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ANALYSS & DESIGN OF MULTI STORY BUILDINGS IN DIFFERENT SEISMIC ZONES

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Abstract:

There is an excess demand for construction of multi storied buildings due to increasing urbanization and spiraling populations. Seismic load has Ultimate adverse effect on building. Earthquake forces are tremendous as it is unforeseeable in nature and unpredictable, the engineering tools require to be improving for analyzing structures under the action of these forces and to determine seismic reactions over those structures. In this study the seismic response of the structures is investigated under earthquake excitation expressed within the kind of Member Forces, Joint Displacement, Support Reaction, Base Shear and Story Drift. This research is based on Seismic Analysis and Design of G+10 building which is located in zone III & IV. A multi-storied RC framed building with Light weight concrete and conventional concrete is taken for Seismic analysis in different earthquake intensities III and IV according to IS 1893 PART 1 (2016). The analysis results are used to confirm the effect light weight concrete and conventional concrete building in different seismic zones

1. INTRODUCTION

Where urbanization is at the faster rate in the country essentially adopting the methods and type of the constructing buildings that have seen tremendous growth over the past few decades. Around the world, there is a tremendous need for the construction of multi-story buildings due to expanding urbanisation and a constantly growing population. It is difficult to study and design structural systems for seismic stresses in multi-story reinforced concrete structures, because they are unpredictable and unpredictably strong earthquakes are most likely to cause damage to tall buildings. To analyse the structures under the influence of these stresses, the engineering techniques must be improved.

Building catastrophe is one of the most unpleasant effects of most natural disasters, especially earthquakes. In the past, seismic design codes focused on ensuring the providing a requisite level of life safety, not on reducing damage. Determining seismic responses over those buildings is therefore now required. The major goal is to analyse the construction in such a manner that it can withstand the high seismic zone as a result.

Seismic load, wind load, dead load and live load is calculated and applied on structure. From Maximum protection against a building failing due to overloading during natural disasters comes from these load combinations. Earthquakes has the probable for causing the greatest damages to the structures. Therefore, it is essential to design the structure for various seismic zones.

The current work is therefore focused on "Analysis and Design of G+10 Multi-Story Residential Building in the Seismic Zone III and IV" and compares the seismic effects of traditional RC framed and light weight concrete buildings.

1.1 Earthquake in India

The ground trembling is all that constitutes an earthquake. Natural events lead to it. Energy is released as a result, causing waves to flow in all directions, which causes it to occur. Seismographs can pick up seismic waves produced by the Earth's vibrations during an earthquake.

Medium-sized earthquakes happen every day. Strong tremors that cause significant damage, however, are less frequent. Earthquakes occur more often along plate borders, especially along convergent boundaries. In the region of India where the Indian Plate and the Eurasian Plate collide, there are more earthquakes. Take the Himalayan area as an example.

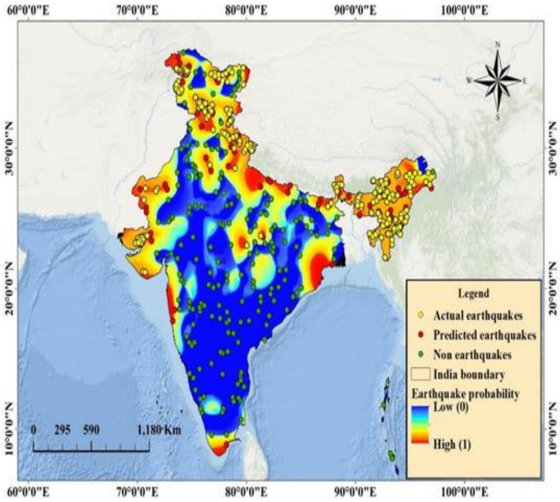


Fig 1.1 Earthquake Probability Map

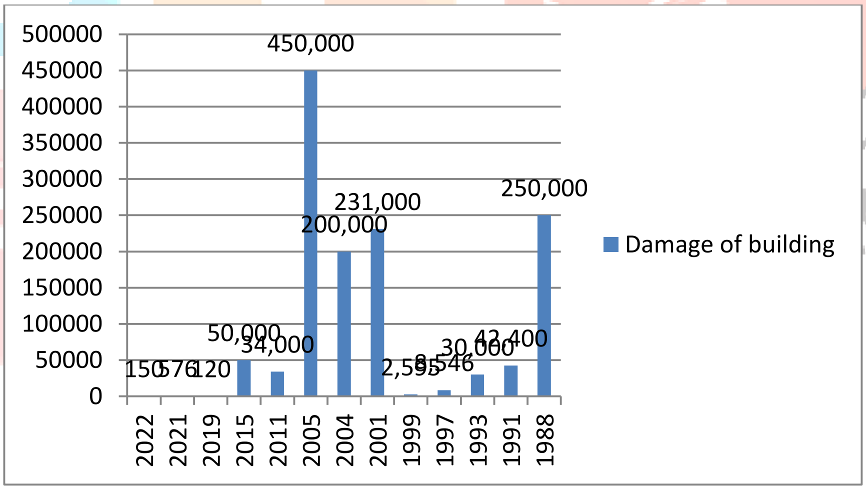


Table 1.1 List of Earthquakes in India

1.2 Seismic Analysis

An earthquake is a natural calamity. That results in enormous loss of life, destruction of property, and severe economic damage to a nation. An earthquake's vibrations can be felt as far away as the epicentre. One of nature's most devastating tragedies, earthquakes cause the surface of the earth to tremble when seismic energy is released. Seismic waves that are generated at the earth's surface have an impact on buildings. Seismic waves are measured using seismographs and the Richter scale. When a building is exposed to seismic waves, the foundation starts to tremble and the building eventually falls. To determine how a structure would react in the case of an earthquake, seismic analysis is used. The natural frequency of the structure, the damping factor, the kind of foundation, etc. are all factors that go into the making of an earthquake-resistant structure. The natural period of a structure determines its total seismic base shear, while the stiffness and mass distribution of the building, combined with its height, define the seismic force distribution.

