Case Study of G+12 RCC Frame Structure in Different Earthquake Zones using ETABS

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Abstract: *A stable as well as durable structure is a needed in this modern era. A large amount of manual work is needed to be done in order to perform the comprehensive analysis of structure, which takes too much time. In order to redeem time, computer aided modelling comes beneficial. Etabs is such a kind of software. With its easy to use user interface as it can handle complex tasks. In this paper a complete case study is done for G+12 RCC multi-storey building under the lateral loading effect of wind and earthquake using ETABS (Extended Three Dimensional Analysis of Building system).*

Keywords: Analysis, Base Reaction, Class, Displacement, Drifts, Etabs, Earthquake load, Wind Speed

I. INTRODUCTION

A lot of studies (or researches) have been done on this topic and still it is continuing, because it is rightly said that "More we try to learn, more we can curtail the detrimental damages and save the lives". As per the latest variation of seismic zones map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. Besides this, the earthquake-zoning map of India divides India into 4 seismic zones (Zone II, III, IV and V) unlike its previous variant, which consisted of five or six zones for the country. According to the present map, Zone V expects the highest level of seismicity while Zone II is of the lowest level of seismicity.

This analysis mainly deals with the study of a rectangular shaped structure using ETAB against wind and earthquake loads as per IS code by using CONCRETE BLOCKS instead of brick masonry. Since the AAC Concrete Blocks are not only economical than Bricks but also diverse fruitful outcomes than brick. A 70x50m, 13 storeys structure 8x8m bays is modelled using this software. The total height of the structure is 41.6m. Loads considered are taken in accordance with the IS-875(Part1, 2), IS-1893(2002), and IS-456:2000.

II. LITERATURE SURVEY

Papa Rao and Kiran Kumar (2013) [1]: In their study they researches on the changes in the percentage of steel and volume of concrete for the RCC framed structure for various seismic zones of India. They have designed the structure for gravity load and seismic forces, which might be effect on building. According to their research, they concluded that the variation in support reactions for exterior columns increased from 11.59% to 41.71% and in case of edge columns, it is 17.72% to 63.7% from Zone II to Zone V and as in the case of interior columns, it is very less. In case of concrete quantities, volume of concrete has been increased for exterior and edge columns from Zone III to Zone V because of increase in support reactions with the effect of lateral forces and variation is very small in interior columns. Percentage variations of steel in external beams are 0.54% to 1.23% and in internal beams, it is noted 0.78% to 1.4%. The bottom reinforcement is not changed for seismic and non-seismic design.

Perla Karunakar (2014) [2]: In their project they find out the performance and variation in steel percentage and concrete quantities in various seismic zones and impact on overall cost of construction. As per the research, the concrete quantities are increased in exterior and edge columns due to increase in support reactions however; variation is very small in interior column footings. Reinforcement variation for whole structure between gravity and seismic loads are 12.96, 18.35, 41.39, 89.05%.the cost variation for ductile vs. non-ductile detailing are 4.06%.

Inchara K P, Ashwini G (2016)[3]: The main moto of this study were to study the performance and variation in steel percentage and quantities concrete in R.C framed irregular building in gravity load and different seismic zones. And to know the comparison of steel reinforcement percentage and quantities of concrete when the building is designed as per IS 456:2000 for gravity loads and when the building is designed as per IS 1893(Part 1):2002 for earthquake forces in different seismic zones. In this study five (G+4) models were considered. All the four models were modelled and analysed for gravity loads and earthquake forces in different seismic zones. ETABS software was used for the analysis of the models. According to their research, it can be inferred that support reactions tended to increase as the zone varied from II to V, which in turn increased volume of concrete and weight of steel reinforcement in footings and in case of beams, percentage of steel reinforcement increased through zones II to V.

Jitendra Choubisa [4]: According to his research, a comparison is done for the story drift, maximum BM, and Max. Base Reaction for earthquake loading between 4 shapes of different buildings using ETABS. In which, he found that structures with symmetric perform quite good at the time of earthquake loading. Although, he also concluded that H and hollow shape can be economic for the high-rise building prone to earthquake attacks. Whereas Box will be then given somehow same results after it, while U shape must have to be avoided.

