or rib
D_f = Thickness of flange
DL = Dead load
d = Effective depth of beam or slab
d' = Depth of compression reinforcement from the highly compressed face
E_C = ModuIus of elasticity of concrete
E_s = Modulus of elasticity of steel
f_{ck} = characteristic cube compressive strength of concrete
f_{cr} = Modulus of rupture of concrete (flexural tensile strength)
f_{ct} = Splitting tensile strength of concrete
f_d = Design strength
f_y = Characteristic strength of steel
H_w = Unsupported height of wall
H_{we} = Effective height of wall
I_{ef} = Effective moment of inertia
I_{gr} = Moment of inertia of the gross section excluding reinforcement
I_r = Moment of inertia of cracked section
K = Stiffness of member
k = Constant or coefficient or factor
L_d = Development length
LL = Live load or imposed load
L_w = Horizontal distance between centres of lateral restraint
l = Length of a column or beam between adequate lateral restraints or the unsupported length of a column

l_{ef} = Effective span of beam or slab or effective length of column
l_{ex} = Effective length about x-x axis
l_{ey} = Effective length about y-y axis
l_a = Clear span, face-to-face of supports
l'_a = for shorter of the two spans at right angles
l_x = Length of shorter side of slab
l_y = Length of longer side of slab
l_o = Distance between points of zero moments in a beam
l_1 = Span in the direction in which moments are determined, centre to centre of supports
l_2 = Span transverse to I_1, centre to centre of supports
l_2' = l_2 for the shorter of the continuous spans
M = Bending moment
m = Modular ratio
P = Axial load on a compression member
q_0 = Calculated maximum bearing pressure of soil
r = Radius
s = Spacing of stirrups or standard deviation
T = Torsional moment
t = Wall thickness
V = Shear force
W = Total load
WL = Wind load
W = Distributed load per unit area
W_d = Distributed dead load per unit area
W_l = Distributed imposed load per unit area
X = Depth of neutral axis
Z = Modulus of section
z = Lever arm
α, β = Angle or ratio
Υ_r = Partial safety factor for load
Υ_m = Partial safety factor for material
δ_m = Percentage reduction in moment
$€_{cc}$ = Creep strain of concrete
σ_{cbc} = Permissible stress in concrete in bending compression
σ_{cc} = Permissible stress in concrete in direct compression
σ_{mc} = Permissible stress in metal in direct compression
σ_{sc} = Permissible stress in steel in compression
σ_{st} = Permissible stress in steel in tension
σ_{sv} = Permissible tensile stress in shear reinforcement
τ_{bd} = Design bond stress
τ_c = Shear stress in concrete
$\tau_{c,max}$ = Maximum shear stress in concrete with shear reinforcement
τ_v = Nominal shear stress

CHAPTER 4

METHODS OF CALCULATING EARTHQUAKE FORCES

CHAPTER 4

METHODS OF CALCULATING

EARTHQUAKE FORCES

There are two methods of calculating seismic forces on the building-

1. **SEISMIC COEFFICIENT METHOD:** The seismic coefficient method is one of the static procedures for earthquake resistant design of structures. Horizontal and/or vertical forces, which are calculated as products of the seismic coefficients H K, V K and the weight of the structures are applied to the structures

2. **RESPONSE SPECTRUM METHOD:** A response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock

SEISMIC COEFFICIENT METHOD

STEP 1:- Calculate the Seismic Weight of the Building

The seismic weight of the whole building is the sum of the seismic weights of all the floors. Seismic weight of building consists of dead load of entire building and fraction of live load as per IS 1893 Part 1:2002

Percentage of Imposed Load to be considered in Seismic Weight Calculation (Clause 7.3.1)

Imposed Uniformly Distributed Floor loads (kN/m^2)	**Percentage of Imposed Load**
Up to and including 3	25
Above 3	50

Fig. 4.1 Percentage of imposed load in seismic weight calculation

- Any weight supported in between the storey shall be distributed to the floor above and below in inverse proportion to its distance from the floor.

STEP 2 :- Calculation of Fundamental Time Period

The approximate fundamental natural period of vibration (T), in seconds, of a moment-resisting frame building without brick info panels may be estimated by the empirical expression:

$$T = 0.075\ h^{0.75} \text{ for RC frame building}$$

$$= 0.085\ h^{0.75} \text{ for steel frame building}$$

The approximate fundamental natural period of vibration (T), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$T_a = \frac{0.09h}{\sqrt{d}}$$

h = height of building in metres;
d = dimension at plinth level in metres

STEP 3 :- Calculation of Horizontal Seismic Coefficient

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

Depending upon fundamental time period and soil conditions, spectral acceleration coefficient is calculated

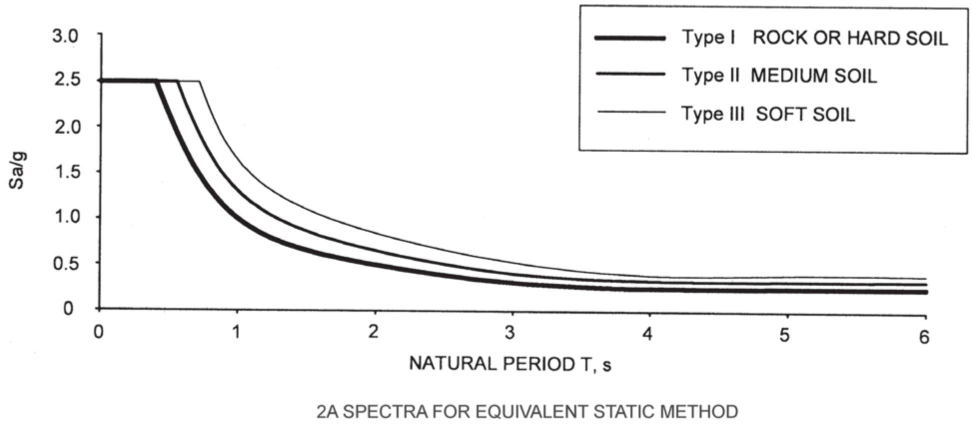


Fig. 4.2 Spectral Acceleration Coefficient

- Value of Z is obtained from earthquake zone

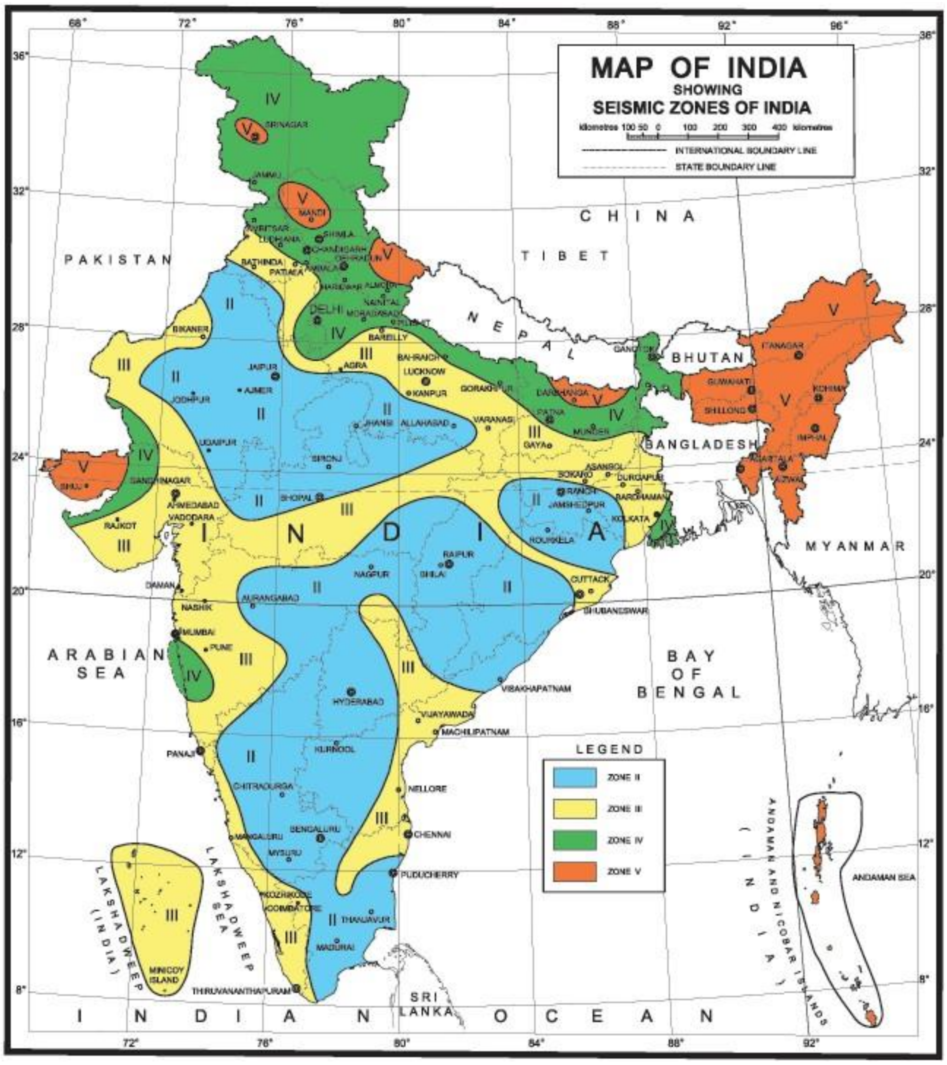


Figure 4.3- Seismic Zones of India

I = importance factor is calculated depending upon type of building

R= Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations.

However, the ratio (I/R) shall not be greater than 1.0

The values of R for buildings are given in IS 1893 – 2002

STEP 4: Design Seismic Base Shear

The total design lateral force or design seismic base shear (V_b) along any principal direction shall be determined by the following expression:

$V_b = A_h W$

where,

A_h = Design horizontal acceleration spectrum value, using the fundamental natural period T in the considered direction of vibration,

W = Seismic weight of the building

STEP 5: Vertical Distribution of Base Shear to Different Floor Level

The design base shear (V_b) computed shall be distributed along the height of the building as per the following expression:

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B$$

Where,

Q_i = Design lateral force at floor i,

W_i=Seismic weight of floor i,

H_i =Height of floor, and

n =Number of stories in the building is the number of levels at which the masses are located.

This force is distributed at each level of a building.

Structure may be analyzed using various structural software such as STAAD.Pro, E-TAB, and SAP, etc.

CHAPTER 5

CASE STUDY

CHAPTER 5
CASE STUDY

5.1 METHODOLOGY

- Studying various seismic mechanism, studying of various IS codes and research paper available on seismic analysis and design.
- Drafting a plan on AutoCAD.
- Preparing a model of G + 4 Residential building using STAAD.Pro
- Carrying out the seismic and static analysis of the model using STAAD.Pro
- Analyzing various components of building in various seismic zones such as zone 3, 4 & 5.
- Comparing results for shear, bending, deflection and amount of steel in various seismic zones.