The main objective of seismic analysis is to lessen the accelerations and displacements of the structure. On the other hand, few, powerful earthquakes are predicted to cause inelastic deformation of the walls. Therefore, shear walls ought to be able to withstand plastic deformation while still supporting a load and releasing energy.

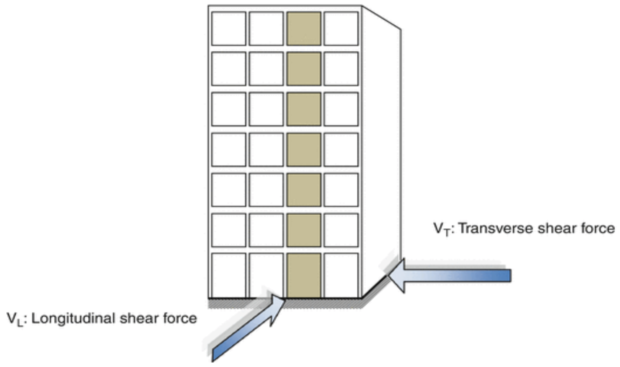


Fig 1.2 Seismic force acting on structure

1. 3 STAAD-Pro Software

Staad.pro consists of the following:-

- The civil engineering community has approved the structural software Staad-pro. This may resolve frequent problems like seismic analysis using various load combinations to verify various codes like IS 456:2000, IS 875:1897, etc.
- It is used to compute the parameters for structural analyses that take into account both steel and concrete.

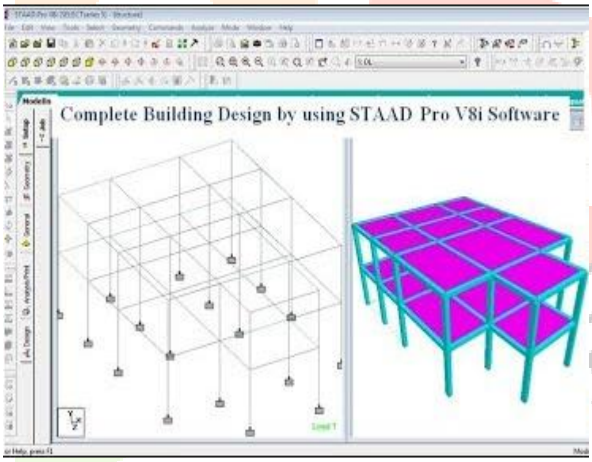


Fig 1.3 Staad Pro Software using Analysis of Structure

BLOCK DIAGRAM

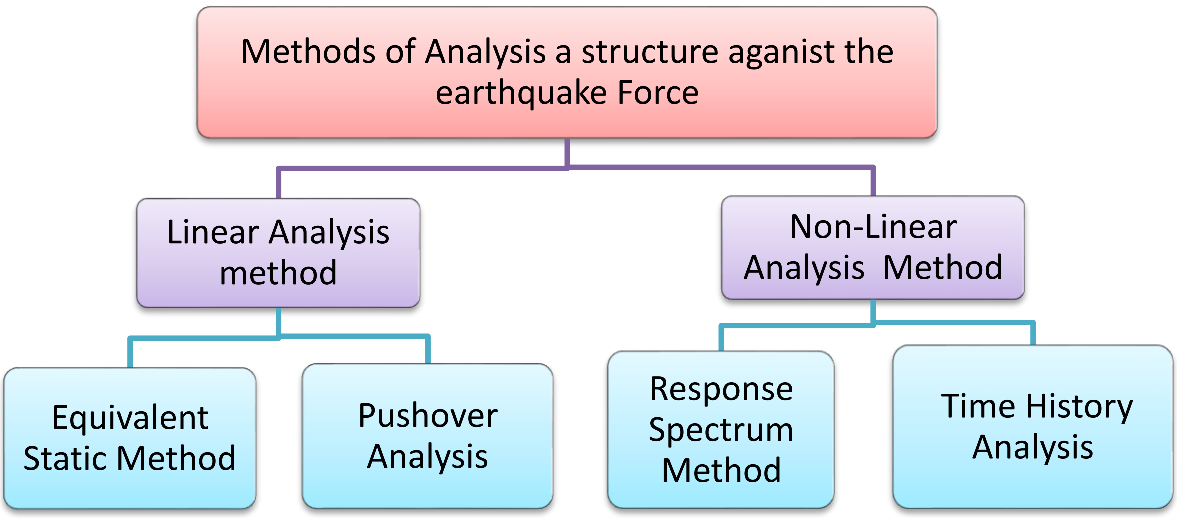


Fig 1.4 Seismic Analysis Method

1.4 Seismic Zones in India

India is susceptible to earthquakes of varying intensity in all, 59% of India's geographical mass (including all of its nations) is affected. The entire area is divided into four seismic zones according to the India seismic zoning map. Zone II has the lowest seismic activity, whereas Zone V has the most.

