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# Comparative Study On The Performance of High Rise Structures Subjected to Wind and Earthquake in Andhra Pradesh

Puligadda Sai Krishna
Civil Engineering
Andhra Pradesh

Malladi Phani Krishna Deepak
Civil Engineering
Andhra Pradesh

**Abstract:- In India in particular, cases of wind (esp. cyclone) and earthquake damage have been escalating rapidly, which requires counter measures in terms of earthquake and wind resistant design of buildings. While the Indian Standards provide a method for calculation of wind and earthquake loads respectively, very little indigenous data exists in terms of research and analysis of design solutions in the field - particularly a design which can offer combined resistance to both forces. The rapid increase of urban population in developing states such as Andhra Pradesh has forced the reevaluation of the importance to high rise buildings. In the present study therefore, two cities Vijayawada and Visakhapatnam are selected, and their geographical parameters (in terms of earthquake and wind) is studied. A residential high rise building with single modification in building shape is designed and tested in the conditions of each of these cities using computational tool. Wind loads acting on the building are studied by the probabilistic and static method based on the concept of equivalent static wind load. Wind produces the three different types of effects on tall buildings such as static, dynamic and aerodynamic. The wind load effect the high-rise structures displacement in the windward and leeward direction. Earthquake loads acting on the building are studied by the response spectrum and equivalent static force methods. The suitability of three different types of building configurations are assessed with suitable usage of lateral load resisting systems.**

***Keywords:-*** *Wind, Earthquake, Highrise Structures, Staad Pro.*

## I. INTRODUCTION

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 wind generally blows horizontal to the ground at high speeds.

Generally, earthquakes are result of rapid release of strain energy that is stored in earth's crust which generates seismic waves. Earthquake ground motion causes damage to the structures. To reduce the damage of structures effected by earth quakes, it's important to study the characteristics of ground motion.

➤ *Modeling Details*

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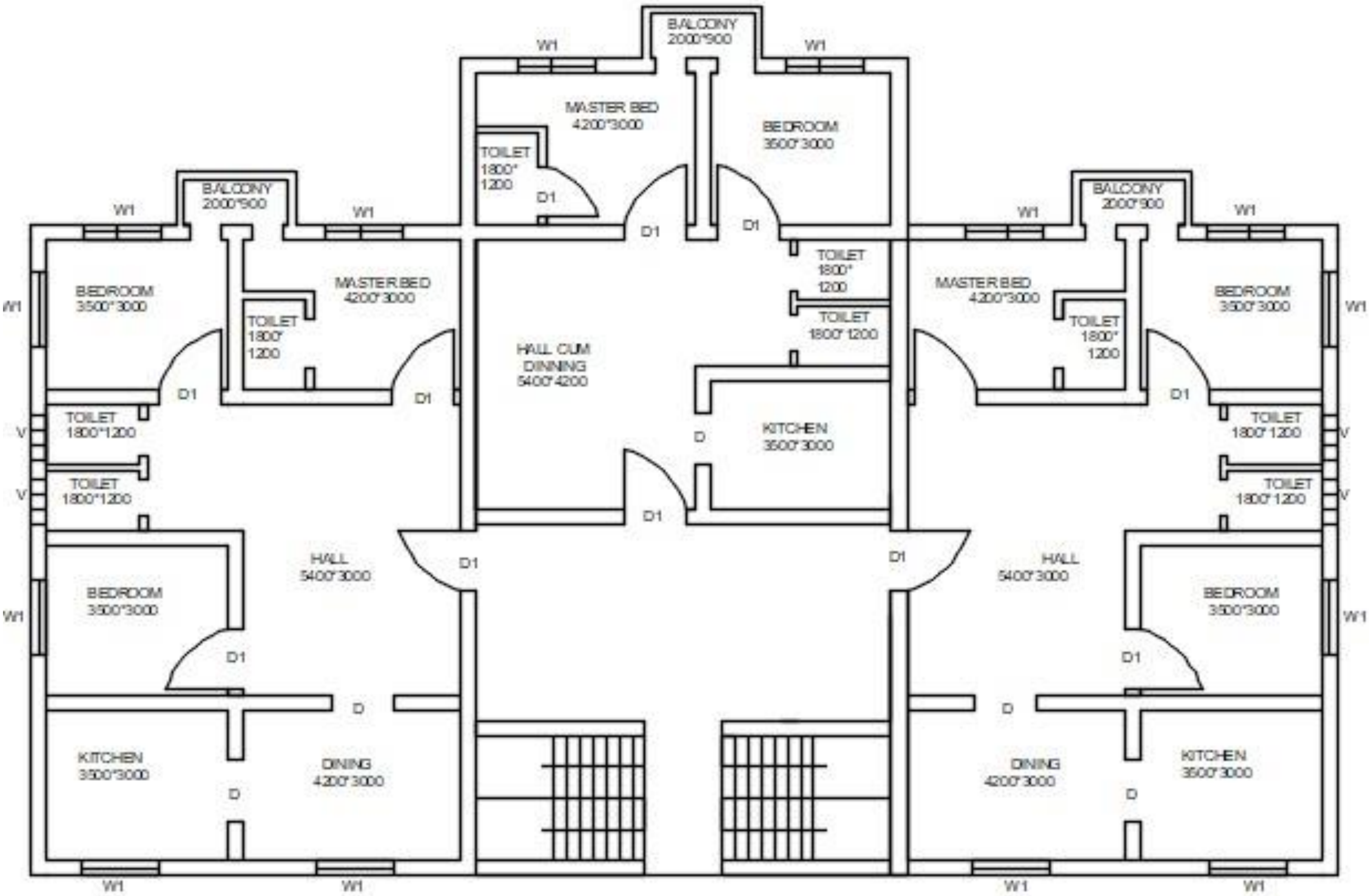