5.2 CASE STUDY

The Building comprises of 4 floors excluding parking. The Carpet area of the building is 172.056m^2 and plot area is 290.6 m^2. Number of flats on the first floor are 2 and on all other floors are 4. The building is located at Pandharkawada (Yavatmal District) which comes under zone 3.

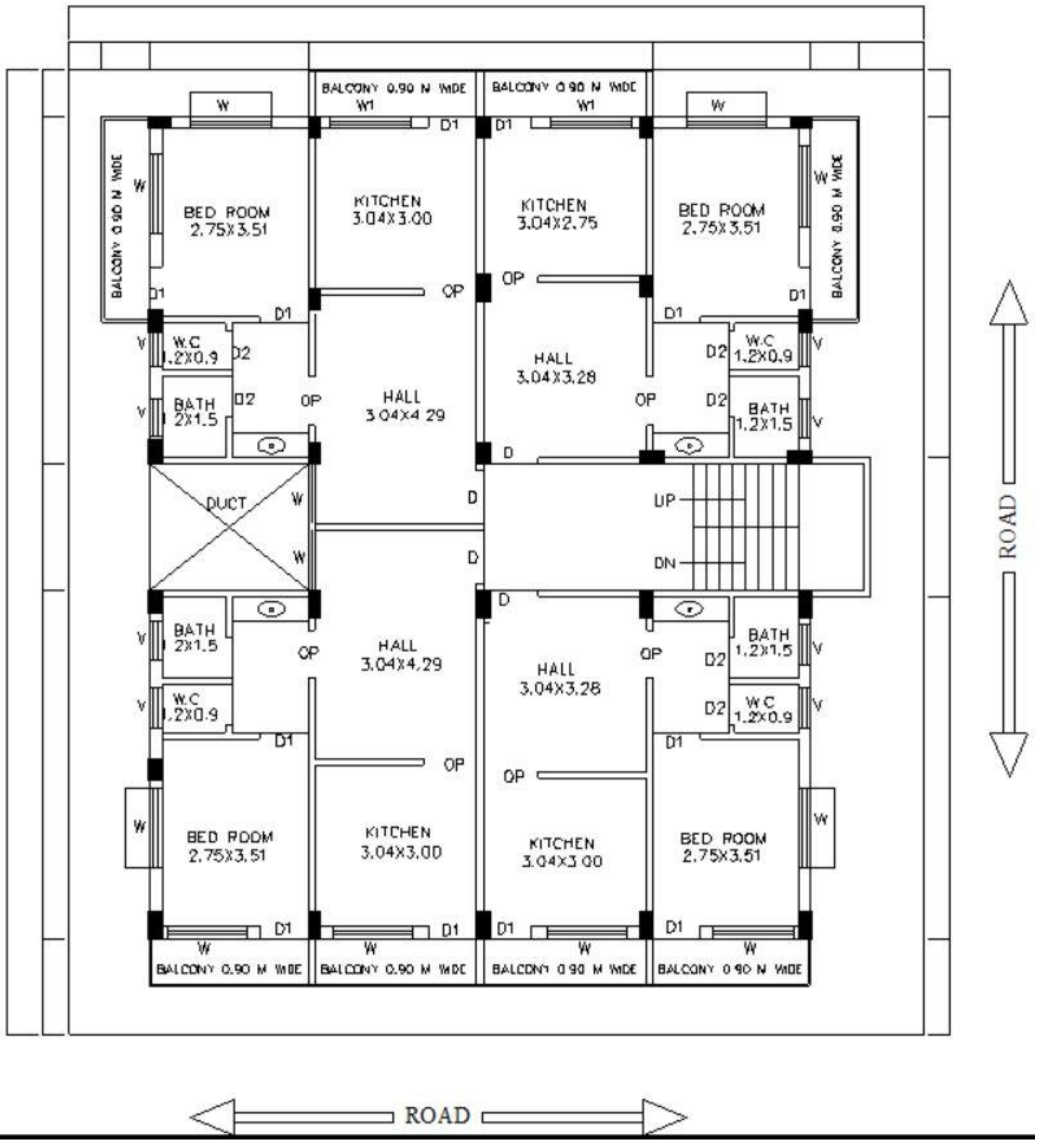


Fig.5.1 Plan of the structure

STRUCTURAL DETAILS:

Live load	2.0 kN/m^2 on typical floor 2.0 kN/m^2 on roof 3.0 kN/m^2 on balcony area
Earthquake load	As per IS-1893 (Part 1) – 2002
Depth of foundation below ground	3 m
Type of soil	Type II, Medium as per IS:1893-2002
Storey height	3.2 m
Floors	G.F + 4 upper floors.
Walls	230 mm thick brick masonry walls
Concrete	M20 for beams M20 for columns
Main Steel	HYSD Fe 415
Structural Steel	Fe 415
Size of Beams	0.23 x 0.30 m 0.23 x 0.40 m
Size of columns(m)	▪ Rect 0.23 x 0.40 ▪ Rect 0.23 x 0.50
All slab panels	0.135 m thick
Parapet Wall	Height = 1 m, width = 0.115 m
Seismic Zone	III
Building Frame System(R)	Special RC moment-resisting frame (SMRF)
Importance Factor	1.0
Damping	5%

Table 5.1 Structural Details

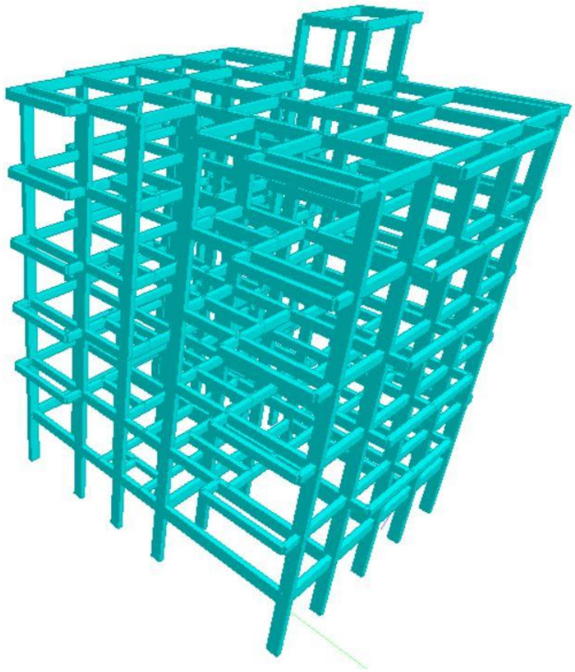


Figure 5.2 STAAD Model of Structure

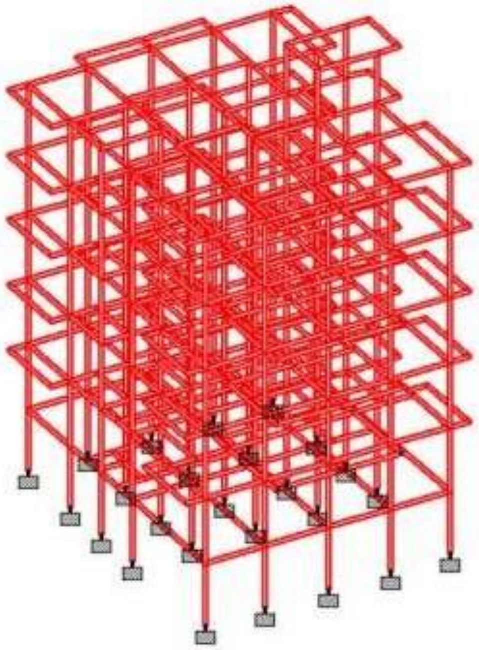


Figure 5.3 Columns beams connection

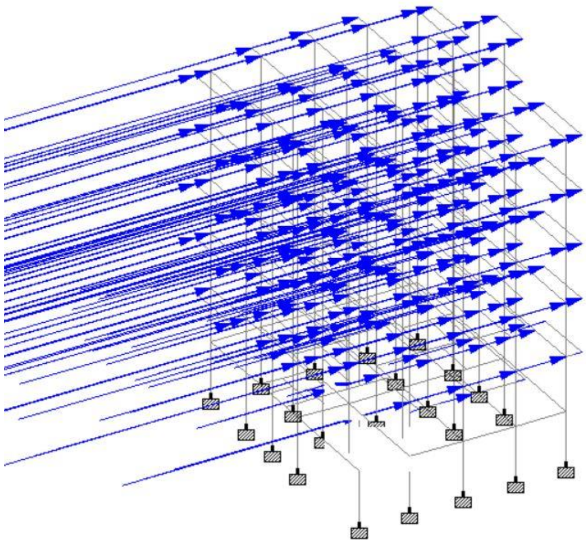


Figure 5.4 Seismic forces in X direction

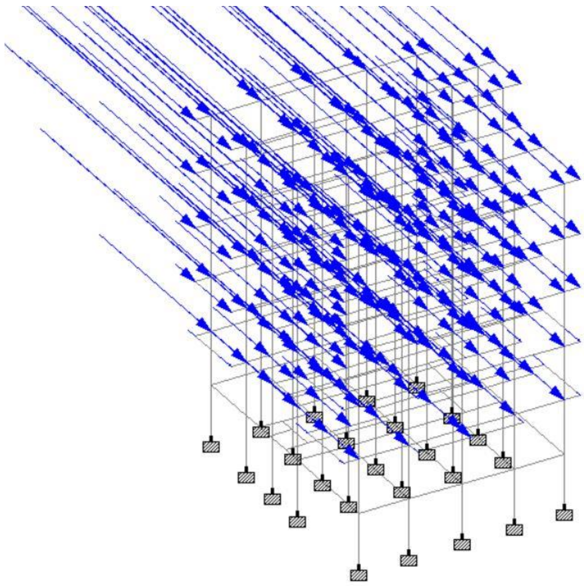


Figure 5.5 Seismic forces in Z direction

5.2 LOADS ASSIGNED ON BUILDING IN STAAD.Pro

Live Load= 2kN/m^2

Dead Load:

Self-wt. of Beams = b*d*γ (γ=25kN/m^3)
Self-wt. of Columns = b*d*γ
External wall (230mm) =14.168kN/m Internal wall (115 mm) = 7.084 kN/m
Parapet wall =7.084kN/m