III. MODELLING OF RCC FRAME

1. Dimension of Structure: 70x50 m
2. Storey Height: 3.2m(each)
3. Grid Lines: in X: 8no's, in Y: 6no's@8m c/c both
4. Type of Soil: Type II (Medium Soil)
5. Terrain category: 4

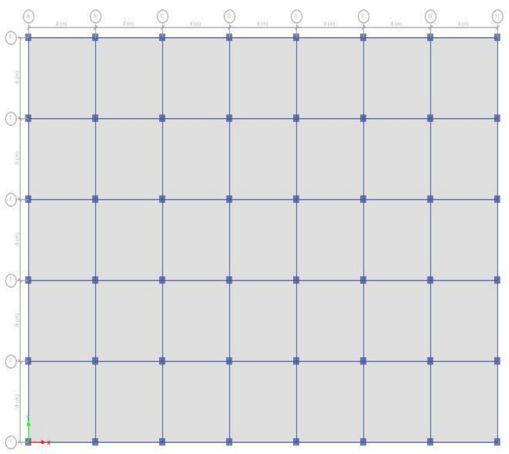

Fig 1: Plan of Building

6. Class: B
7. Importance Factor: 1
8. R: 5
9. Support Condition: Fixed
10. Dimensions:
    a). Beam: 550x750mm
    b). Column: 750x750mm & 850x850mm
11. Slab Thickness: 150mm
12. Thickness of wall: 0.3m (external), 0.23m (internal)
13. Grade of Concrete: M30
14. Grade of Steel: Mild Steel Fe250 & HYSD Fe550
15. Density of AAC Concrete Block: 650Kg/m^3 ~ **6.4kN/m^3**

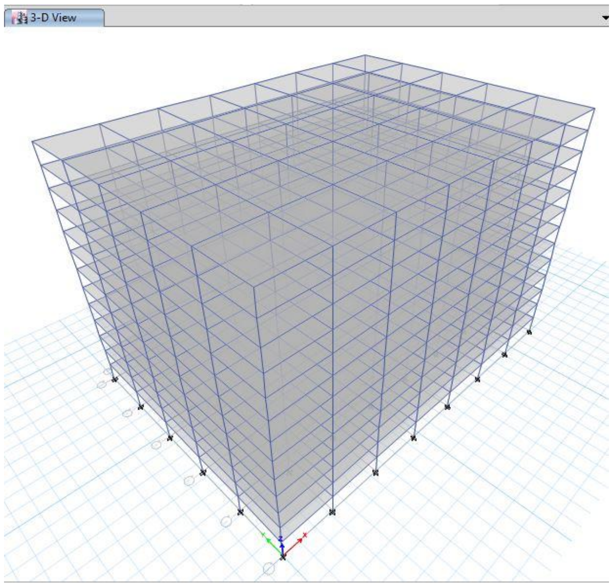

Fig 2: 3D-View

IV. LOADING CONSIDERATION

A). Dead Load (DL):

- DL for external wall using concrete blocks= {6.4x0.3x(3.2-0.75)}
  = 4.704kN/m
- DL for internal wall=
  = {6.4x0.23x(3.2-0.75)}
  = 3.6064kN/m
- DL for parapet wall
  = (6.4x0.3x1) = 1.92kN/m

B). Live Load (LL): 3kN/m^2

C). Floor Finish: 1kN/m^2

V. METHODOLOGY

The process of modelling the structure is depicts in following flow chart:

Preparation of Grid & Stories

↓

Defining the Material Properties

↓

Defining Members & their respective size

↓

Placing members on their respective places

↓

Applying Support Conditions

↓

Defining Load Pattern & Load Combination

↓

Applying Dead Loads on Beams & Floors

↓

Applying Live Loads on Floors

↓

Defining Diaphragm & Apply

↓

Model Checking

↓

Run the Model (Analysing)

↓

Design the Structure

A). Wind Analysis:

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 metres above ground.

Nature of Wind in Atmosphere: In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in the code. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the averaging time employed in analysing the meteorological data and this averaging time varies from a few seconds to several minutes. The magnitude of fluctuating component of the wind speed which is called gust, depends on the averaging time. In general, smaller the averaging interval, greater is the magnitude of the gust speed.

