# Seismic Analysis of G+5 Storeys Residential Building for All Zones in India

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***Abstract-*** **India is prone to strong earthquake shaking, and hence earthquake resistant design is essential. The Engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquake. Such buildings will be too robust and also too expensive. Practically no building can be made earthquake proof. The engineering intention is to make buildings earthquake resistant, such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, the safety of people and contents is assured in earthquake resistant design of buildings and thereby a disaster is avoided. This is a major objective of seismic design codes throughout the world in recent times. The sixth revision of IS 1893 (Part 1): 2016, "Criteria for Earthquake Resistant Design of Structures" have been published by Bureau of Indian Standards recently in December 2016. In this new code many changes have been included considering standards and practices prevailing in different countries and in India. Extended Three-dimensional Analysis of Building Systems is a special purpose computer program developed specifically for building systems .The main objective of this study is to review seismic analysis of multi story buildings by various researchers using ETABS as per the provisions of IS 1893 (Part 1): 2016. The various parameters considered in analysis by researchers are Geometric irregularity, mass irregularity, re-entrant corners, different locations of shear walls, different building shapes, masonry infill walls, etc.**

***Index Terms-*** **ETABS, Earthquake resistant structure, Equivalent Static analysis.**

## 1. INTRODUCTION

### 1.1GENERAL

The rapid industrialization and increase in population have called for optimum use of scale land due to which multi-storey building have become inevitable. Apart from dead and live loads, the structures have to withstand lateral forces. Under the action of natural wind and earthquake a tall building will be continually buffeted by gusts and other dynamic foes. Most Reinforced Concrete frame buildings in developing countries are in-filled with masonry walls. Experience during the past earthquakes has demonstrated the beneficial effects as well as the ill-effects of the presence of infill masonry walls. In at least two moderate earthquakes (magnitude 6.0 to 6.5 and maximum intensity VIII on MM scale) in India, frame buildings with brick masonry infills have shown excellent performance even though most such buildings were not designed and detailed for seismic response.

The primary purpose of all kinds of structural systems used in the building type of structure is to transfer gravity loads effectively. The most common loads resulting from the effect of Gravity is dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway

Movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

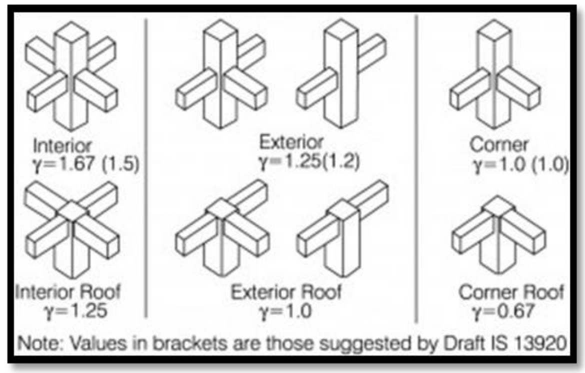
Earthquake resistant structures are structures designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake-resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts. According to building codes, earthquake resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location.

This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of functionality should be limited for more frequent ones. To combat earthquake destruction, the only method available to ancient architects was to build their landmark structures to last, often by making them excessively stiff and strong.

Beam-column joint is an important component of a reinforced concrete moment resisting frame and should be designed and detailed properly, especially when the frame is subjected to earthquake loading. Failure of beam-column joints during earthquakes is governed by bond and shear failure mechanism which are brittle in nature. Therefore, current international codes give high importance to provide adequate anchorage to longitudinal bars and confinement of core concrete in resisting shear

It has to be noted that when buildings are subjected to earthquake loads, as they are often designed only for a fraction of the earthquake loads (about 10% of load), plastic hinges will be formed at the ends of the members where there are heavy bending moments, and subsequently the frames will fail when there are enough plastic hinges to form a mechanism. Hence, one has to follow the general rules while planning and designing buildings in earthquake zones-for example, the buildings should be regular, soft and weak stories should be avoided, and columns should be carefully designed (300 mm minimum size is required), column ties should have closely spaced near plastic hinge zones and should have 135o hooks with six diameter or greater than 65 mm extensions. Moreover strong column-weak beam principle should be followed.