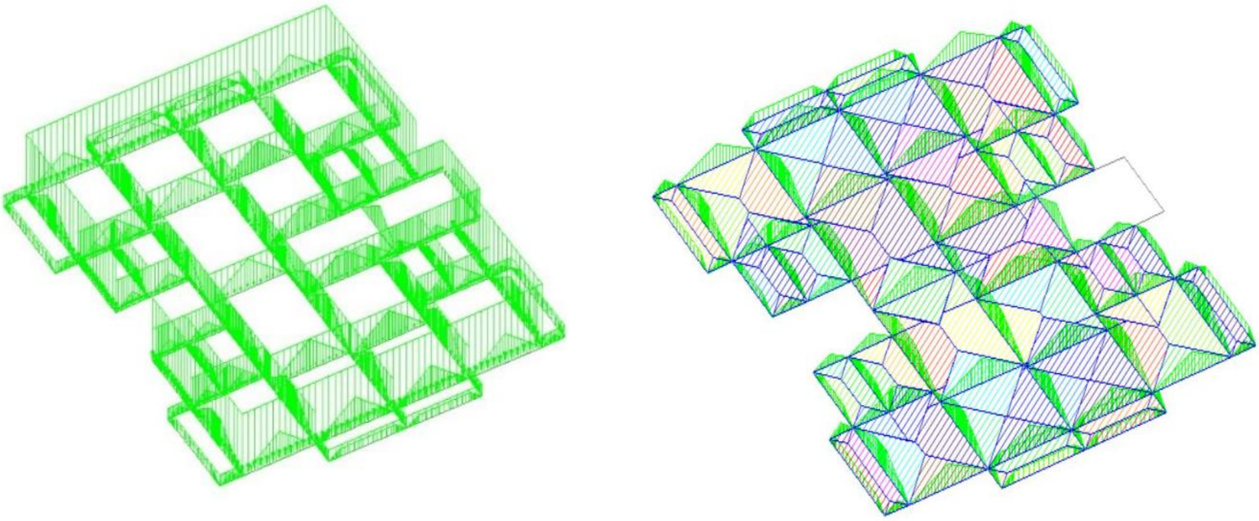


Fig. 5.6 Distribution of dead load and live load

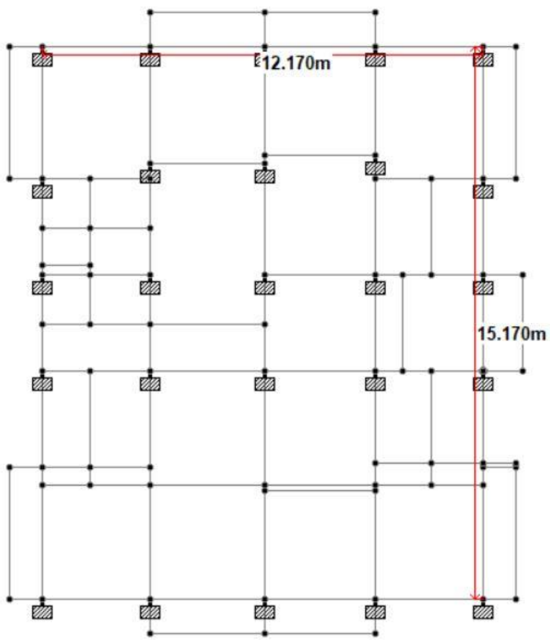


Fig. 5.7 Column positioning plan

5.3 CALCULATION OF BASE SHEAR BY SEISMIC COEFFICIENT METHOD:-

Column size: 230 x 400 mm
230 x 500 mm
Beam Size: 230 x 300 mm
230 x 400 mm
Slab: 135 mm thick
Imposed Load on floor: 2 kN/m^2
Imposed Load on roof: 2 kN/m^2
Floor finish: 1 kN/m^2
Roof finish: 3 kN/m^2
Brick Wall: 230 mm thick
Each floor is 3.2 m high
Parapet 115 mm thick and 1 m high
Zone III, Residential building
R=5, Soil: medium

Step 1: Determination of seismic weight

A) Dead load on Floor

i) Weight of slab per floor = 12.17 x 15.17 x 0.135 x 25 = 623.1 Kn

ii) 5 beams: 2 of (400mm depth); 3 of (500 mm depth)
For size of beam 2.75m
= 0.23 x 0.265 x 2.75 x 25 x 2 + 0.23 x 0.165x2.75x 25 x 3 = 16.2 kN

For size of beam 2.93 m
= 0.23 x 2.93 x 25 (2 x 0.265 + 3 x 0.165) = 17.3 kN

For size of beam 2.82 m
= 0.23 x 2.82 x 25 (1 x 0.165 + 2 x 0.265) =11.27 kN

For size of beam 3.57 m = 0.23 x 3.57 x 25 x 0.165 = 3.4 kN
For size of beam 2.75m = 0.23 x 2.75 x 25 0.165 = 11 kN
For size of beam 2.0 m = 0.23 x 2 x 25 x 0.165 = 1.9 kN
For size of beam 1.09 m = 0.23 x 1.09 x 25 x 0.165 = 1.03 kN
For size of beam 2.63 m = 0.23 x 2.63 x 25 x 0.165 = 2.5 kN
For size of beam 6.04 m = 0.23 x 6.04 x 25 x 0.165 x 2 = 11.5 kN
For size of beam 2.4 m = 0.23 x 2.4 x 25 x 0.165 x 2 = 2.28 kN
Weight of beams per floor (Total) = 165.2 kN

iii) Weight of column per floor
1^{st} column = 0.23 x 0.5 x 2.8 x 25 = 8.05 kN
2^{nd} column = 0.23 x 0.4 x 2.8 x 25 = 6.44 kN
Total Weight = 23 x 8.05 + 3 x 6.44 = 204.5 kN

iv) Weight of brick wall for single storey =1884 kN

v) Floor finish = (14.94 x 11.94) x 2 = 178.4 x 2 = 356.8 kN

vi) Balcony: Total = 216.2 kN

4 floors with 8 balconies

25 x 0.9 x 0.135 x (3.51 + 3.04 + 3.51 + 2.75 + 3.04 + 3.04 + 2.75) x 24.68 = 75 kN

Floor finish: (24.68 – 8 x 0.115) x (0.9 – 2 x 0.115) x 3 = 47 kN

Parapet: 37.24 x 0.115 x 1 x 22 = 94.2 kN

TOTAL DEAD LOAD ON FLOOR = I+II+III+IV+V = 3449.8 kN

B) Dead load on Roof

i) Weight of slab on roof = 623.1 kN
ii) Weight of beams = 165.2 kN
iii) Roof Finish = [(12.17 – 0.230) x (15.17 – 0.23)] x 2 = 357 kN
iv) Weight of parapet = 0.115 x (2 x 12.17 + (15.17-0.23) x 2) x 1 x 22 = 137.2 kN

Total Dead Load on roof = 494.2 kN

C) Live load on Floor

178.4 x 2 = 320.4 kN

D) Live load on Roof

(12.17) x (15.17- 0.23) x 2 = 363.7 kN

$W_1 = W_2 = W_3 = W_4 = 3449.8 + 0.5 \text{ X } 320.4 = 3610$ kN

$W_5 = 623.1 + 165.2 + 204.5/2 + 1123/2 + 357 + 137.2 = 1946.3$ kN

$W = W_1+W_2+W_3+W_4+W_5 = 16386.3$ kN

Step 2: Determination of Fundamental Time Period

A) **EQ in X direction:**

$Ta = (0.09\ h/d^{0.5}) = (0.09 \times 3.2 \times 4)/(12.17)^{0.5}$
$= 0.477$ seconds

B) **EQ in Y direction:**

$Ta = (0.09\ h/d^{0.5}) = (0.09 \times 3.2 \times 4)/(15.17)^{0.5}$
$= 0.427$ seconds

Step 3: Determination of design horizontal acceleration coefficient

Z = 0.16 (For zone III)
I = 1 (residential building)
R = 5 (For framed residential building)
A_h = 0.05 (for soil type II, T=0.477 & 0.427)

Step 4: Determination of design base shear

$V_B = A_h \times W = 0.05 \times 12439.1 = 621.9$ kN

5.4 LOAD COMBINATIONS IN SEISMIC ANALYSIS OF BEAM:-

LOAD NO.	LOAD COMBINATION (as per IS1893)
1	EQ +X
2	EQ-X
3	EQ +Z
4	EQ –Z
5	DL
6	LL
7	1.5(DL+LL)
8	1.2(DD+LL+EQX)
9	1.2(DL+LL-EQX)
10	1.5(DL+EQX)
11	1.5(DL-EQX)
12	0.9DL+1.5EQX
13	0.9DL-1.5EQX
14	1.2(DD+LL+EQZ)
15	1.2(DD+LL-EQZ)
16	1.5(DL+EQZ)
17	1.5(DL-EQZ)
18	0.9DL+1.5EQZ
19	0.9DL-1.5EQZ

Table 5.2 Load Combinations

ANALYSIS AND DESIGN OF BEAM USING STAAD.Pro

A **beam** is a structural element that primarily resists loads applied laterally to the **beam's** axis. Deflection is primarily done by bending. The designing of the beam comprises of fixing the breadth and depth of the beam and calculating the area of steel and the diameter of bars to be used. The width of the beam is generally kept equal to the thickness of the column & it shall not exceed the width of the column for effective transfer of load from beam to column. The depth of the beam should lie between L/10 to L/16.

The chosen dimensions of beam are: breadth=230mm and depth=300mm,400mm.

Procedure to design beams:

- The beam is analyzed first in order to calculate the Bending Moment and Shear Force. A simplified substitute frame analysis can be used for determining the bending moments and shearing forces at any floor or roof level due to gravity loads. The results of analysis is obtained from STAAD pro, then designed manually and compared with the STAAD.Pro Design.
- The loads to which the beams are subjected to, are needed to be calculated in order to analyze the frame. Following are the different loadings

i) Uniformly Distributed Load: (w) in kN/m

The load transferred from the slab per meter length will be either rectangular from one way slab or trapezoidal/triangular from two-way slab. The loading may be decided depending on the position of the slab. Trapezoidal load comes from the longer side while the triangular load comes from the shorter side, in the case of two way slabs.

ii) Weight of Masonry wall Ww = Υ*tw*H_w = 22*0.23*2.8 =14.168 kN/m

Where t_w = thickness in m, H_w = height in m and Υ = unit weight of masonry = 22 kN/m^3

iii) Self weight of concrete members: Ws = 25*b*D
= 25*0.23*0.30 = 1.725kN/m

Total working load (W) = (W_{s1}+W_{s2}) + W_w + W_s for calculation of B.M and S.F.

Design (ultimate) load: W_u = 1.5W kN/m.

Design Moment: Before designing it should be noted that if it is a flanged section or a rectangular section. Rectangular sections are mostly preferred for intermediate beams. The main beams may be designed as flanged sections. For rectangular beams, the maximum depth of N.A lies at the center. For flanged sections, check if the N.A lies within the flange or not and then proceed to calculate the moment. The dimensions of flanged section are designed as per the code IS: 456-2000 as per Clause 23.1.

If design moment $M_d \leq$ Mu, then N.A is known to lie within the flange. This is the case that usually governs the slab-beam construction. The continuous beams at supports are generally required to be designed as a doubly reinforced section.