Design Wind Speed: The basic wind speed for any site shall be obtained from IS: 875 (Part 3) – 1987 and shall be modified to include the following effects to get design wind velocity at any height for the chosen structure: a) Risk level; b) Terrain roughness, height and size of structure; and c) Local topography. It can be mathematically expressed as follows:

$$V_z = V_b.k_1.k_2.k_3$$

Where,

V_z = design wind speed at any height z in m/s;

K_1 = probability factor (risk coefficient);

K_2 = terrain, height and structure size factor;

and k_3 = topography factor.

Zone	II	III	IV	V
Wind Speed(m/s)	39	44	47	50

Table 1: Wind Speed for Different Zones

Design Wind Pressure: The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_z = 0.6.V_z^2$$

Where,

p_z = design wind pressure in N/m^2 at height z,

v_z = design wind velocity in m/s at height z.

B). Seismic Analysis (Earthquake Load):

The characteristics (intensity, duration and so on) of seismic ground vibrations expected at any location depends upon the magnitude of earthquake, its depth of focus, distance from the epicentre, characteristics of the path through which the seismic waves travel, and the soil strata on which the structure stands. The random earthquake ground motions, which cause the structure to vibrate, can be resolved in any three mutually perpendicular directions. The predominant direction of ground vibration is usually horizontal.

Earthquake-generated vertical inertia forces are to be considered in design unless checked and proven by specimen calculations to be not significant. Vertical acceleration should be considered in structures with

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large spans, those in which stability is a criterion for design, or for overall stability analysis of structures. Reduction in gravity force due to vertical component of ground motions can be particularly detrimental in cases of pre-stressed horizontal members and of cantilevered members. Hence, special attention should be paid to the effect of vertical component of the ground motion on pre-stressed or cantilevered beams, girders and slabs.

Design Spectrum:

For the purpose of determining seismic forces, the country is classified into four seismic zones viz.; Zone II, Zone III, Zone IV, and Zone V.

The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{ZIS_a}{2Rg}$$

where

Z = Zone factor given in following Table, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

Seismic Zone	Zone II	Zone III	Zone IV	Zone V
Z	0.10	0.16	0.24	0.36

Table 2: Zone factor for different zones

R = Importance factor, depending upon the functional use of the structures, characterised by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (As per Table 6 - Clause 6.4.2 of IS 1893).

S_a/g = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterised by ductile or brittle deformations.

VI. ANALYSIS RESULTS

A). Base Reaction

Following table compares the maximum base reaction in kN in F_z direction for the different load combinations.

Table 3: Base Reaction(in kN)

Zone→ Load Combinations↓	II	III	IV	V
1.5(DL+LL)	280001.59	547926.4	438341.1	457902.2
1.5(DL+EL)	209801.59	416886.4	416886.4456	416886.4
1.2(DL+LL+EL)	224001.27	438341.15	547926.4	438341.15
1DL+0.8(LL+EL)	177307.72	347812.29	347812.297	347812.297

B). Story Displacement:

The give line graphs reveals the mm displacement of multi-storey structure under a various load combinations.

1. **Earthquake Load:**

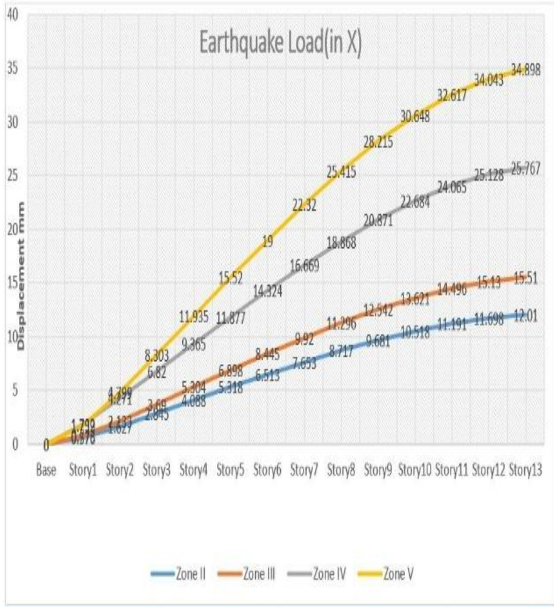


Chart-1: Displacement due to Earthquake Load

As it can be seen that, there is noticeable rise in the displacement in each zone due to earthquake load merely, but, in Zone V, a speedy soar is observe which was 34.898mm, followed by Zone IV were 25.767mm.