Zone	Intensity	Area Affected by Seismic Activity (%)
Zone II	VI (Low Risk Zone)	40.93
Zone III	VII (Moderate Risk Zone)	30.79
Zone IV	VIII (High Risk Zone)	17.49
Zone V	IX (Very High Risk Zone)	10.79

Table no 1.2 Seismic Zones in India

1.5 OBJECTIVES

- Ensure Structural Safety
- Determine Seismic Forces
- Evaluate Zone-Specific Performance
- Optimize Structural Design
- Compare Structural Response

1.6 PROBLEM STATEMENT

To analyze and design a multi-storey (e.g., G+6, G+10, G+20) RCC framed structure under varying seismic intensity levels (Zones II, III, IV, and V) using software such as STAAD.Pro or ETABS, ensuring safety against horizontal lateral loads, while optimizing material consumption (concrete and steel) based on IS 1893:2016 or similar seismic codes.

2. LIERATURE REVIEW

Study of seismic effect on RCC and precast construction of buildings is demonstrated by **Adesh Thakare** and **Salman Shaikh** (2022) [1]. When analysing a building during an earthquake, the severe damage, in the case of RCC, is at the beam-column joints. However, in a precast structure, the severe damage is at the joint of the secondary and primary beams. More so than other joints, the design and details of the beam-column junction is crucial.

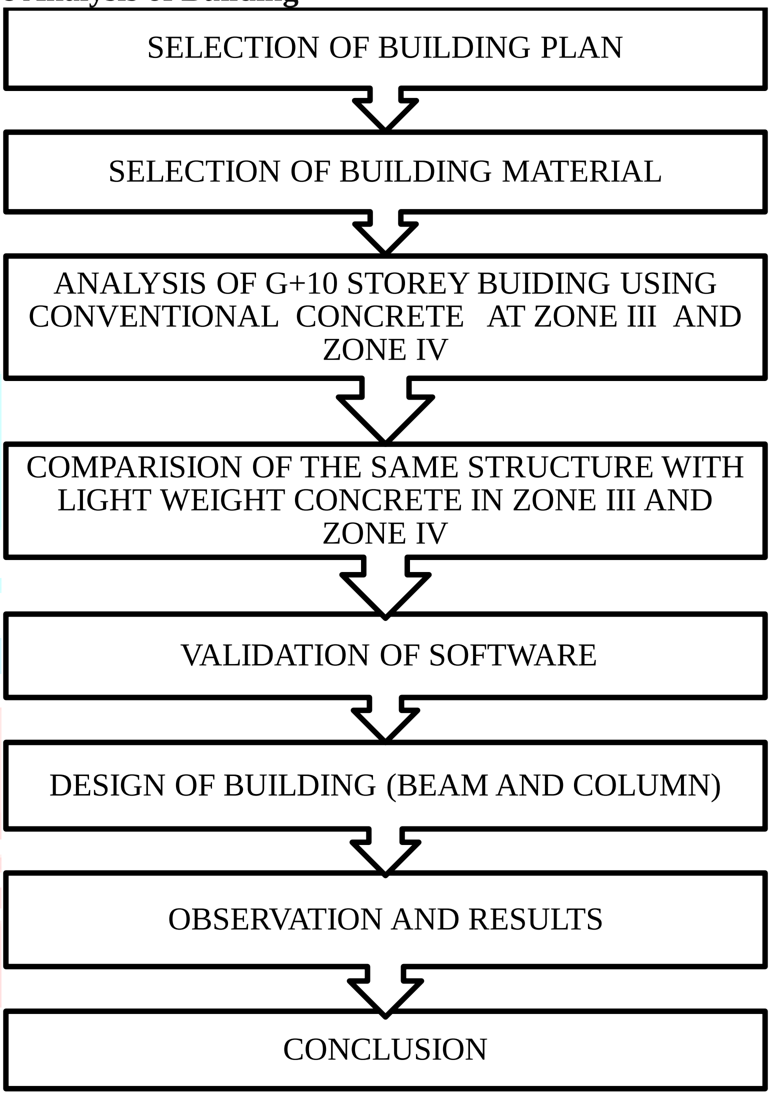
Ashwini Dnyaneshwarrao Bode *et al.* (2021) [2], concentrated his examination on the G+15, Ordinary RC moment-resisting frame (OMRF). The models' analyses are compared to ascertain how well-performing a structure is against lateral stiffness. Node displacement also increases with additional zones. If soft soil is present and the support reaction increases from zone IV to zone V. Node displacement increases as the number of storeys rises.

Asadullah Dost (2021) [3], conducted a comparative study on Seismic Resistant Design and analysis of (G+15), (G+20) and (G+25) Residential Building. In order to reinforce the structural measures in the relevant treatment of the significant components and achieve superior seismic performance, the structure and layout of the overall design process are optimised as necessary. The outcome demonstrates that the height/number of stories and shape of the structure have an impact on lateral displacement. The investigation showed that the lateral displacement increased when shear walls were eliminated from each model, the author came to this conclusion.

A review of seismic Analysis of multi-storied building was performed by **Mirza Mahaboob Baig, C Mahalingam and Yalavarty Nithin** (2021) [4] is concluded that the seismic behaviour of lightweight concrete structure gives the best performance in low seismic zones. In this paper, seismic behaviour of a G+15 high-rise building constructed of structural lightweight concrete (SLWC) and normal weight concrete (NWC) is compared for various soil conditions and seismic zones. The results show that using SLWC under extreme conditions reduces the maximum bending moment and shear force by 40% and 34%, respectively, and the maximum member sizes and steel reinforcement by 31% and 38%

3. METHODOLOGY& MATERIALS

Methodology of Seismic Analysis of Building



3.1 Selection of Building Material

An ordinary G+10 story building floor plan was chosen for the project. After planning for seismic loads, it was discovered that LWC structures weigh 18000 kN less than NWC structures.The data that were utilised to analyse the structures are as follows:

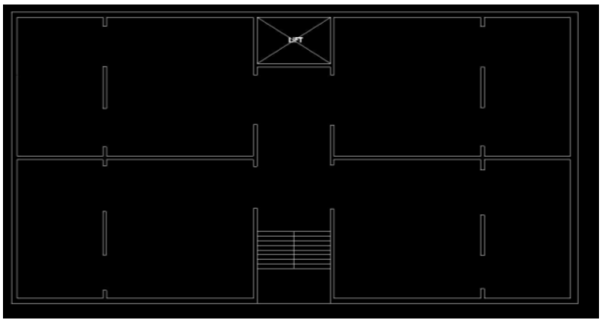
- Material = Conventional concrete
- Grade of concrete (for all structural elements) = M 30
- Unit weight of Conventional concrete = 2500 kg/m^3
- Compressive strength for concrete = 30 Mpa
- Material 2 = light weight concrete
- Grade of concrete (for all structural elements) = M 30
- Unit weight of light weight concrete = 1800 kg/m^3
- Unit weight of cement mortar = 24kN/m3
- Unit weight of water = 10kN/m3

- Unit weight of Brick = 19kN/m3
- Unit weight of Plaster = 20kN/m3
- Steel = HYSD 450

4. EXPERIMENTAL TEST \ ANALYSIA AND RESULT

4.1 Selection of Building Plan

The building's design consists of a multi-story RCC residential building (G+10 Storey). Drawings of the building's architecture and structural plans with accurate details include:



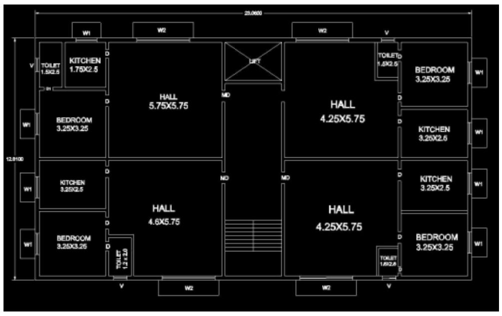


Fig 4.1 Ground Floor plan **Fig 4.2 Floor plan (1st to 7th,9th,10th Floor)**

Vertical mobility is made possible by the building's layout, open well staircase and lifts. For emergency evacuation, a fire-escape chamber (open hall) is available on the building's eight story. One refuge area is available every 24 metres of height. Everything is measured in metres. The area of the building between two succeeding beam grids is assigned a storey number. The storey numbers for the building are defined as follows:

Portion of the building	Storey no.	Portion of the building	Storey no.
Ground floor	1	Sixth floor	7
First floor	2	Seventh floor	8
Second floor	3	Eighth floor	9
Third floor	4	Ninth floor	10
Fourth floor	5	Tenth floor	11
Fifth floor	6	Terrace	12

Table 4.1 Storey numbers

4.2 Statement of the project:-

Analysis and Design of Residential Building (G+10) Specifications are as:-

RCC Building

Size of beam= 0.30 X 0.50 m in rectangular section

Size of column = 0.50 X 0.60 m in rectangular section

Slab thickness = 0.150 m

Height of each floor = 3 m

Height of Ground floor = 2.8 m

Support = Fixed

Seismic zones = III and IV

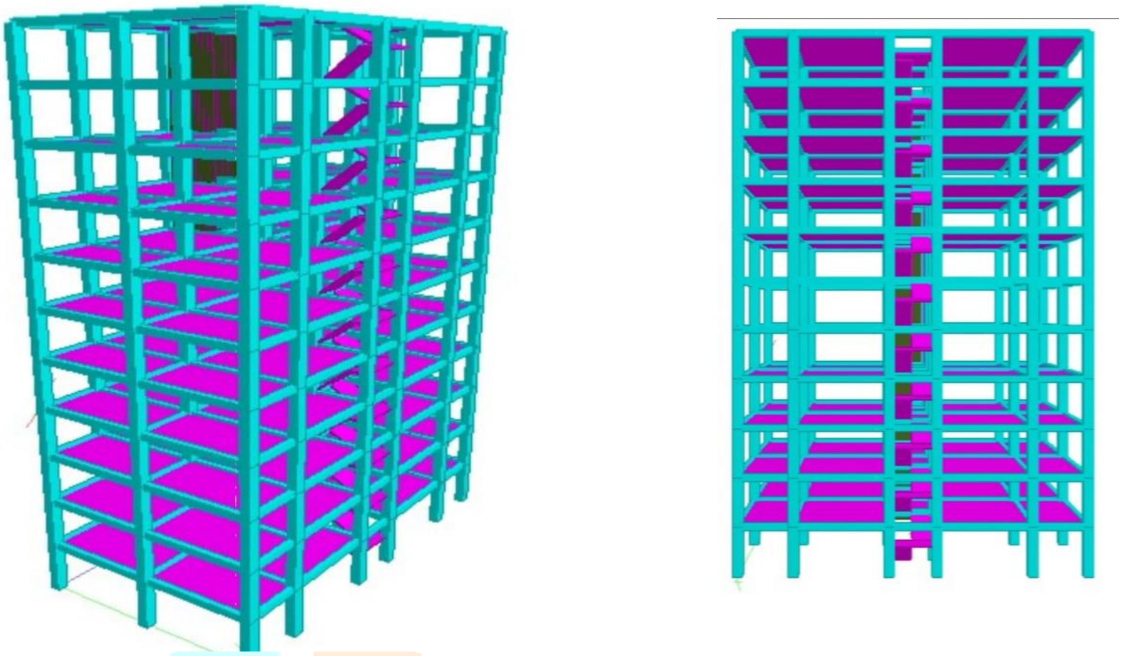


Fig 34.3 3D Rendering View

4.3 Load Calculation

The following design data must be used:

Live load	: 4.0 kN/m2 at typical floor
	: 1.5 kN/m2 on terrace
Floor finish	: 1.0 kN/m2
Water proofing	: 2.0 kN/m2
Terrace finish	: 1.0 kN/m2
Depth of foundation below ground	: 2.5 m
Type of soil	: Type II, Medium as per IS:1893
Walls	: 230 mm thick brick masonry walls only

4.4 Unit load calculations

- sizes of beam and column sections are:
- Columns size: 500 x 600
- Main beams and Secondary beams size : 300 x 400
- Columns (500 x 600) 0.50 x 0.60 x 25 = 7.5 kN/m
- Main & Secondary beams (300 x 400) 0.30 x 0.40 x 25 = 3 kN/m
- Slab (150 mm thick) 0.15 x 25 = 3.75 kN/m2
- Brick wall (250 mm thick) 0.25 x 19 (wall) +2 x 0.012 x 20 (plaster) = 5.23 kN/m2
- Floor wall (height 3.0 m) 3.0 x 5.23 = 15.69 kN/m
- Terrace parapet wall (height 0.9 m) 0.9 x 5.23 = 4.71 kN/m
- Total load on slab = 4 + 3.75 = 7.75 Kn/m2 (DL+LL)
- Load from Staircase Slab = 3.75kN/m2

4.5 Analysis of G+10 storey buiding using conventional concrete at zone III and zone IV

This study includes the analysis and design of multistory buildings using the equivalent static approach for various seismic intensities, III and IV. Building structure modelling, definition, assignment, and analysis are being carried out with the aid of the Staad Pro programme. Base shear, maximum displacement, storey drift, and other phenomena are also being monitored. Determining thr bese shear by using following steps:

1. Calculations are made to divide grouped masses among different floor levels. It includes masses on roofs and other floors while considering the weight of walls, columns, beams, floors, infills, and slabs into mind.
2. Determined design parameters (as per IS 1893 Part 1: 2016) :

   Zone factor (Z) (as per Clause 6.4.2 , Table No. 2),

   Importance factor (I) (as per Clause 6.4.2, Table No. 6)

   Response Reduction factor (R) (as per Clause 6.4.2, Table No. 7)

   Then fundamental natural period is determined using the formula (as per Cl 7.6.2.)

   $Ta = 0.075 \times h^{0.75}$

   Where,

   Ta = fundamental natural period of vibration in seconds

   h = height of building in meters.

3. Spectral Acceleration Coefficient (Sa/g) is depends on time period and type of soil, (as per Clause 6.4.5.)
4. The design horizontal seismic coefficient (Ah) for a structure shall be determined by the following expression (As per IS 1893 (Part I): 2002 Cl. No. 6.4.2,)

   Ah = (Z/2)*(I/R)*(Sa/g)

5. We calculate Base Shear, (As per Cl 7.6.1. of IS 1893 Part 1: 2016)

   $V_B = A_h \times W$

6. The design Base Shear is distributed along the height of the building as per expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}$$

   Where,

   Qi = Design lateral forces at level i,
   Wi = Seismic weights of the floor i
   hi = Height of the floor i
   n = Number of stories

5. Design of Building

5.1 Design methodology

A reinforced concrete structure should be so designed that it fulfils its intended purpose during its life time with:

1. Adequate safety, in terms of strength and stability.

2. Adequate serviceability in terms of stiffness and durability.

3. Reasonable economy.

The following are used for the design of reinforced concrete structures / elements:

1. Working Stress Method (WSM).

2. Ultimate Load Method (ULM).

3. Limit State Method (LSM).

In this project, we are used limit state method of design. So, let us discuss the concept of limit state method.

5.2 Limit state method (lsm)

The structure in this design technique based on the limit state idea must be built to safely bear all loads that may be placed on it over the course of its life and must also meet serviceability standards, such as cracking and deflection restrictions. A Limit State is the upper bound at which the safety and serviceability standards may be said to be met before failure. The objective of design is to establish reasonable probability that the structure won't stop functioning as it is intended, or that it won't approach a limit state. In order to provide a sufficient level of safety and serviceability, all pertinent limit states must be taken into account during design.Limit Serviceability Level Deflection IS:456-2000 clause 23.2 lists the deflections' maximum values. Cracking The permitted limits of concrete cracking will vary depending on the kind of construction and environment. Concrete cracking shouldn't negatively impact the structure's look or durability. Partial safety factor The values of the partial safety factor should be considered as 1.5 for concrete and 1.15 for steel when evaluating the strength of a structure or structural member for the condition of collapse.

5.3 Design of Beams

Beams are structural components tasked with transferring loads through the slab to the column. In the beam specifically, flexure predominates over shear. Reinforced concrete beams come in three different varieties:

1. Singly reinforced beams

2. Doubly reinforced beams

3. Singly or doubly reinforced flanged beams

Reinforcements are positioned at the bottom of single reinforced simply supported beams as opposed to the top of the beam in the case of cantilever beams. Both the compression and tension areas of a beam made of doubly reinforced concrete are strengthened. When the depth of the section must be limited owing to functional or aesthetic considerations, steel must be used in the compression area. A full design of a beam takes into account safety under the serviceability limit states of deflection, crack width, durability, and bond as well as safety under the ultimate limit states of flexure, shear, torsion, and bond. Generally speaking, two sorts of labour are done: section analysis and section design. Knowing the cross section and reinforcement information is necessary for the study of a section in order to calculate the moment of resistance.Knowing the factored design loads is necessary to calculate the cross section and quantity of reinforcement while designing sections.