5.5 STATIC ANALYSIS AND DESIGN OF BEAM USING STAAD.Pro

BEAM - ZONE - 3

1. ANALYSIS RESULT FROM STAAD.Pro

- **STATIC ANALYSIS OF BEAM**

The table shows axial forces, shear forces, torsion, and bending moment for dead load, live load, and static load combination 1.5(DL+LL).

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
333	1 DL	448	-0.001	40.620	-0.113	0.202	0.197	23.176
		457	0.001	38.253	0.113	-0.202	0.212	-18.880
	2 LL	448	-0.104	5.475	-0.019	0.081	0.033	3.336
		457	0.104	5.257	0.019	-0.081	0.038	-2.941
	3 DL+LL	448	-0.105	46.094	-0.132	0.283	0.230	26.512
		457	0.105	43.510	0.132	-0.283	0.250	-21.821
	4 1.5(DL+LL)	448	-0.158	69.142	-0.198	0.424	0.345	39.768
		457	0.158	65.265	0.198	-0.424	0.375	-32.731

Table 5.3 Static analysis of beam in STAAD.Pro

- **BENDING MOMENT DIAGRAM**

The diagram shows maximum sagging and hogging bending moment.

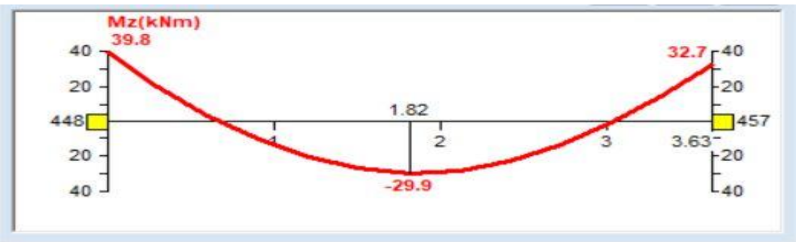


Figure 5.8 Bending moment diagram for beam 333 (Static)

- **DEFLECTION IN BEAM**

The diagram shows global deflection of beam under static loading.

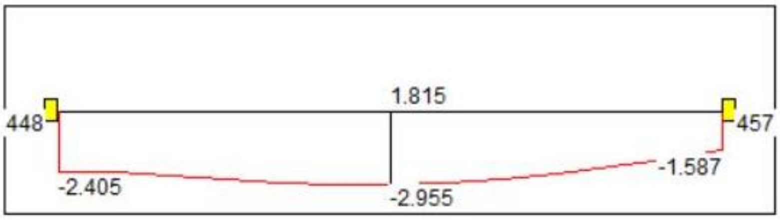


Figure 5.9 Deflection for beam 333 (Static)

- **SHEAR FORCE**

The diagram shows maximum shear force out of all load combination at different sections.

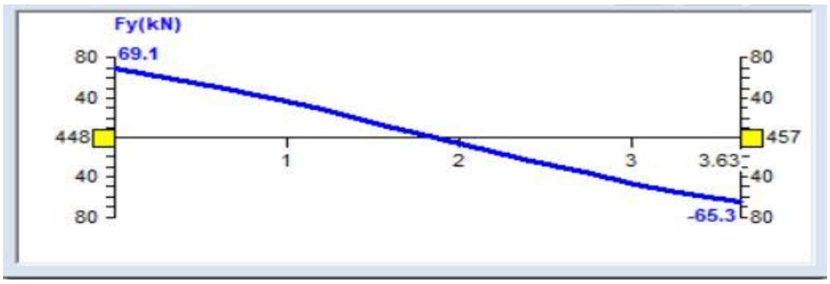


Figure 5.10 Shear force diagram for beam 333 (Static)

DESIGN OF BEAM USING STAAD.Pro

The table shows reinforcement required at different section

B E A M   N O.   333   D E S I G N   R E S U L T S

M20 Fe415 (Main) Fe415 (Sec.)

LENGTH: 3630.0 mm SIZE: 230.0 mm X 400.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	907.5 mm	1815.0 mm	2722.5 mm	3630.0 mm
TOP REINF.	330.64 (Sq. mm)	0.00 (Sq. mm)	0.00 (Sq. mm)	0.00 (Sq. mm)	268.67 (Sq. mm)
BOTTOM REINF.	0.00 (Sq. mm)	174.30 (Sq. mm)	243.71 (Sq. mm)	174.30 (Sq. mm)	0.00 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	907.5 mm	1815.0 mm	2722.5 mm	3630.0 mm
TOP REINF.	3-12í 1 layer(s)	2-12í 1 layer(s)	2-12í 1 layer(s)	2-12í 1 layer(s)	3-12í 1 layer(s)
BOTTOM REINF.	3-10í 1 layer(s)	3-10í 1 layer(s)	4-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)
SHEAR REINF.	2 legged 8í @ 135 mm c/c	2 legged 8í @ 135 mm c/c	2 legged 8í @ 135 mm c/c	2 legged 8í @ 135 mm c/c	2 legged 8í @ 135 mm c/c

Table 5.4 Reinforcement area required and provided at top and bottom for beam 333 (Static)

a) Reinforcement Details

- 3 bars of 12mm diameter are provided at the edge section of the top of the beam and 2 bars of 12 mm diameter are provided as extra top bars.
- 3 bars of 10 mm diameter are provided throughout the length as bottom reinforcement.

b) Shear Reinforcement

2- Legged stirrups of 8mm diameter is provided at 135 mm center to center.

SCHEDULE OF REINFORCEMENT

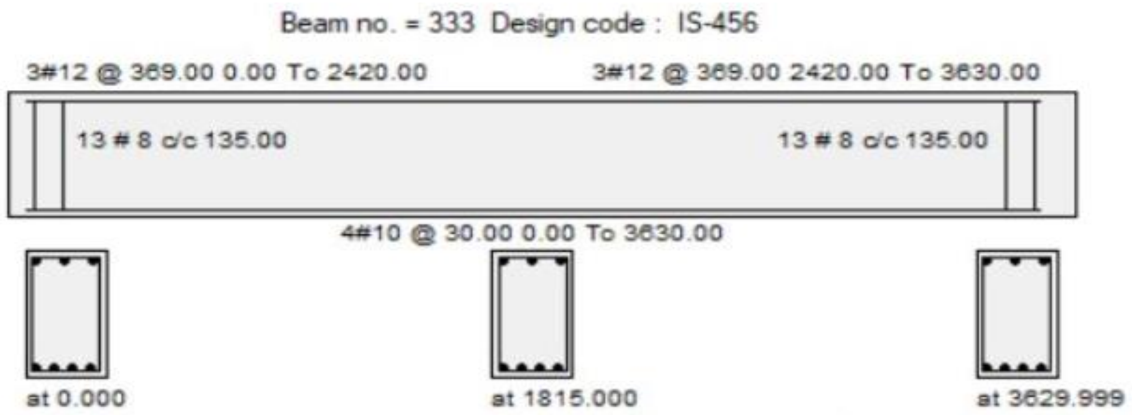


Figure 5.11 Longitudinal reinforcement schedule for beam 333 (Static)

5.6 <u>SEISMIC ANALYSIS AND DESIGN OF BEAM USING STAAD.Pro</u>

Seismic Analysis Result From STAAD.Pro :

The table no. 6.1 Shows analysis result i.e. axial forces, shear forces, torsions and bending moments for all the load combinations. For the design of beam maximum of axial force, shear force, torsion and bending moment is to be selected.

1) Seismic Analysis of Beam

The table no. 6.1 Shows analysis result i.e. axial forces, shear forces, torsions and bending moments for all the load combinations. For the design of beam maximum of axial force, shear force, torsion and bending moment is to be selected.

From the table no. 6.1
Maximum axial force = 3.43 kN
Maximum shear force = 88.10 kN
Maximum torsion forces = 1.11 kN
Maximum bending moments = 87.28 kN-m

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
333	1 EQX	448	0.208	2.379	0.633	-1.647	-1.211	4.442
		457	-0.208	-2.379	-0.633	1.647	-1.086	4.195
	2 EQZ	448	2.289	18.119	0.399	-0.357	-0.731	35.017
		457	-2.289	-18.119	-0.399	0.357	-0.717	30.756
	3 DL	448	-0.001	40.620	-0.113	0.202	0.197	23.176
		457	0.001	38.253	0.113	-0.202	0.212	-18.880
	4 LL	448	-0.103	5.482	-0.020	0.079	0.034	3.350
		457	0.103	5.249	0.020	-0.079	0.039	-2.928
	5 DL+LL	448	-0.104	46.102	-0.133	0.281	0.231	26.526
		457	0.104	43.503	0.133	-0.281	0.251	-21.808
	6 DL+EQX	448	0.207	42.999	0.520	-1.446	-1.014	27.617
		457	-0.207	35.874	-0.520	1.446	-0.873	-14.685
	7 DL+EQZ	448	2.288	58.739	0.286	-0.155	-0.535	58.193
		457	-2.288	20.134	-0.286	0.155	-0.504	11.876
	8 DL-EQX	448	-0.209	38.240	-0.745	1.849	1.407	18.734
		457	0.209	40.632	0.745	-1.849	1.298	-23.075
	9 DL-EQZ	448	-2.290	22.500	-0.512	0.558	0.928	-11.842
		457	2.290	56.372	0.512	-0.558	0.929	-49.636
	19 (0.9DL+1.5EQX)	448	0.311	40.127	0.847	-2.290	-1.639	27.520
		457	-0.311	30.859	-0.847	2.290	-1.437	-10.699
	20 (0.9DL-1.5EQX)	448	-0.313	32.989	-1.050	2.653	1.993	14.196
		457	0.313	37.997	1.050	-2.653	1.820	-23.285
	21 (0.9DL+1.5EQZ)	448	3.432	63.737	0.497	-0.353	-0.920	73.384
		457	-3.432	7.249	-0.497	0.353	-0.884	29.142
	22 (0.9DL-1.5EQZ)	448	-3.434	9.379	-0.700	0.716	1.274	-31.668
		457	3.434	61.607	0.700	-0.716	1.266	-63.126
	23 1.5(DL+LL)	448	-0.002	60.930	-0.169	0.303	0.295	34.763
		457	0.002	57.380	0.169	-0.303	0.318	-28.320
	24 1.5(DL+EQX)	448	0.310	64.499	0.780	-2.168	-1.521	41.426
		457	-0.310	53.811	-0.780	2.168	-1.310	-22.027
	25 1.5(DL-EQX)	448	-0.313	57.361	-1.118	2.774	2.111	28.101
		457	0.313	60.949	1.118	-2.774	1.947	-34.613
	26 1.5(DL+EQZ)	448	3.432	88.109	0.429	-0.232	-0.802	87.289
		457	-3.432	30.201	-0.429	0.232	-0.757	17.814
	27 1.5(DL-EQZ)	448	-3.435	33.751	-0.767	0.838	1.392	-17.763

Table 5.5 Analysis of beam using STAAD.Pro

- **Bending Moment Diagram**

The diagram shows maximum sagging and hogging moments.