The beam-column joint is defined as the portion of the column within the depth of the deepest beam that frames into the column (ACI 352-02). The types of beam-column joints in a moment resistant frame can be classified as (a) interior joint, (b) exterior joint and (c) corner joint. When four beams frame into the vertical faces of a column, the joint is called an interior joint. When one beam frames into the vertical face of a column and two more beams frame into the column in the perpendicular direction it is called an exterior joint. A corner joint is one in which beams frame into two adjacent vertical faces of a column. In a roof joint (also called knee joint), the columns will not extent above the joint, whereas in a floor joint, the columns will extend above the joint as shown in Fig




## 2. OBJECTIVES

The principal objectives of the study are as follows:

1. To study the behaviour of structure subjected to seismic.
2. To study the variation of bending moment, shear forces when structure subjected to seismic for different zones.
3. To study the effect seismic for building for displacement, drift, storey shear, time period and base shear for different zones.
4. The effect of zone on behaviour of concrete structures is summarized using the obtained results, by concluding the variation of results in structures.

## 3. BUILDING CONFIGURATION AND METHODOLOGY

Following methodology is adapted to analyses tall tube in tube structure:

1 RC concrete structure is considered for the study having 5 storey of height 15 m each floors is considered as 3 m height.

2 The regular concrete moment resisting frame of plan is considered for analysis.

3 For same plan zone factors are varied for all zones in India.

4 In order to get consistent results, the floor height is kept constant for all geometric configurations.

5 To understand the behaviour under lateral loads applied IS 1893: 2002 are used respectively.

6 Based on the results and responses from earthquake loads applied, conclusion is made.

Mainly two types of design procedures, we are considering one method for analysis

1. Equivalent Static Analysis
2. Dynamic Response Spectrum Analysis

3.1 Equivalent Static load analysis of building Design seismic Base shear as per IS 1893 (Part I):2002

First step is find out design base shear, the design base shear of any building along principle direction is given below

$V_b = (A_h) \times W$

Where, $A_h$= seismic design co-efficient of the structure in horizontal direction.

W= weight of the seismic building.

Horizontal co-efficient of the structure is given by

$A_h = (Z\ I/2R) * Sa/g$

In this equation,

Where, Z = Zone factor depends on the region in which the structure is constructed.

I = Importance factors.

R = reduction factor. It explains the structure is brittle or ductile.

Sa/g = it is the average response acceleration co-efficient; it is varying for different type of soil.

T = Approximate fundamental natural period vibration.

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

In these equations 'h' is total building height in meters.

Lateral force at each floor depends on

1. Mass of the floor
2. Stiffness distribution of the structure
3. Displacement of nodes at each mode shape

Base shear Distribution along the height building height is given by

$Q = Vb*(Wi\ hi / \sum_{i=1}^{n} Wi\ hi)$

Where, Qi = Design lateral force at floor i

Wi = Seismic weight of floor i

hi = Height of floor measured from base, and

n = Number of story's in the building is the number of levels at which the masses are Located.

3.2 Modelling

1. Bare frame for gravity load analysis.
2. Bare frame for seismic analysis (all zones).

3.3 Building Modelling and Loading Data

3.3.1 Building Data

Type of structure - Concrete moment resisting frames

Plan Configurations – Regular

Number of Stories - G+5

Height of each floor - 3 m

Height of building - 18 m

Building type- Residential

3.3.2 Material Properties

Grade of concrete $F_{CK}$ – M20

Grade of steel- $F_Y$ -500

3.3.3 Material Property Design Data Section Properties

Column sections – C230X500mm.

Beam Sections – B230X400mm.

Slab Section – 150 mm thick.

3.4 Gravity and Lateral load consideration

3.4.1 Gravity load:

a. Live load - 2kN/$m^2$
b. Wall load – 11.178KN/$m^2$

3.4.2 Earthquake inputs as per IS 1893 (Part I): 2002

Location of Building - Moderate intensity (Z-II, Z-III, Z-IV, Z-V)

Soil type - Type II

Importance factors - 1.0 for all other structures.

- 1.5 important buildings.

Response reduction factors - 3.0

3.5 Software

The software used in this program is ETABS 2016. ETABS software is a special computer program developed specifically for different building systems. However, the need for special programs like ETABS has never been more evident for structural engineers to put nonlinear static and dynamic analysis into practice and to use the greater computer power available today to create larger, more complex analytical models.

With ETABS, modelling and modifying a model, analysis, design and optimizing the design all these are done through a single interface which is completely integrated within Microsoft windows. These ETABS produces graphical displays of the results more easily. Printed output and even we can save a file for selected elements or for all the elements are also easily available by using ETABS.

## 4. RESULTS AND DISCUSSION

The behaviour of each model is captured and the results are tabulated. The variation of systematic parameters like story lateral displacement, story drift, natural time period and base shear has been studied for equivalent static method. The results of all the models are observed and comparing the results of each model.