5.4 Beam Reinforcement Drawing:

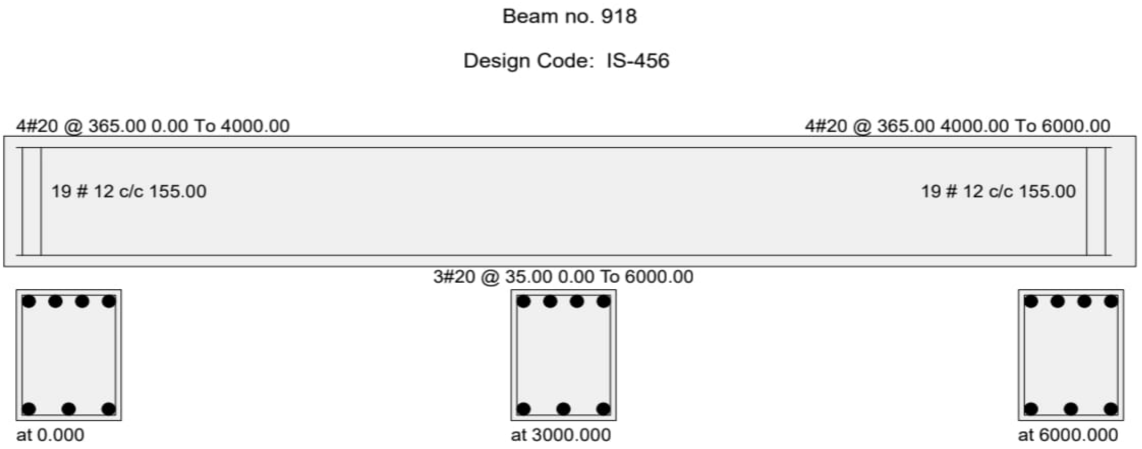


Fig 5.1 Detailing of Beam Reinforcement

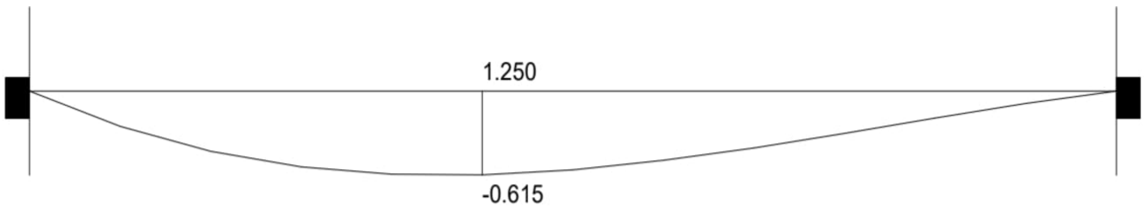


Fig 5.2 Deflection in Local Z direction Load case 20

5.5 Design of Column

Columns are structural components in vertical compression that experience axial forces. The weight from the beam and slab is transferred to the column and then to the foundation.

A column may be categorised using many factors, including:

1. Based on shape

- Rectangle
- Square
- Circular
- Polygon

2. Based on slenderness ratio

Slenderness expressed in terms of the slenderness ratio, which is the ratio of the effective length to the least lateral dimension of the column. Based on the nature of loading,

- Short RCC column, =< 10
- Long RCC column, > 10

3. Based on type of loading

- Axially loaded column
- A column subjected to axial load and unaxial bending
- A column subjected to axial load and biaxial bending

When designing columns, the following steps were taken.

Step 1: Determine the effective length of the column and determine whether it is long or short.

On the basis of the end supports and the sway/no sway situation, the effective length of the column is calculated. A column is categorised as either short or long depending on the relationship between its effective length and its smallest lateral dimension. If its effective length to its smallest lateral dimension is less than 1,

- ≤ 12 ,Short RCC column.

  > 12 ,Long RCC column.

Step 2: Check for eccentricity

Eccentricity in columns refers to the axial load application point's displacement from the column's centre. Eccentric load causes the column to bend towards the loaded point and causes the column to experience a bending moment. According to I.S. 456-2000, we must take into account the eccentricity that is the larger of the following while designing.

I) 20mm. II) (Leff/500) + (b/30)

Where,

Leff = Effective Length of the Column

b = Lateral Dimension of the Column

The column is categorised as being under compression, uniaxially bent, or biaxially bent depending on the eccentricity.

Step 3: Design of longitudinal reinforcement

- The minimum cross-sectional area of longitudinal bars must equal at least 0.8% of the column's gross sectional area.
- The total cross-sectional area of longitudinal bars cannot be greater than 6% of the column's gross cross-sectional area.
- The bars must have a minimum diameter of 12 mm.
- The minimum number of longitudinal bars in a rectangular column must be four, whereas the minimum number of longitudinal bars in a circular column must be six.

Step 5: Design of Lateral Ties

The lateral ties' diameter shouldn't be less than 14 the greatest longitudinal bar's diameter and in no instance less than 6 mm.