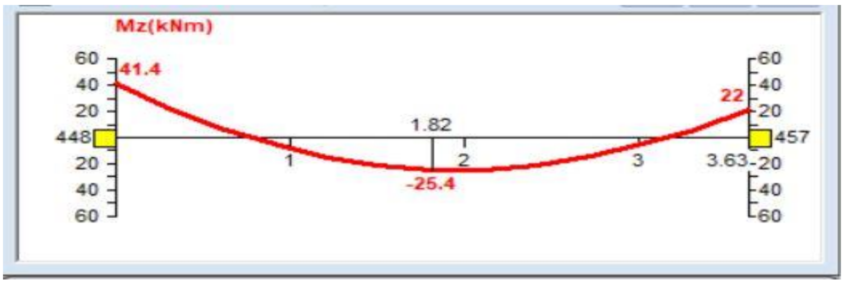


Figure 5.12 Bending moment diagram for beam 333 (Seismic)

- **Shear Force Diagram**

The diagram shows maximum shear force from all the load combination at different sections.

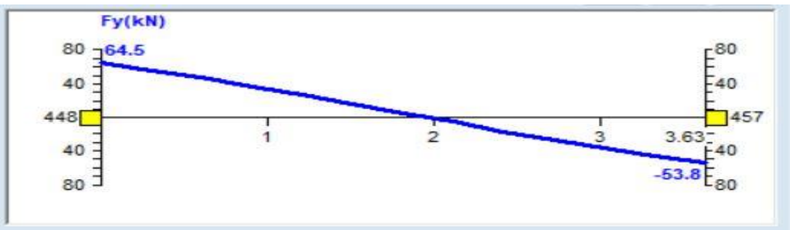


Figure 5.13 Shear force diagram for beam 333 (Seismic)

- **Deflection diagram**

The diagram shows the global deflection of beam under seismic analysis. This is within permissible limits.

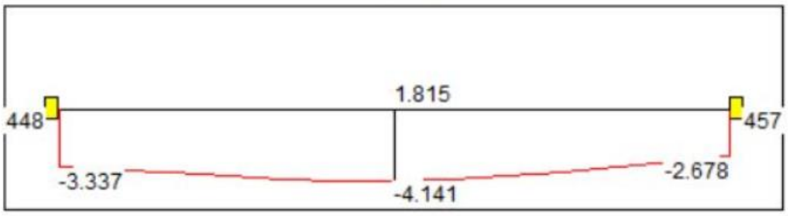


Figure 5.14 Deflection diagram for beam 333 (Seismic)

2) DESIGN OF BEAM USING STAAD.Pro V8i

a) Reinforcement Details

- 8 bars of 12mm diameter are provided at the edge section of the top of the beam and 2 bars of 12 mm diameter are provided as extra top bars.
- 3 bars of 12 mm diameter are provided throughout the length as bottom reinforcement.

b) Shear Reinforcement

2- Legged stirrups of 8mm diameter is provided at 135 mm center to center.

```
                B E A M  N O.     333   D E S I G N  R E S U L T S

      M20                    Fe415 (Main)              Fe415 (Sec.)

     LENGTH:  3630.0 mm      SIZE:   230.0 mm X  400.0 mm   COVER: 25.0 mm


                     SUMMARY OF REINF. AREA (Sq.mm)
 ----------------------------------------------------------------------------
 SECTION       0.0 mm      907.5 mm     1815.0 mm     2722.5 mm     3630.0 mm
 ----------------------------------------------------------------------------
  TOP          838.01        181.06        173.83        173.83        706.85
 REINF.       (Sq. mm)      (Sq. mm)      (Sq. mm)      (Sq. mm)      (Sq. mm)

 BOTTOM        263.56        310.58        241.48        274.21        250.73
 REINF.       (Sq. mm)      (Sq. mm)      (Sq. mm)      (Sq. mm)      (Sq. mm)
 ----------------------------------------------------------------------------


                     SUMMARY OF PROVIDED REINF. AREA
 ----------------------------------------------------------------------------
 SECTION       0.0 mm      907.5 mm     1815.0 mm     2722.5 mm     3630.0 mm
 ----------------------------------------------------------------------------
  TOP          8-12í         2-12í         2-12í         2-12í         7-12í
 REINF.     2 layer(s)    1 layer(s)    1 layer(s)    1 layer(s)    2 layer(s)

 BOTTOM        3-12í         3-12í         3-12í         3-12í         3-12í
 REINF.     1 layer(s)    1 layer(s)    1 layer(s)    1 layer(s)    1 layer(s)

 SHEAR     2 legged  8í  2 legged  8í  2 legged  8í  2 legged  8í  2 legged  8í
 REINF.   @ 135 mm c/c  @ 135 mm c/c  @ 135 mm c/c  @ 135 mm c/c  @ 135 mm c/c
 ----------------------------------------------------------------------------
```

Table 5.6 Reinforcement area requirement, provided and shear reinforcement provided (STAAD.Pro) for beam 333 (Seismic)

- **SCHEDULE OF REINFORCEMENT**

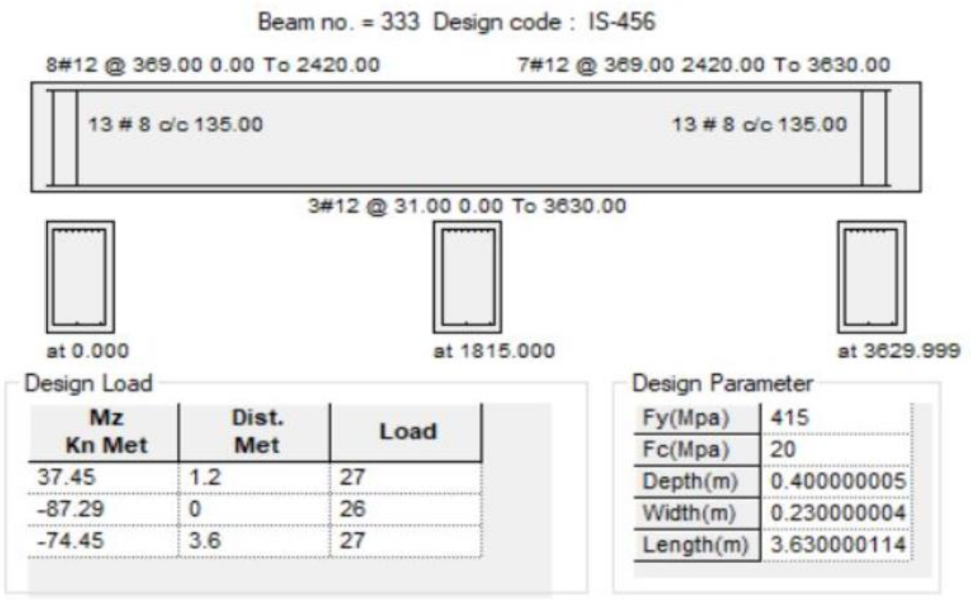


Figure 5.15 Longitudinal Reinforcement schedule for beam 333 (Seismic)

5.7 ANALYSIS & DESIGN OF COLUMN USING STAAD.Pro

A column is generally defined as a member carrying direct axial load which causes compressive stresses of such magnitude that these stresses largely control its design. A column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension.

Functions of longitudinal and transverse reinforcements in a column:

- **Longitudinal reinforcement**
    - To share the vertical compressive load, thus reducing the overall size of the column.
    - To prevent sudden brittle failure of the column
    - To impart certain ductility to the column.

- **Transverse reinforcement**
    - To prevent longitudinal buckling of longitudinal reinforcement.
    - To hold the longitudinal reinforcement in position at the time of concreting.
    - To confine the concrete, thereby preventing its longitudinal splitting.

Sample of Column no. 766

Size: 230mm x 400mm
Height of Column-3200 mm

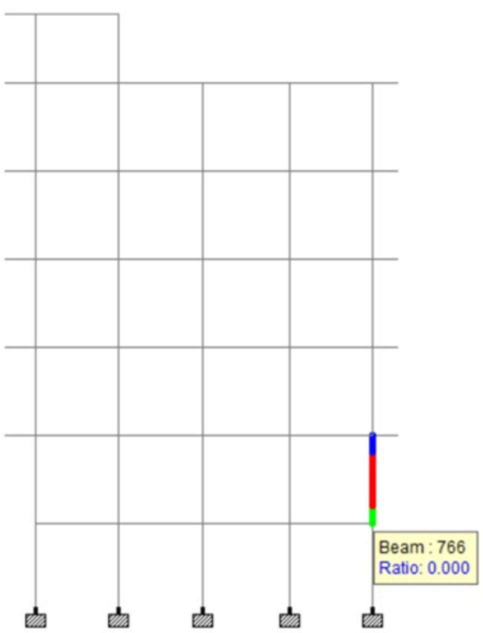


Fig no. 5.16 Column no. 766 in frame

STATIC ANALYSIS AND DESIGN OF COLUMN USING STAAD.Pro

COLUMN - ZONE - 3

1. ANALYSIS RESULT FROM STAAD.Pro

- **STATIC ANALYSIS OF COLUMN**

The table shows axial forces, shear forces, torsion, and bending moment for dead load, live load, and static load combination 1.5(DL+LL).

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
766	1 DL	34	441.920	-2.830	5.048	-0.036	-6.994	-4.692
		390	-433.249	2.830	-5.048	0.036	-9.161	-4.364
	2 LL	34	55.378	-0.033	0.491	-0.009	-0.519	-0.152
		390	-55.378	0.033	-0.491	0.009	-1.051	0.044
	3 DL+LL	34	497.298	-2.863	5.539	-0.044	-7.513	-4.843
		390	-488.627	2.863	-5.539	0.044	-10.211	-4.319
	4 1.5(DL+LL)	34	745.947	-4.295	8.308	-0.066	-11.269	-7.265
		390	-732.941	4.295	-8.308	0.066	-15.317	-6.479

Table 5.7 Static Analysis Of Column 766

- **BENDING MOMENT DIAGRAM**

The diagram shows maximum sagging and hogging bending moment.

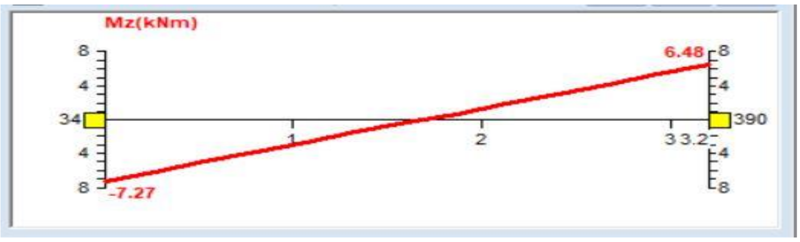


Fig. 5.17 Bending moment diagram for Column 766 (Static)

- **SHEAR FORCE DIAGRAM**

The diagram shows maximum shear force from all the load combination at different sections.