Fig 1:- Auto Cad Plan

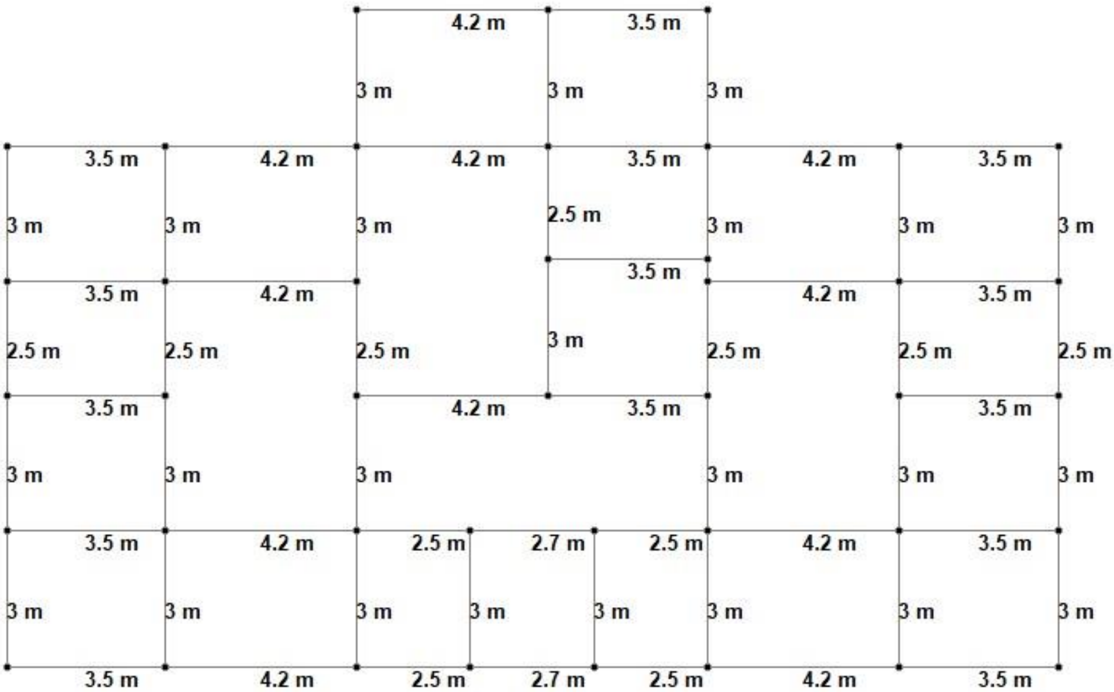


Fig 2:- STAAD.Pro Plan

## II. A BRIEF DESCRIPTION ON WIND ANALYSIS

### *A. Details of Structure*

| | |
|---|---|
| Number of storey | G+15 |
| Bottom storey height | 3 m |
| Each storey height | 3 m |
| Soil type | Medium |
| Wind zone | Zone V (for both cities) |
| Terrain category | 3 |
| Shape of building | Irregular |
| Plan area | 334.95 $m^2$ |
| Thickness of slab | 150 mm |
| Beam size | 0.3 m x 0.45 m |
| Column size | 0.45 m x 0.45 m |
| Material property | |
| Grade of concrete | M20 |
| Grade of steel | Fe 415 |
| Dead load intensities | |
| DL on floors | 3.75 $KN/m^2$ |
| DL of exterior walls | 12 $KN/m^2$ |
| DL of interior walls | 6.5 $KN/m^2$ |
| Live loads intensities | |
| LL on floors | 3 $KN/m^2$ |
| LL on roof | 1.5 $KN/m^2$ |

Table 1

### *B. Design Wind Speed*

Design wind speed can be determined by estimating Basic Wind Speed as well as some other factors such as \ topographical factor, risk coefficient factor, terrain & height factor and importance factor for cyclonic region. Relation between all these factors is given by following formulae:

$V_Z=K_1K_2K_3K_4V_b$ - (IS 875:2015 - Part 3)

$V_Z=K_1K_2K_3V_b$ - (IS 875:1987 - Part 3)

Where

$V_Z$ = design wind speed at any height z in m/s

- $V_b$ = basic wind speed in m/s
- $K_1$ = probability factor (risk coefficient)
- $K_2$ = terrain, height and structure size factor
- $K_3$ = topography factor
- $K_4$ = importance factor for cyclonic region

➢ *Basic Wind Speed*