The pitch of lateral ties should not exceed

- Least lateral dimension
- 16 x diameter of longitudinal bars (small)
- 300mm

5.6 Column Reinforcement diagram:

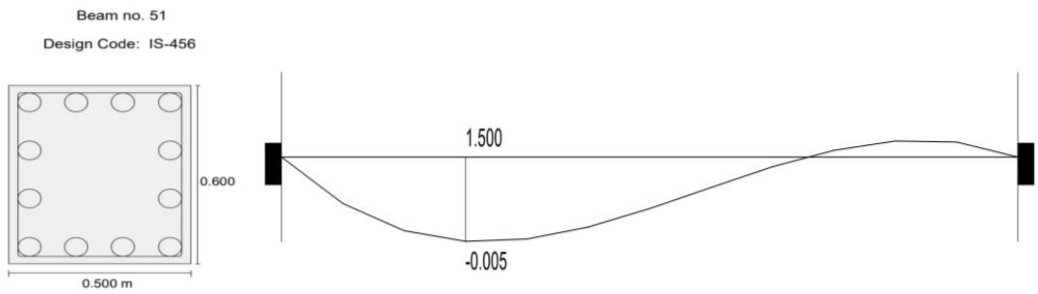


Fig 5.3 Detailing of Column Reinforcement & Deflection in Local Z direction Local case 20

Column	MAIN REINFORCEMENT in Zone III	TIE REINFORCEMENT in Zone III	MAIN REINFORCEMENT in Zone IV	TIE REINFORCEMENT in Zone IV
	Provide 8 - 20 dia.	Provide 12 mm dia. @ 300 mm c/c	Provide 12 – 20mm dia	Provide 12 mm dia. @ 300 mm c/c

Table no. 5.1 Column Reinforcement details :

6. ANALYSIA AND RESULTS

Equivalent static (linear static) seismic analysis is used for G+10 building. Using Staad Pro software, structural reactions such as lateral displacement, story drifts, and base shear for both LWC and NWC are discovered during seismic study of G+10 buildings in Zone III and Zone IV. The findings obtained as follows:

6.1 Volume of concrete and weight of steel

Volume of concrete and weight of steel required for the design of G+10 building. The volume of concrete required for design is 211.3 m^3 and Table 4.1 shows weight of steel in Newton. Fig. 4.1 shows the graph for weight of steel in Newton used for design of G+10 building.

Table 6.1 Weight of steel for different seismic zone

Sl. No.	Zone	weight of steel in (N) for NWC	weight of steel in (N) for LWC
1	Zone III, Z=0.16	365976	365976
2	Zone IV, Z=0.24	374987	374987

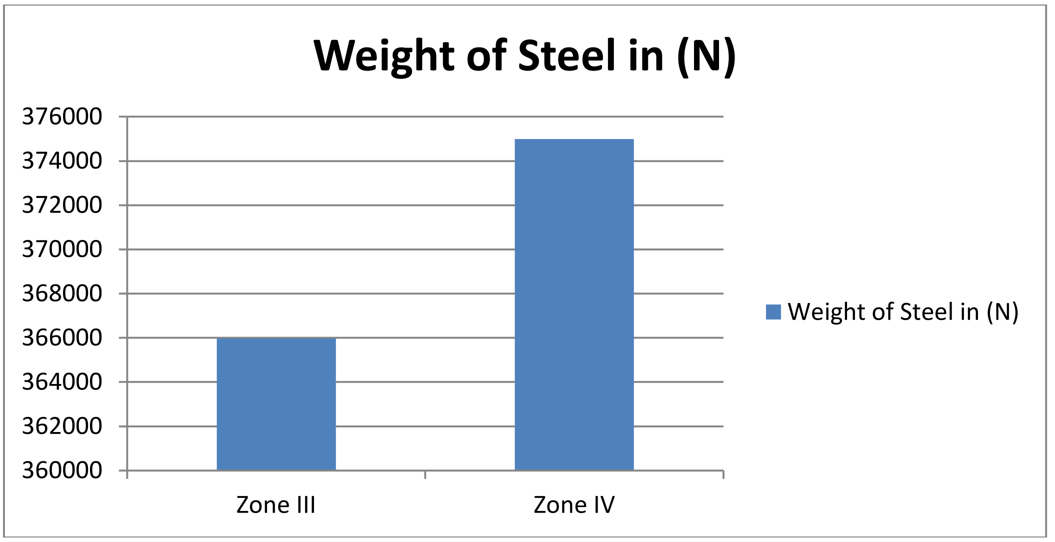


Fig 6.1. Weight of steel in Newton for different seismic zone

Above analysis the result obtained the weight of steel increase when zone factor increases. In table 4.1 shows the weight of steel in Zone III is 365976N and weight of steel in Zone IV is 374987N. When Zone factor increase 0.16 to 0.24, then the weight of steel increase 2% in both type of Structure (NWC and LWC).

6.2 Storey drift

Storey drift is the difference between a high rise building's first floor level and either the floor level above or below. Additionally, it must fall within the permitted range, which, according to IS 1893 part1, is 0.004H, where H is the structure's storey height. Storey Drift coefficient factor of 0.0045 is used for analysis in various zones.

Maximum limit = 0.004H = 0.004x33x1000=132mm

Analysis of Conventional Concrete –

Table 6.2 Storey Drift of Normal Weight Concrete in Zone III and Zone IV

Storey	Height	Storey Drift (CM) in Zone III		Storey Drift (CM) in Zone IV	
		X	Z	X	Z
1	0.0	0.0056	0.0097	0.0088	0.0107
2	3.0	0.8667	0.4267	0.9001	0.4760
3	6.0	0.8815	0.4148	0.9466	0.5229
4	9.0	0.9400	0.4243	0.8730	0.5447
5	12.0	0.9194	0.4116	0.9865	0.5323
6	15.0	0.8751	0.3921	0.9273	0.5096
7	18.0	0.8121	0.3683	0.8439	0.4795
8	21.0	0.7163	1.2635	1.0744	1.8340
9	24.0	0.8386	1.2244	1.2031	1.7751
10	27.0	0.7211	0.9205	1.0295	1.3276
11	30.0	0.5935	0.4934	0.8389	0.7096
12	33.0	0.7067	0.1666	0.9366	0.1990