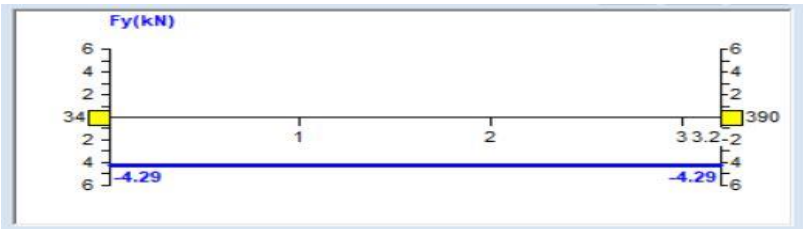


Fig. 5.18 Shear force diagram for Column 766 (Static)

COLUMN- ZONE 3

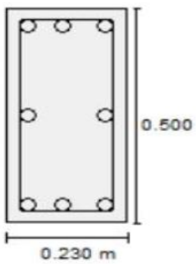
1) ANALYSIS OF COLUMN

- **ANALYTICAL RESULT OF COLUMN FROM STAAD Pro.**
  The table shows axial force, shear force, bending moment and torsion from STAAD Pro. For different load combination

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
766	1 EQX	34	-138.436	32.902	-1.400	-0.878	2.458	61.753
		390	138.436	-32.902	1.400	0.878	2.021	43.532
	2 EQZ	34	-92.208	2.806	-9.716	0.525	16.670	5.524
		390	92.208	-2.806	9.716	-0.525	14.419	3.455
	3 DL	34	441.920	-2.830	5.048	-0.036	-6.994	-4.692
		390	-433.249	2.830	-5.048	0.036	-9.161	-4.364
	4 LL	34	55.274	-0.023	0.488	-0.007	-0.514	-0.135
		390	-55.274	0.023	-0.488	0.007	-1.047	0.062
	5 DL+LL	34	497.194	-2.853	5.536	-0.043	-7.508	-4.827
		390	-488.523	2.853	-5.536	0.043	-10.208	-4.301
	6 DL+EQX	34	303.483	30.072	3.648	-0.914	-4.536	57.061
		390	-294.812	-30.072	-3.648	0.914	-7.139	39.168
	7 DL+EQZ	34	349.711	-0.024	-4.667	0.490	9.676	0.832
		390	-341.041	0.024	4.667	-0.490	5.259	-0.908
	8 DL-EQX	34	580.356	-35.731	6.448	0.843	-9.452	-66.445
		390	-571.685	35.731	-6.448	-0.843	-11.182	-47.896
	9 DL-EQZ	34	534.128	-5.636	14.764	-0.561	-23.664	-10.216
		390	-525.457	5.636	-14.764	0.561	-23.580	-7.819
	19 (0.9DL+1.5EQX)	34	190.073	46.806	2.444	-1.349	-2.607	88.407
		390	-182.269	-46.806	-2.444	1.349	-5.213	61.371
	20 (0.9DL-1.5EQX)	34	605.382	-51.899	6.643	1.286	-9.982	-96.853
		390	-597.579	51.899	-6.643	-1.286	-11.276	-69.225
	21 (0.9DL+1.5EQZ)	34	259.415	1.662	-10.030	0.756	18.711	4.063
		390	-251.612	-1.662	10.030	-0.756	13.385	1.256
	22 (0.9DL-1.5EQZ)	34	536.040	-6.756	19.117	-0.820	-31.300	-12.508
		390	-528.236	6.756	-19.117	0.820	-29.874	-9.110
	23 1.5(DL+LL)	34	662.879	-4.245	7.572	-0.053	-10.491	-7.038
		390	-649.873	4.245	-7.572	0.053	-13.741	-6.545
	24 1.5(DL+EQX)	34	455.225	45.108	5.473	-1.371	-6.803	85.592
		390	-442.219	-45.108	-5.473	1.371	-10.709	58.753
	25 1.5(DL-EQX)	34	870.534	-53.597	9.672	1.264	-14.178	-99.668
		390	-857.528	53.597	-9.672	-1.264	-16.772	-71.843
	26 1.5(DL+EQZ)	34	524.567	-0.036	-7.001	0.735	14.515	1.248
		390	-511.561	0.036	7.001	-0.735	7.888	-1.362
	27 1.5(DL-EQZ)	34	801.192	-8.454	22.146	-0.841	-35.496	-15.324

Table 5.8 Seismic analysis of column 766 (STAAD.Pro)

- **Design axial force**



Design Load

Load	25
Location	Long Col
Pu(Kns)	870.53
Mz(Kns-Mt)	99.67
My(Kns-Mt)	6.71

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	20
As Reqd(mm²)	2420
As (%)	2.18
Bar Size	20
Bar No	8

Table 5.9 Design axial force for Column 766 (Seismic)

- **Bending Moment Diagram**
  The diagram shows maximum sagging and hogging bending moment.

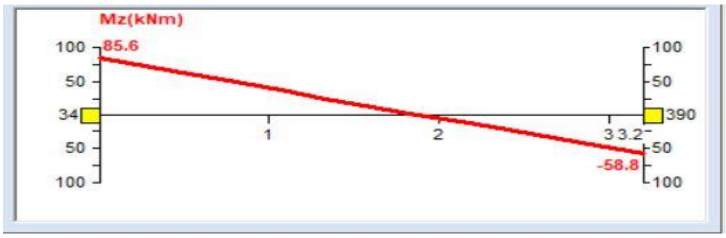


Figure 5.19 Bending moment diagram for Column 766 (Seismic)

- **Shear Force Diagram**
  The diagram shows maximum shear force out of all the load combination at different sections

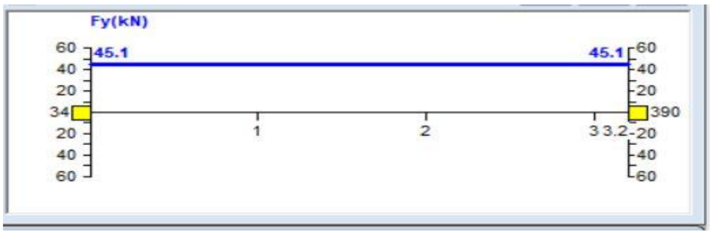


Figure 5.20 Shear force diagram for Column 766 (Seismic)

2) Design of Column using Staad-Pro

The image shows columns geometry, reinforcement required, reinforcement provided and the section capacity against axial force and biaxial moments.

```
                C O L U M N   N O.    766  D E S I G N   R E S U L T S

     M20                      Fe415 (Main)                 Fe415 (Sec.)

LENGTH:  3200.0 mm   CROSS SECTION:  230.0 mm X  500.0 mm  COVER: 40.0 mm

** GUIDING LOAD CASE:   25  SHORT(Z)        /BRACED LONG(Y)


REQD. STEEL AREA   :      2420.32 Sq.mm.
REQD. CONCRETE AREA:    112579.69 Sq.mm.
MAIN REINFORCEMENT : Provide   8 - 20 dia. (2.19%,   2513.27 Sq.mm.)
                     (Equally distributed)
TIE REINFORCEMENT  : Provide  8 mm dia. rectangular ties @ 230 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)
----------------------------------------------------------
Puz :   1766.54   Muz1 :    148.67   Muy1 :     53.97

INTERACTION RATIO: 0.98 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)
----------------------------------------------------------
WORST LOAD CASE:    25
Puz :   1794.64   Muz :    155.97   Muy :     54.84   IR: 0.98
```

Figure 5.21 Design and section capacity of column 766 (Seismic)

5.8 ZONEWISE SEISMIC ANALYSIS OF BEAM AND COLUMN

BEAM - ZONE - 4

ANALYSIS RESULTS FROM STAAD-Pro

- **Bending Moment Diagram**

The diagram shows maximum sagging and hogging moment.

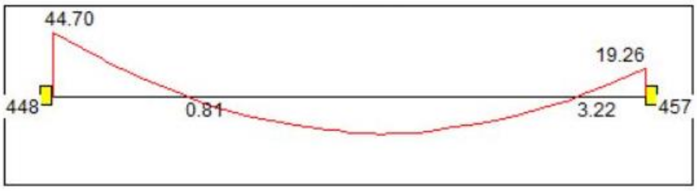


Figure 5.22 Bending moment diagram for Beam 333 (zone 4)

- **Shear Force Diagram**

The diagram shows maximum shear force from all the load combination at different Sections.

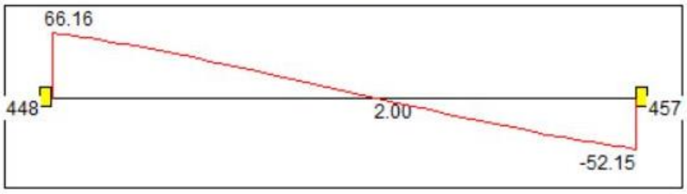


Figure 5.23 Shear force diagram for Beam 333 (zone 4)

COLUMN- ZONE 4

ANALYSIS OF COLUMN

- **Bending Moment Diagram**

The diagram shows maximum sagging and hogging moments.

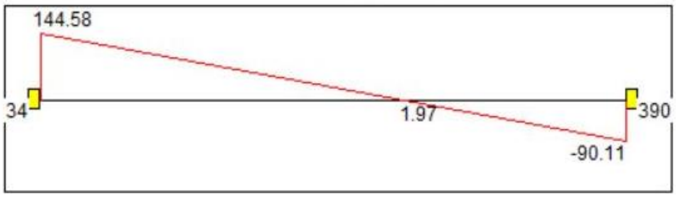


Figure 5.24 Bending moment diagram for Column 766 (zone 4)

- **Shear Force Diagram**

The diagrams show maximum shear force and bending moment out of all the load combination at different sections.

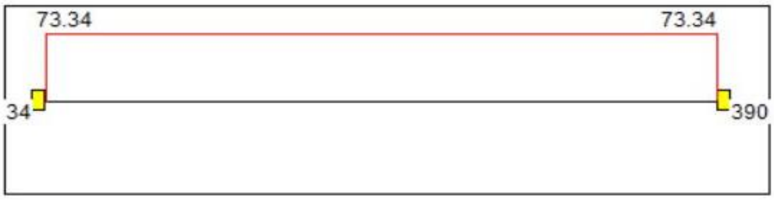


Figure 5.25 Shear force diagram for Column 766 (zone 4)

BEAM- ZONE-5

ANALYSIS RESULTS FROM STAAD.Pro

- **Bending Moment Diagram**

The diagram shows maximum sagging and hogging moments.