India is divided in 6 zones according to basic wind velocity which is applicable for height about 10 m from mean ground level which is explained in introduction of wind. Basic wind speeds represented in Fig. 1 have been worked out for 50 years return period.

In Appendix A, IS 875: part3-2015 & 1987, basic wind speed ($V_b$) for some important cities is listed by studying wind speeds over 50 years.

| Name of the cities | Basic wind speed ($V_b$) new code | Basic wind speed ($V_b$) old code |
|---|---|---|
| Visakhapatnam | 50 m/s | 50 m/s |
| Vijayawada | 50 m/s | 50 m/s |

Table 2

➢ *Probability Factor (Risk Coefficient) ($K_1$):*

| NAME OF THE CITIES | PROBABILITY FACTOR ($K_1$) AS PER NEW CODE | PROBABILITY FACTOR ($K_1$) AS PER OLD CODE |
|---|---|---|
| VISHAKAPATNAM | 1 | 1 |
| VIJAYAWADA | 1 | 1 |

Table 3

➢ *Terrain, Height And Structure Size Factor ($K_2$):*

| **Height in m** | **$K_2$ as new code** | **$K_2$ as old code** |
|---|---|---|
| 10 | 0.91 | 0.88 |
| 15 | 0.97 | 0.94 |
| 20 | 1.01 | 0.98 |
| 30 | 1.06 | 1.03 |
| 48 | 1.114 | 1.08 |
| 50 | 1.12 | 1.09 |

Table 4

*Topography Factor ($K_3$)*:

| Name of the cities | Topography factor ($k_3$) as per new code | Topography factor ($k_3$) as per old code |
|---|---|---|
| Vishakhapatnam | 1 | 1 |
| Vijayawada | 1 | 1 |

Table 5

➢ *Importance Factor For Cyclonic Region ($K_4$):*

Cyclonic wind speeds may be higher than basic wind speed. To consider increase in this velocity during cyclones $K_4$ factor is introduced in IS875: Part 3 (2009) draft version. This factor will be mostly useful in cyclonic regions like eastern coastal areas of India.