2. Wind Load:

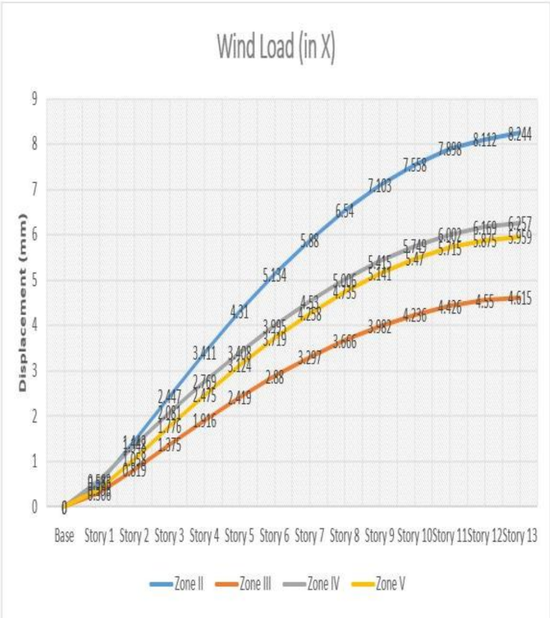


Chart-2: Displacement due to Wind Load

It is interesting to note that Zone II shows the highest displacement when wind load is applied, which is 8.244mm, while Zone III reveals the lowest displacement of 4.615mm. However, Zone IV and Zone V shows tedious sequential upsurge of 6.25mm and 5.9mm respectively.

3. 1.2(DL+LL+WLinX) :

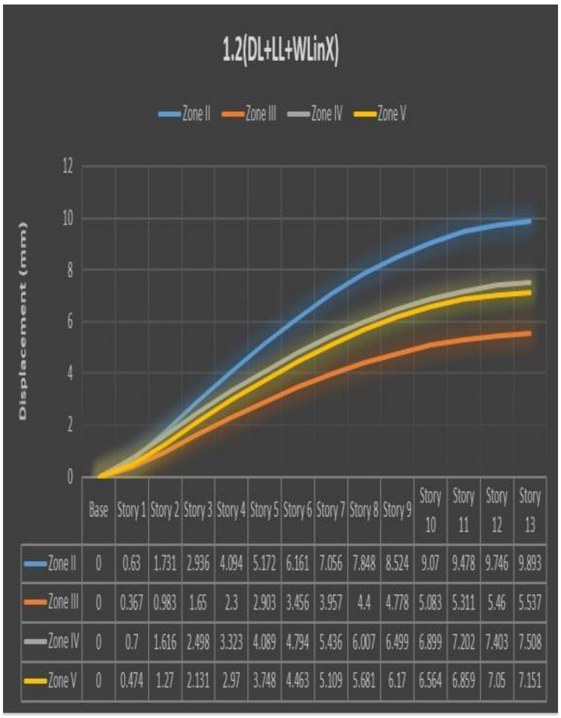


Chart-3: Displacement due to Load Combination

4. 1.2(DL+LL+ELinX) :