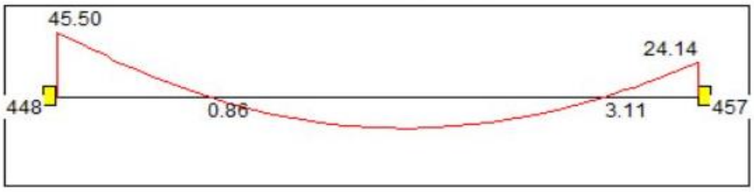


Figure 5.26 Bending moment diagram for Beam 333 (zone 5)

- **Shear Force Diagram**

The diagram shows maximum shear force from all the load combination at different sections.

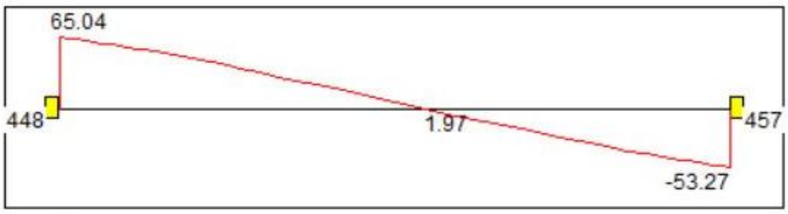


Figure 5.27 Shear force diagram for Beam 333 (zone 5)

COLUMN – ZONE 5

ANALYSIS OF COLUMN

- **Bending Moment Diagram**

The diagram shows maximum sagging and hogging moments.

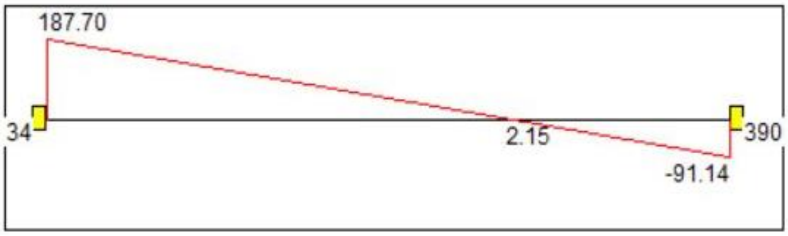


Figure 5.28 Bending moment diagram for Column 766 (zone 5)

- **Shear Force Diagram**

The diagram shows maximum shear force from all the load combination at different sections.

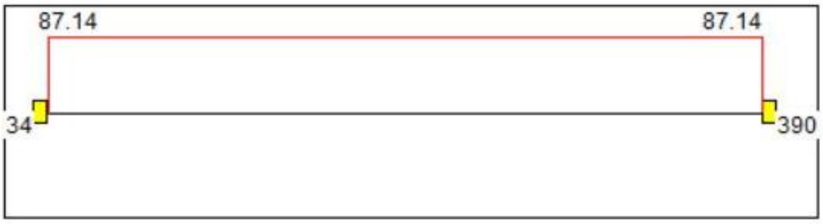


Figure 5.29 Shear force diagram for Column 766 (zone 5)

CHAPTER 6

RESULTS AND CONCLUSION

CHAPTER 6

RESULTS AND CONCLUSION

In this project, a (G+4) building is designed for Seismic Zone 3 in STAAD Pro. The geometry of the building is created in the standard software STAAD.Pro. Followed by creating the geometry respective materials and properties is assigned to the geometry to make it actual prototype of the building. Following the application of all the seismic loads with all other standard loads, the comprehensive analysis and design is done simultaneously manual analysis and design is also work out by using IS 456 Method and Seismic coefficient method of design.
The tasks of providing full seismic safety for the residents inhabiting the most earthquake prone regions are far from being solved.
However, in present time there are new regulations in place for construction that greatly contribute to earthquake disaster mitigation and are being in applied in accordance with world practice.
In the regulations adopted for implementation in India the following factors have been found to be critically important in the design and construction of seismic resistant buildings:

- Sites selection for construction that are the most favourable in terms of the frequency of occurrence and the likely severity of ground shaking and ground failure.
- High quality of construction to be provided conforming to related IS codes such as IS 1893, IS 13920 to ensure good performance during future earthquakes.
- To implement the design of building elements and joints between them in accordance with analysis i.e. ductility design should be done.
- Structural-spatial solutions should be applied that provide symmetry and regularity in the distribution of mass and stiffness in plan and in elevation.

VALIDATION OF STAAD OUTPUT :-

- The **BASE SHEAR VALUE** calculated manually is equal to **663.2 kN** and from STAAD it is **644.85 kN**. The values obtained are nearly equal.

```
**********************************************************
*                                                        *
* TIME PERIOD FOR X 1893 LOADING =    0.47700 SEC        *
* SA/G PER 1893=    2.500, LOAD FACTOR= 1.000            *
* VB PER 1893=    0.0400 X    16121.28=     644.85 KN    *
*                                                        *
**********************************************************


**********************************************************
*                                                        *
* TIME PERIOD FOR Z 1893 LOADING =    0.42700 SEC        *
* SA/G PER 1893=    2.500, LOAD FACTOR= 1.000            *
* VB PER 1893=    0.0400 X    16121.28=     644.85 KN    *
*                                                        *
**********************************************************
```

Fig. 6.1 Base Shear by STAAD.Pro

COMPARISON OF STATIC AND SEISMIC ANALYSIS IN ZONE 3:

FOR BEAM 333 – ZONE 3:

STATIC ANALYSIS 1.5 (DL +LL)			SEISMIC ANALYSIS 1.5(DL+EQZ)		
Fy (kN)	**Mz (kN-m)**	**Deflection (mm)**	**Fy (kN)**	**Mz (kN-m)**	**Deflection (mm)**
64.5	**39.8**	**2.955**	**69.1**	**41.4**	**4.141**

Table 6.1 Comparison Of Static And Seismic Analysis For Beam 333

FOR COLUMN 766 – ZONE 3:

STATIC ANALYSIS 1.5 (DL +LL)			SEISMIC ANALYSIS 1.5(DL+EQZ)		
Fy(kN)	**Mz(kN-m)**	**Deflection (mm)**	**Fy(kN)**	**Mz(kN-m)**	**Deflection (mm)**
4.29	**7.27**	**1.122**	**45.1**	**85.6**	**1.946**

Table 6.2 Comparison Of Static And Seismic Analysis For Column 766

SEISMIC ANALYSIS OVER DIFFERENT ZONES

1) **BEAM 333**

ZONES	ZONE 2	ZONE 3	ZONE 4	ZONE 5
BENDING MOMENT (kN-m)	**66.7**	**85.6**	**113**	**157**
SHEAR FORCE (kN)	**77.5**	**87.9**	**102**	**125**
DEFLECTION (mm)	**3.137**	**3.754**	**3.89**	**4.145**