4.1 Storey Displacement

It is total displacement of $i^{th}$ storey with respect to ground and there is maximum permissible limit prescribed in IS codes for buildings.

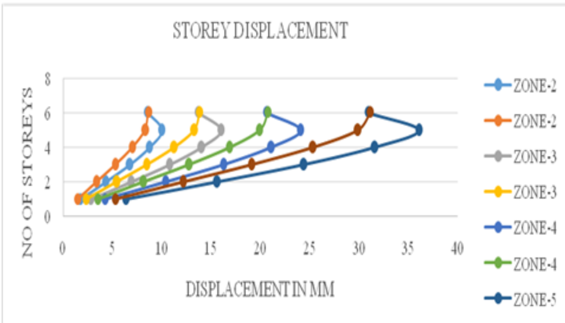



Fig 4.1 Storey vs. Displacement For Bare Frame Structures Without Seismic

The lateral displacements obtained for equivalent static method (EQS) for G+4 (including stair case head room) storey building models of different Zones, along both X and Y directions are listed in the tables below

| BARE FRAME DISPLACEMENT IN MM | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ZONE-2 | | ZONE-3 | | ZONE-4 | | ZONE-5 | |
| | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y |
| 6 | 8.587 | 8.642 | 13.738 | 13.827 | 20.608 | 20.74 | 30.912 | 31.111 |
| 5 | 10.011 | 8.291 | 16.017 | 13.266 | 24.026 | 19.899 | 36.039 | 29.849 |
| 4 | 8.761 | 7.025 | 14.017 | 11.24 | 21.026 | 16.86 | 31.539 | 25.29 |
| 3 | 6.767 | 5.306 | 10.826 | 8.489 | 16.24 | 12.734 | 24.359 | 19.101 |
| 2 | 4.332 | 3.387 | 6.931 | 5.419 | 10.396 | 8.129 | 15.595 | 12.194 |
| 1 | 1.779 | 1.481 | 2.847 | 2.369 | 4.27 | 3.553 | 6.405 | 5.33 |

4.1.1 Observations and Discussions on Storey Displacement

By studying from Table 6.1 and comparing their values in fig. 6.1 we can see that displacement increases as storey height increases. We can clearly see that there is increase of lateral displacement with increasing the zone factors where we can see less displacement in top because of only stair case head room in model for along both X and Y direction. Comparing to the structure we can conclude that zone factor effects to displacement value.

Also it is observed that the value of displacement for zone V is greater than that of zone II. Out of all the considered models Zone –V has maximum displacement value. In graph at top we find minimum displacement because of stair case head room.

4.2 Storey Drift

It is defined as ratio of displacement of two consecutive floors to height of that floor. It is very important term used for research purpose in earthquake engineering.

Storey drift obtained for G+4 storey all building models along both X and Y directions are listed for both Equivalent static in the below tables

Table 4.2 Storey Drift for Bare Frame Structures

| BARE FRAME Drift | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ZONE-2 | | ZONE-3 | | ZONE-4 | | ZONE-5 | |
| | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y |
| 6 | 0.000368 | 0.000506 | 0.000589 | 0.00081 | 0.000883 | 0.001215 | 0.001324 | 0.001823 |
| 5 | 0.000417 | 0.000422 | 0.000667 | 0.000675 | 0.001 | 0.001013 | 0.0015 | 0.00152 |
| 4 | 0.000665 | 0.000573 | 0.001064 | 0.000917 | 0.001595 | 0.001375 | 0.002393 | 0.002063 |
| 3 | 0.000812 | 0.00064 | 0.001298 | 0.001023 | 0.001948 | 0.001535 | 0.002922 | 0.002302 |
| 2 | 0.000851 | 0.000636 | 0.001361 | 0.001017 | 0.002042 | 0.001525 | 0.003063 | 0.002288 |
| 1 | 0.000593 | 0.000494 | 0.000949 | 0.00079 | 0.001423 | 0.001184 | 0.002135 | 0.001777 |

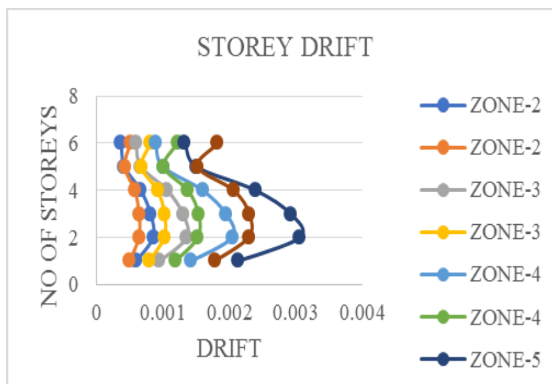



Fig 4.2 Storey vs. Drift for Bare Frame Structures With Seismic

4.2.1 Observations and Discussions on Storey Drift

By studying from Table 6.2 and comparing their values in fig. 6.2 we can see that variation in drift as storey height increases. We can clearly see that there is a increase of lateral drift for varying the zonal value along both X and Y direction respectively for equivalent static analysis.