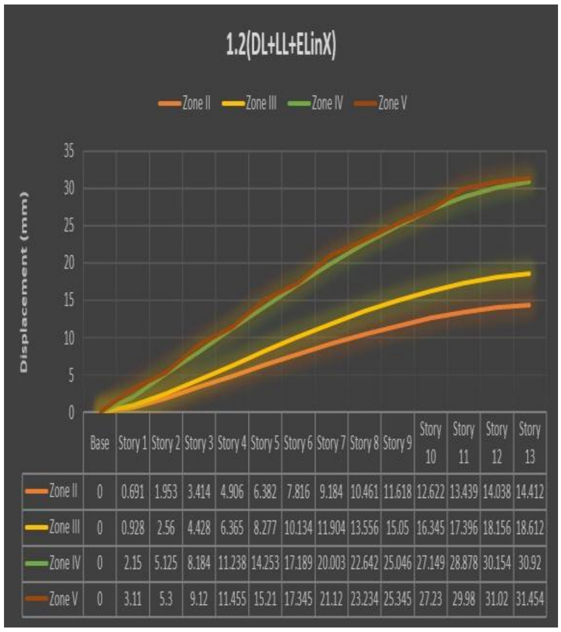


Chart-4: Displacement due to Load Combination

It can be seen that, the most common trend is Zone IV and Zone V are progressively rise with an almost around the same displacement. Moreover, the lowest number of displacement is found in Zone II which is 14.412mm, followed by 18.612mm in Zone III as the floor increased.

5. 1.5(DL+ELinX) :

According to the graph, Zone V enumerates the maximum mm of displacement in this type of load combination for story drift, which was 52.346mm at storey 13. Besides this, dramatic downward trend were seen as descend to Zone II from zone IV.

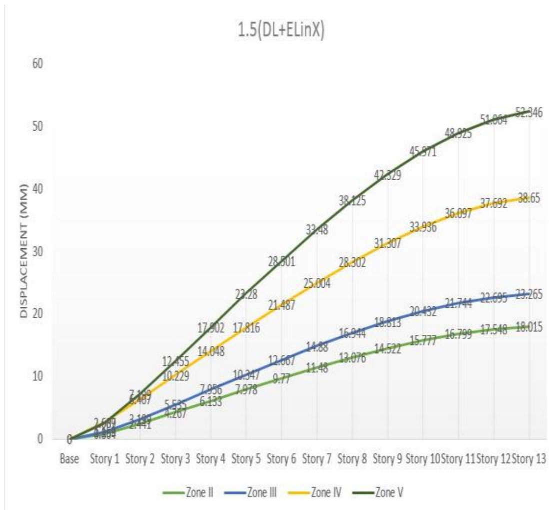


Chart-5: Displacement due to Load Combination

6. **1.5(DL+WLinX) :**

Surprisingly, the result shows opposite (or contrary) trend and because of that Zone II stood the place of maximum displacement in this combination. However, Zone IV and Zone V were gradually soared to their respective values up to the storey 13.

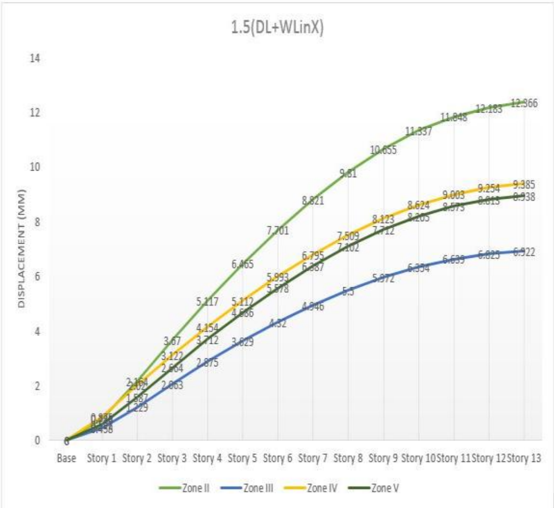
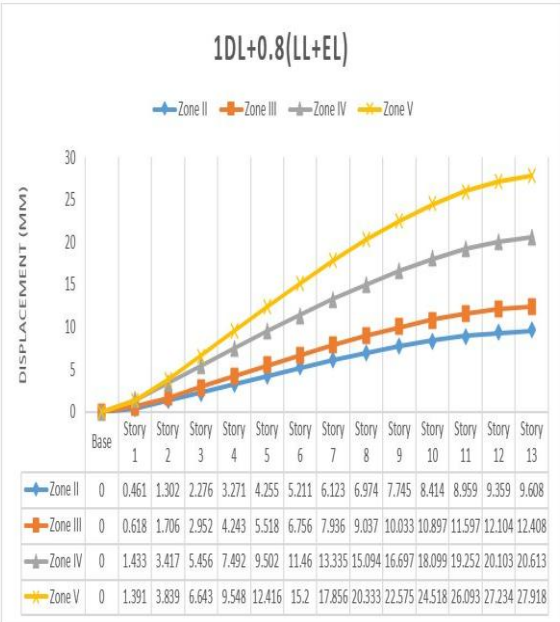