Table 6.3 Comparison Of Seismic Analysis For Beam 333 Over Seismic Zones

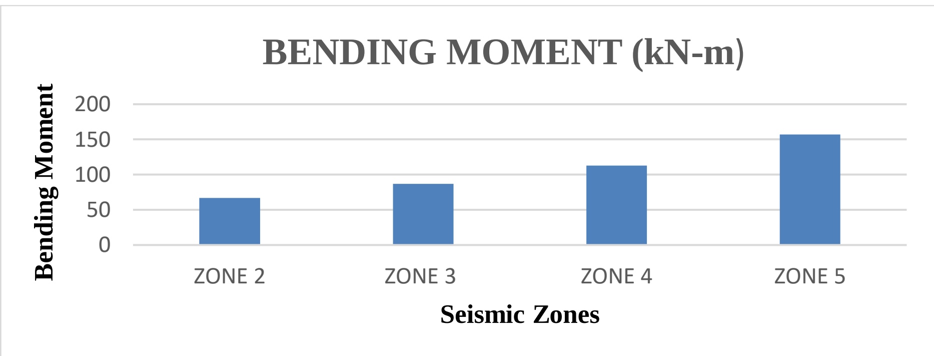


Fig. 6.2 Comparison Of Maximum Bending Moment For Beam 333 Over Seismic Zones

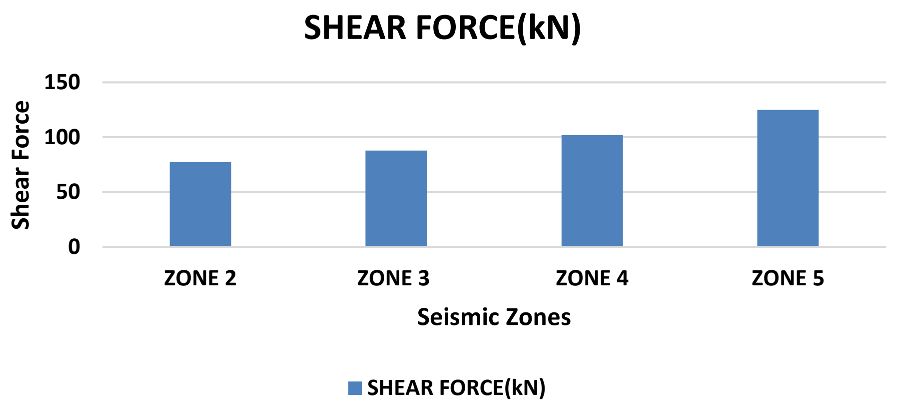


Fig. 6.3 Comparison Of Maximum Shear Force For Beam 333 Over Seismic Zones

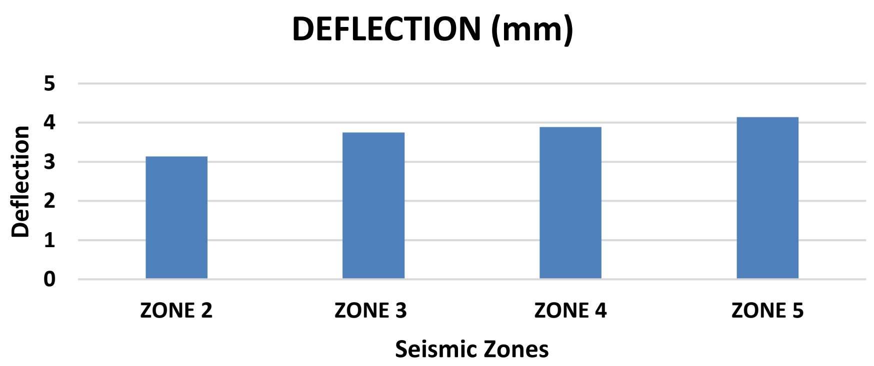


Fig. 6.3 Comparison Of Maximum Shear Force For Beam 333 Over Seismic Zones

2) COLUMN 766

ZONES	ZONE 2	ZONE 3	ZONE 4	ZONE 5
AXIAL FORCE	991.14	1015.196	1047.271	1109.78
Ast(mm$^{2)}$	1167	2420	2641	3585

Table 6.4 Comparison Of Axial force and Steel For Column 766 Over Seismic Zones

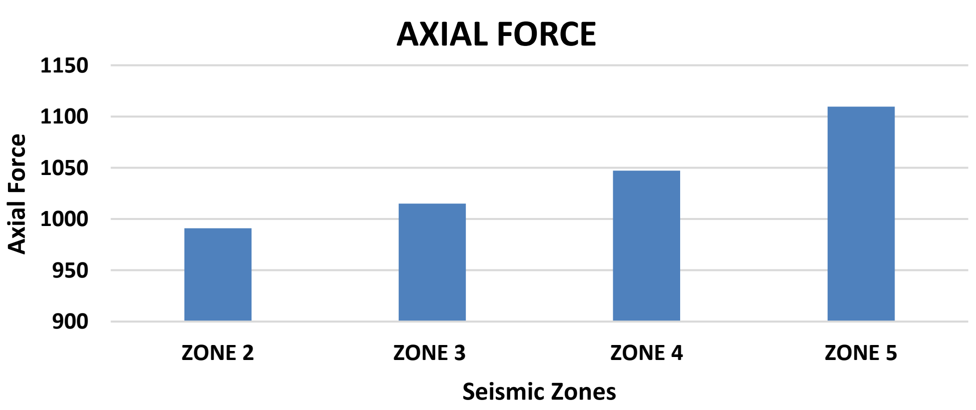


Fig. 6.4 Comparison Of Axial Force For Column 766 Over Seismic Zones

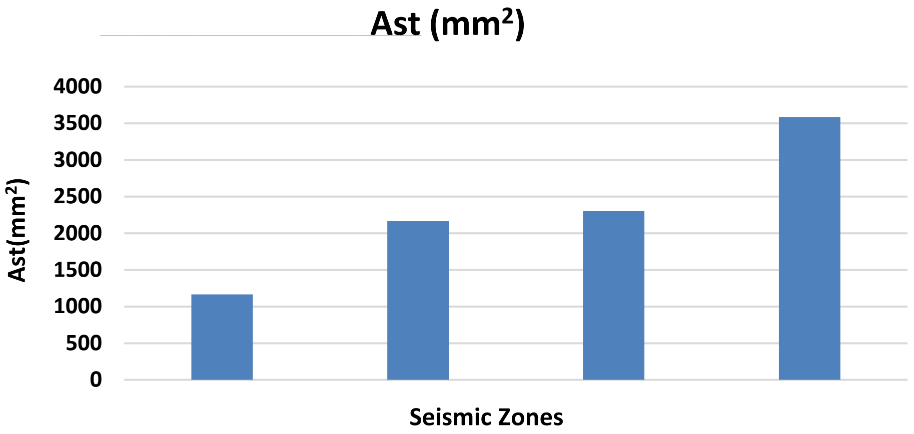


Fig. 6.5 Comparison Of Reinforcement steel For Column 766 Over Seismic Zones

- The variation of bending moment with respect to zone 2 for beam is as shown:-

ZONE	ZONE III	ZONE IV	ZONE V
TIMES	1.28	1.70	2.35

Table 6.5 Change in Bending moment For Beam 333 Over Seismic Zones

- The variation of shear force with respect to zone 2 for beam is as shown:-

ZONE	ZONE III	ZONE IV	ZONE V
TIMES	1.13	1.32	1.61

Table 6.6 Change in Shear force For Beam 333 Over Seismic Zones

- The variation of deflection with respect to zone 2 for beam is as shown:-

ZONE	ZONE III	ZONE IV	ZONE V
TIMES	1.20	1.24	1.32

Table 6.7 Change in Deflection for Beam 333 Over Seismic Zones

- The variation of axial force with respect to zone ii for column is as shown:-

ZONE	ZONE III	ZONE IV	ZONE V
TIMES	1.02	1.06	1.11

Table 6.8 Change in Axial force For Column 766 Over Seismic Zones

- The variation of reinforcement with respect to zone ii for column is as shown:-

ZONE	ZONE III	ZONE IV	ZONE V
TIMES	1.85	2	3

Table 6.9 Change in Reinforcement Steel For Column 766 Over Seismic Zones

DYNAMIC TAKE OFF QUANTITIES OF STEEL FROM STAAD.PRO:

BAR SIZE (mm)	Zone III (kg)	Zone IV (kg)	Zone V (kg)
8	4163.8	3824.8	4102.2
10	2054.0	1560.5	1497.3
12	3459.3	2632.9	2943.8
16	4157.2	3485.2	7125.7
20	1003.5	1742.1	4956.3
25	3417.8	5068.3	3154.5
TOTAL	**18255.5**	**18640.8**	**25932.8**

Table 6.10 Dynamic Take Off Quantities Of Steel

DYNAMIC TAKE OFF QUANTITIES OF CONCRETE FROM STAAD.PRO:

ZONE	VOLUME OF CONCRETE (m^3)
III	133.2
IV	149.1
V	175.4

Table 6.11 Dynamic Take Off Quantities Of Concrete

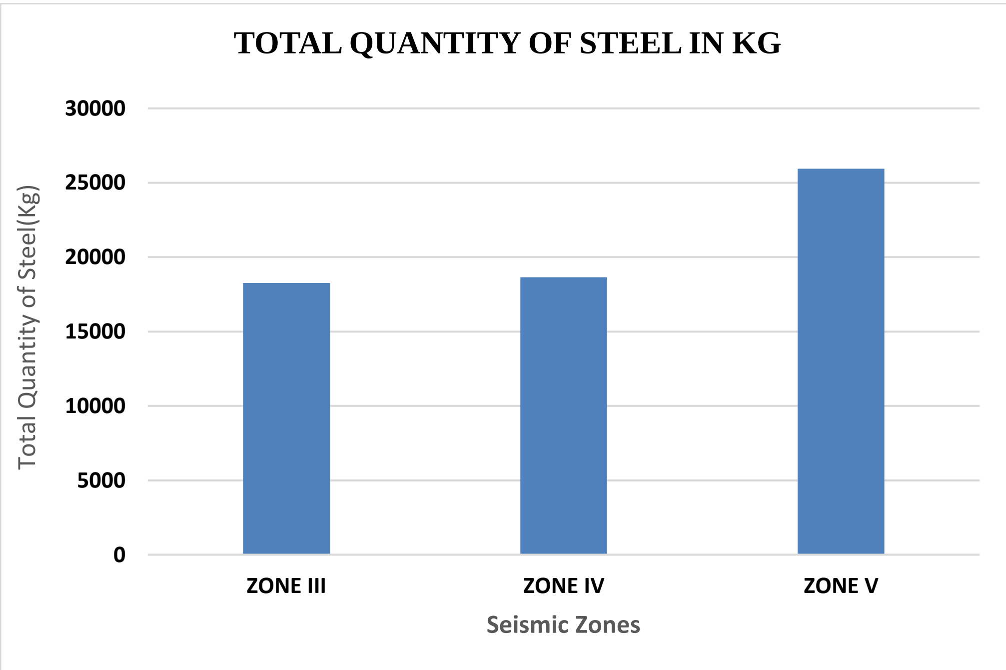


Fig.6.6 Change of Quantity Of Steel In Kg Over Seismic Zones

Thus, it can be concluded from the above results that:

- The results from STAAD.Pro are verified and found to be valid in the case of base shear through manual calculation.
- When the static analysis and seismic analysis are compared, it is found that analysis parameters such as shear force, bending moment and deflection have higher values under the seismic loading condition.
- There is a significant rise in the values of bending moment as the seismic zone changes from zone III to zone V.
- Shear force has also increased notably in the other zones when compared with Zone II.
- The increment in bending moment with the change of zones ultimately leads to accretion of reinforcement i.e. A_{st}
- Highest amount of reinforcement is provided for Zone V while it is lowest for zone II.
- The axial force in column is higher in zones III, IV & V as compared to zone II.
- As far as design is concerned, the quantity of concrete also increases with the zones.
- The values for deflection in beam under seismic loading have grown up slightly as the seismic intensity rises.

CHAPTER 7

FUTURE SCOPE OF WORK

CHAPTER 7

FUTURE SCOPE OF WORK

The present study is limited to analysis and earthquake-resistant design of G + 4 storied residential building using STAAD.Pro. The analysis of base shear in STAAD.Pro is compared with manual analysis and it is observed that the result is almost same. So, there is a large scope in our project work for further study. Thus, the study can be extended to

1. Analysis and design of building for different story heights and dimension.
2. Design of earthquake resistant multi storied building in STAAD Pro by response spectrum method.
3. Addition of infill and shear wall.
4. Design of foundation.
5. An experimental investigation and verification can be done with small scale model on a shake table under simulated motions.

CHAPTER 8

REFERENCES

CHAPTER 8

REFERENCES

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9. Bhargav Jyoti Borah, Amit Kalita, Manikuntala Sutradhar, Indranuj Pathak “A Comparative Study on Analysis and Design of Multi-storey (G+6) Building By STAAD.PRO AND SAP2000”

10. Bo-quan LIU1, Ming LIU2 and Ying-bin LI3 “Research and Develoment Of Performance-based Seismic Design Theory”

11. C. V. R. Murty, Rupen Goswami, A. R. Vijayanarayanan, Vipul V. Mehta “Earthquake behaviour of buildings”

12. By M. A. Austin,1 K. S. Pister and S. A. Mahin, “Probalistic Design of Earthquake -resistant Structures”

13. Mark Grigorian, Ph.D., S.E.1; and Carl E. Grigorian, Ph.D., S.E.2 “Sustainable Earthquake Resisting System”

14. Mohammad Adil Dar, Prof. (Dr.) A.R. Dar, Asim Qureshi, Jayalakshmi Raju, American Journal of Engineering Research (AJER), 2013 “Study on Earthquake Resistant Construction Techniques”

15. IS Codes-

IS 1893:2002 - Indian Standard Criteria for Earthquake Resistant Design of Structures

IS 13920:2016 - Indian Standard Code of Practice for Ductile Design and Detailing of Reinforced Concrete Structures

IS 875 Part-2-1987- Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures, Part 2: Imposed Loads

IS 456:2000 - Indian Standard Code of Practice for Plain and Reinforced Concrete

16. Books-

a) Dynamics of structures: Theory and applications to Earthquake Engineering by Anil Kumar Chopra, University of California at Berkeley
Published by: Pearson Education, Inc. and Dorling Kindersley Publishing, Inc.

b) Earthquake Tips by C.V.R. Murty
Published by: National Information Centre of Earthquake Engineering Indian Institute of Technology Kanpur

17. Graphs and pictorial representations taken from: “Some concepts in Earthquake behavior of buildings” by C. V. R. Murty, Rupen Goswami, A. R. Vijayanarayanan, Vipul V. Mehta.

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TITLE : COMPARISON OF SEISMIC ANALYSIS AND STATIC ANALYSIS OF RESIDENTIAL BUILDING USING STAAD.PRO

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