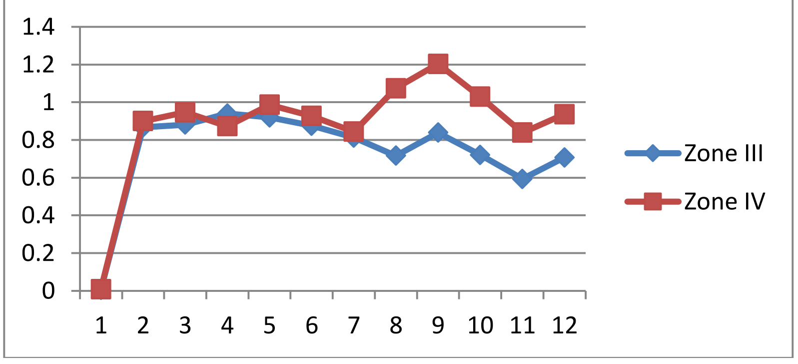


Fig 6.2 Graph of Storey Drift in X- Direction (NWC)

From the Figure 4.2 it is seen that building in Zone IV shows maximum storey drift as compared to building in Zone III. From the graph we can observed that seismic zone as change, then at storey level two to five and seven , there is a sudden change in the drift pattern.

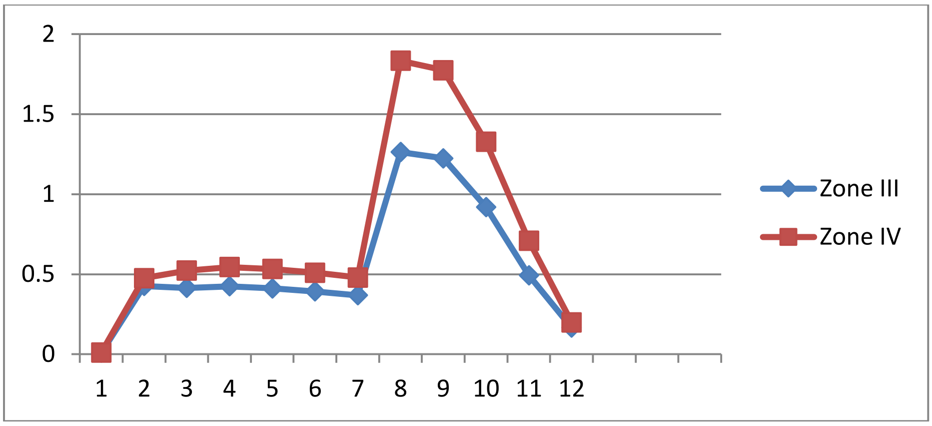


Fig 6.3 Graph of Storey Drift in Z- Direction (NWC)

From the Figure 4.3 it is seen that building in Zone IV shows maximum storey drift as compared to building in Zone III. From the graph observed that seismic zone as change, then storey drift as same at storey level Zero,Two,seven and twelve.

7. APPLICATIONS AND FUTURE SCOPE

➢ APPLIACTIONS

STRUCTURAL OPTIMISATION : Determining suitable sizes for beams, columns, and shear walls to manage increased lateral force, particularly in higher seismic zones.
SAFETY VERIFICATION : Ensuring structural integrity against collapse by evaluating ductility, bending moments, and shear forces using software analysis.
DESIGN COMPILANCE : Adhering to seismic codes (e.g., IS 1893-2002) to calculate proper load combinations—including dead, live, and seismic loads.
DAMAGE CONTROL : : Utilizing techniques like shear walls or bracing to minimize storey drift, reducing non-structural damage.
MATERIAL EFFICIENCY : Analyzing how different zones affect reinforcement ratios and concrete grades (e.g., M30) to optimize cost without compromising safely.

➢ ADVANTAGES

- Optimized Safety & Reduced Risk
- Controlled Structural Response
- Ductile Performance
- Minimized Damage and Serviceability
- Efficient Material Usage

➢ DISADVANTAGES

- High Structural Costs & Materials
- Structural Irregularity Vulnerability
- High Inter-storey Drif
- Design Complexity & Limitations
- Soft Story/Floating Column Risk

➢ FUTURE SCOPE

- Performance-Based Design (PBD): Shifting from purely prescriptive methods to designing for specific performance objectives (e.g., immediate occupancy vs. collapse prevention) during earthquakes.
- Nonlinear Analysis Adoption: Increased use of nonlinear static (pushover) and dynamic (time history) analyses to accurately predict damage, especially for irregular, high-rise, and soft-storey structures.
- Structural Control Systems: Research into active/passive base isolation, dampers, and vibration-control devices to dissipate energy and reduce structural drift.

- Advanced Computational Techniques: Implementing AI and machine learning for rapid seismic damage assessment and optimizing structural configuration for minimum weight and maximum stiffness using software like ETABS or STAAD.PRO.

8. CONCLUSION

From the above analysis work and result obtained from STAAD Pro, it was found that:

- Requirement of steel, storey drift, storey displacement and base shear is more in Zone IV as compared to Zone III, which as 1-3% is more.
- Storey drift, storey displacement is maximum in Z- direction, i.e. Structure maximum displacement at least length of building (e.g. 22*12m, max. displaced at 12m length)
- The result LWCS is less as compared result NWCS. LWCS is economical than NWCS.

In this regard, the info of the structure we've got designed for used as a residential apartment building, to the best of our team's knowledge, include the specified precautionary measures that allow it to overcome the serious danger that come with being situated in an earthquake prone zone along with the nominal gravity masses which can be expected in such a structure.

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