Chart-6: Displacement due to Load Combination

7. **1DL+0.8(LL+ELinX) :**

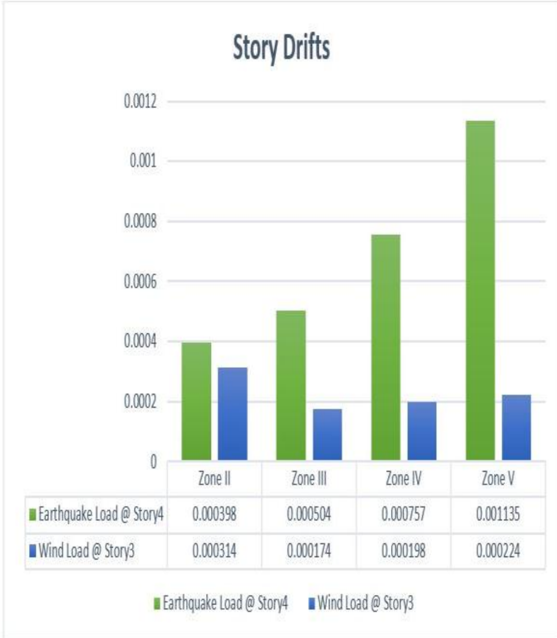
It is explicitly observed that, the most common trend is as move from Zone II to Zone V, the displacement is also go up with each storey.



	Base	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Story 8	Story 9	Story 10	Story 11	Story 12	Story 13
Zone II	0	0.461	1.302	2.276	3.271	4.255	5.211	6.123	6.974	7.745	8.414	8.959	9.359	9.608
Zone III	0	0.618	1.706	2.952	4.243	5.518	6.756	7.936	9.037	10.033	10.897	11.597	12.104	12.408
Zone IV	0	1.433	3.417	5.456	7.492	9.502	11.46	13.335	15.094	16.697	18.099	19.252	20.103	20.613
Zone V	0	1.391	3.839	6.643	9.548	12.416	15.2	17.856	20.333	22.575	24.518	26.093	27.234	27.918

Chart-7: Displacement due to Load Combination

C). Story Drifts:



	Zone II	Zone III	Zone IV	Zone V
Earthquake Load @ Story4	0.000398	0.000504	0.000757	0.001135
Wind Load @ Story3	0.000314	0.000174	0.000198	0.000224

Chart-8: Story Drifts

As can be seen that, the main trend is as the zone is changed from II to V, the value of drifts also go up at story 4 due to earthquake load, whereas in case of wind load, Zone II depicts highest number of drift. However, in following zones, graph shows moderate fluctuations.

VII. CONCLUSIONS

Based on the analysis and design of multi-story (G+12) building, following conclusion are made:

1. The foremost conviction is that the use of AAC concrete blocks instead of bricks will not only reduce the dead load of the structure but also conquer the purchasing cost of the material.
2. Besides this, it allows the structural designer to cut down the size of footing and other load bearing elements.
3. Moreover, as the number of story go up, displacement on the story also upsurge and stood maximum at the top most story in different seismic zone.
4. Because of the earthquake load, story shows dramatic rise at specific story as we go up in seismic zone, whereas it oscillates (or fluctuates) in diverse zones.
5. ETABS software makes work more efficient, convenient and helps engineer to get idyllic results in less time than required for manual handy calculations.

6. While assigning the load combinations as well as designing the structure, limit state design is perfect approach.

VIII. FUTURE SCOPE

These days, to design buildings against earthquake as well as wind load has become a tough job and pressing issue for the civil engineer. The basic approach in this paper will shed the light for selecting the condensed angle (or strategies) of plethora of buildings across such a detrimental effects caused by this loads.

The particular size, shape and number of storey will assist the structural engineer to boost (or gain) in-depth basic knowledge about how the structure behave under seismic load, which can help them to design the building more safe by taking all this basics in to consideration.

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