The following values of $K_4$ are stipulated, as applicable according to the importance of the structure:

- Structures of post-cyclone importance - 1.30
- Industrial structures - 1.15
- All other structures - 1.00

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This factor is useful for 60 km inland from eastern sea coast and Gujarat sea

➢ *Design Wind Pressure ($P_d$):*

It is newly added in the latest revision (2015) and not there in the previous revision (1987). It can be mathematically expressed as follows

$$P_d = K_d K_a K_c P_Z$$

Where,

- $K_d$ = 1 (as the selected regions are considered cyclonic effected regions $K_d$ shall be taken as 1.0)
- $K_a$ = 0.8 (as tributary area is greater than 100 the $K_a$ is taken as 0.8)
- $K_c$ = 0.9

| HEIGHT IN MT | $P_D$ IN K N/M2 (new code) | $P_Z = 0.6 (V_z)^2$ in Kn/m² (old code) |
|---|---|---|
| 48 | 1.3406256 | 1.7496 |
| 45 | 1.319436 | 1.73445 |
| 42 | 1.2982464 | 1.70583 |
| 39 | 1.2770568 | 1.67721 |
| 36 | 1.2558672 | 1.64859 |
| 33 | 1.2346776 | 1.61997 |
| 30 | 1.213488 | 1.59135 |
| 27 | 1.179954 | 1.546125 |
| 24 | 1.14642 | 1.5009 |
| 21 | 1.112886 | 1.455675 |
| 18 | 1.0674936 | 1.39452 |
| 15 | 1.016172 | 1.3254 |
| 12 | 0.9430776 | 1.22712 |
| 9 | 0.894348 | 1.1616 |
| 6 | 0.894348 | 1.1616 |
| 3 | 0.894348 | 1.1616 |
| 0 | 0.894348 | 1.1616 |

Table 6

## III. A BRIEF DESCRIPTION ON EARTHQUAKE ANALYSIS

Buildings develop vibratory motion during dynamic loading due to stiffness. These are similar to vibrations of a violin string with fundamental modes etc. Based on natural period of vibration buildings can be classified as Rigid ($T < 0.3s$); semi-rigid ($0.3s < T < 1.0s$) and flexible structure ($T > 1.0s$). High natural frequencies and short natural period causes higher accelerations and smaller displacements to the building and vice versa. Determination of design lateral forces may be carried out using equivalent lateral force method and response spectrum method. The main difference between these methods is that equivalent lateral force method , the force is estimated based on fundamental period and distribution of force using simple formulas whereas in response spectrum method lateral forces are determined based on natural modes of vibration of building which in turn depend on distribution of stiffness and mass over the height of the building.

### A. *Details of Structure*

| | |
|---|---|
| Number of storey | G+15 |
| Each storey height | 3 m |
| Soil type | Medium (for both cities) |
| Seismic zones | |
| Visakhapatnam | Zone ii |
| Vijayawada | Zone iii |
| Shape of building | Irregular |
| Plan area | 334.95 m² |
| Thickness of slab | 150 mm |
| Beam size | 0.3 m x 0.45 m |
| Column size | 0.45 m x 0.5 m |
| Material property | |
| Grade of concrete | M20 |
| Grade of steel | Fe 415 |
| Dead load intensities | |
| DL on floors | 3.75 KN/m² |
| DL of exterior walls | 12 KN/m² |
| DL of interior walls | 6.5 KN/m² |
| Live loads intensities | |
| LL on floors | 3 KN/m² |
| LL on roof | 1.5 KN/m² |

Table 7

### B. *Equivalent Lateral Force Method*

This is the simplest method of analysis and requires fewer computations. Design base shear is calculated as a whole and later distributed along the height of building. Usually conservative for low to medium height buildings with a regular confirmation. The following are the major steps involved.

| Name Of The City | $\frac{Z}{2}\frac{I}{R}$(As Per New Code) | $\frac{Z}{2}\frac{I}{R}$(As Per Old Code) |
|---|---|---|
| Vishakhapatnam | 0.012 | 0.01 |
| Vijayawada | 0.0192 | 0.016 |

Table 8

*C. Response Spectrum Method*

| Name Of The City | $\frac{\boldsymbol{Z}}{\boldsymbol{2}}\frac{\boldsymbol{I}}{\boldsymbol{R}}$(As Per New Code) | $\frac{\boldsymbol{Z}}{\boldsymbol{2}}\frac{\boldsymbol{I}}{\boldsymbol{R}}$(As Per Old Code) |
|---|---|---|
| Vishakhapatnam | 0.012 | 0.01 |
| Vijayawada | 0.0192 | 0.016 |