Also it is observed that the value of Drift for zone V is greater than that of zone II. Out of all the considered models model in zone-V have maximum value because affect of zone factor.

4.3 Storey Shear

It is the lateral force acting on a storey due to the forces such as seismic and wind force. It is calculated for each storey, changes from minimum at the top to maximum at the bottom of the building.

Table 4.3 Storey Shear For Bare Frame Structures With Zone Comparison

| STOREY SHEAR IN KN | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ZONE-2 | | ZONE-3 | | ZONE-4 | | ZONE-5 | |
| | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y | EQ X | EQ Y |
| 6 | 9.0887 | 8.2679 | 14.542 | 13.2286 | 21.813 | 19.8428 | 32.7195 | 29.7643 |
| 5 | 110.2251 | 100.2697 | 176.3601 | 160.4315 | 264.5402 | 240.6472 | 396.8102 | 360.9708 |
| 4 | 180.6671 | 164.3495 | 289.0674 | 262.9591 | 433.601 | 394.4387 | 650.4016 | 591.658 |
| 3 | 220.398 | 200.4919 | 352.6368 | 320.7871 | 528.9553 | 481.1806 | 793.4329 | 721.7709 |
| 2 | 238.0562 | 216.5552 | 380.8899 | 346.4884 | 571.3349 | 519.7326 | 857.0024 | 779.5989 |
| 1 | 242.4708 | 220.5711 | 387.9532 | 352.9137 | 581.9298 | 529.3706 | 872.8947 | 794.0559 |

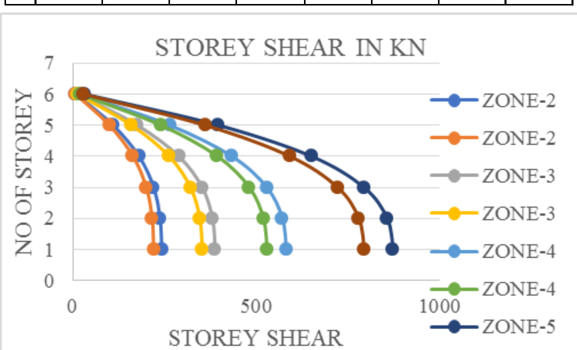



Fig 4.3 Storey vs. Storey Shear For Bare Frame Structures With Seismic

4.3.1 Observations and Discussions on Storey shear

By studying from Table 6.3 and comparing their values in fig. 6.3 we can see that variation in shear as storey height increases. We can clearly see that there is a reduction of storey shear for bare frame structure along both X and Y direction respectively for equivalent static analysis.

Here the storey shear depends on the weight of the storey so shear wall has maximum shear along the storey.

4.4 Natural Time Period

A time period is the time needed for one complete cycle of vibration to pass a given point.

Table 4.4 Story Drift for Shear Wall With Frame Structures With Zone Comparison

| Time Period in sec | | | | |
|---|---|---|---|---|
| MODE | ZONE-2 | ZONE-3 | ZONE-4 | ZONE-5 |
| 1 | 0.814 | 0.814 | 0.814 | 0.814 |
| 2 | 0.694 | 0.694 | 0.694 | 0.694 |
| 3 | 0.631 | 0.631 | 0.631 | 0.631 |
| 4 | 0.265 | 0.265 | 0.265 | 0.265 |
| 5 | 0.227 | 0.227 | 0.227 | 0.227 |
| 6 | 0.209 | 0.209 | 0.209 | 0.209 |
| 7 | 0.155 | 0.155 | 0.155 | 0.155 |
| 8 | 0.149 | 0.149 | 0.149 | 0.149 |
| 9 | 0.131 | 0.131 | 0.131 | 0.131 |
| 10 | 0.124 | 0.124 | 0.124 | 0.124 |
| 11 | 0.118 | 0.118 | 0.118 | 0.118 |
| 12 | 0.11 | 0.11 | 0.11 | 0.11 |

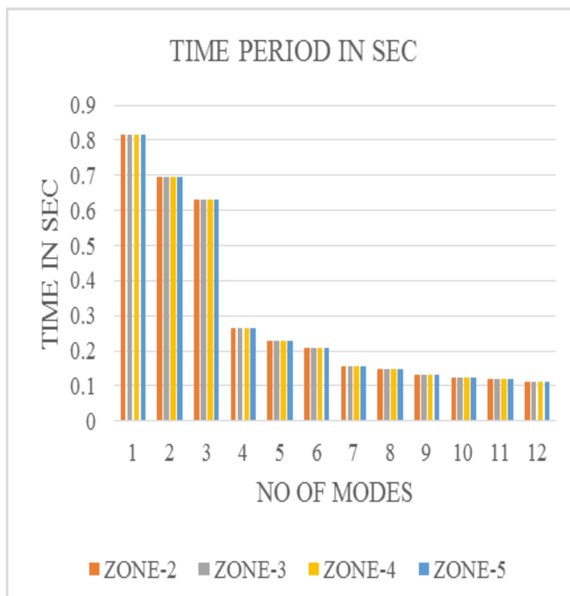



Fig 6.4 Time Vs. Mode for Bare Frame Structures with Seismic

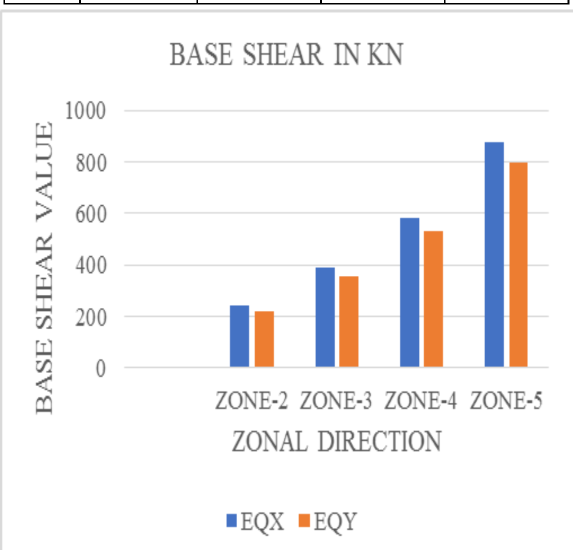
4.4.1 Observations and Discussions on time period

By studying from Table 6.4 and comparing their values in fig. 6.4 we can see that variation in Time period according to model shapes, by default

software will consider 12 mode shapes in which first three models are considered for analysis.
Also it is observed that the value of Time period is more for bare frame structures compared to shear wall structures so shear wall increases the stiffness and reduces the displacement and time period.

4.5 BASE SHEAR
It is the total lateral force acting on the building at its base, which is equal to storey shear of the bottom storey.
Table 4.5 Base Shear For Bare Frame Structures With Zone Comparison

| BASE SHEAR IN KN | | | | |
|---|---|---|---|---|
| | ZONE-2 | ZONE-3 | ZONE-4 | ZONE-5 |
| EQX | 242.4708 | 387.9532 | 581.9298 | 872.8947 |
| EQY | 220.5711 | 352.9137 | 529.3706 | 794.0559 |




4.5.1 Observations and Discussions on Base shear
By studying from Table 6.5and comparing their values in fig. 6.5 we can see that variation in base shear value along with zone factor.
Base shear depends on the total weight of the structure so when we compared Zone-II and zone-V, Zone-V structure have maximum weight and maximum base shear.

5. CONCLUSIONS

5.1 General
The present work is focused on the study of behaviour of structure with varying zone are studied and displacement, drift, storey shear, time period and base shear are the parameters considered for analysis and study the variation in the beam details, column details, base reaction for all zones in the structure..

5.2 Conclusions
[1] From the above study we can observed that the displacement increases when we considered seismic action for the structure.
[2] Compare to zone-II, Zone –V have maximum value for all considered parameters.
[3] Time period is similar for all zones and is within limit.
[4] From the study we can say that the building have effect from the seismic factors.
[5] While designing the structures we need to consider the seismic factor for the analysis.

5.3 Scope for Future Work
Within the limited scope of the present work, the broad conclusions drawn from this work have been reported. However, further study can be undertaken in the following areas:
1. By considering different material property analysis can be done.
2. By varying the story height and increasing story number the analysis can be done for different zones.
3. Varying the column and beam dimensions for same models can be analyzed.
4. Consideration of soil surface interaction for the model.
5. Irregular structures are considered for analysis.

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