Table 9

## IV. RESULTS AND ANALYSIS IN STAAD PRO

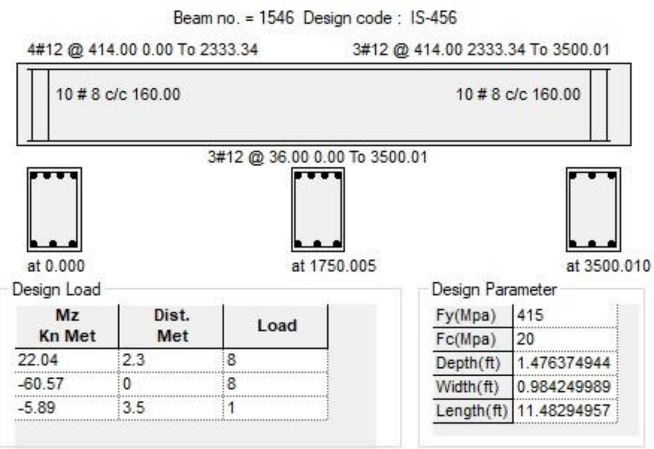
*A. Software Used*

STAAD.Pro is a structural analysis design program software. It includes a state of the art user interface, visualization tools and international design codes. It is used for 3D model generation, analysis and multi material design. The commercial version of STAAD.Pro supports several steel, concrete and timber design codes. It is one of the software applications created to help the structural engineers to automate there tasks and to remove the tedious and long procedures of the manual methods.

STAAD. Pro was originally developed by research engineers international in Yorba Linda, CA. In late 2005, research engineer international was bought by Bentley systems. A structure can be defined as an assemblage of elements. STAAD is capable of analyzing and designing structures consisting of both frame, and finite elements. Almost any type of structure can be analyzed by STAAD.

*B. For Wind(Vishakhapatnam And Vijayawada)*

➢ *Beam Reinforcement Details & Column Reinforcement Details:*



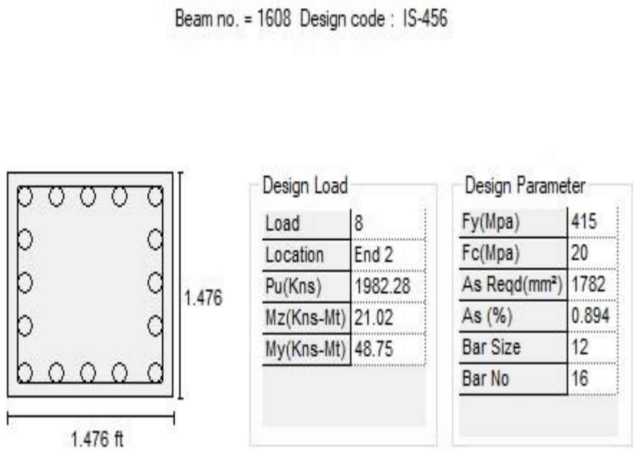
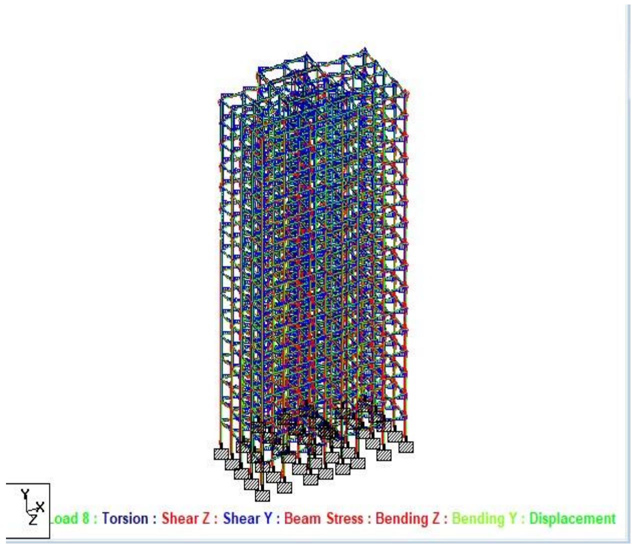




Fig 3

➢ *Shear Force And Bending Moment Graphs*
:



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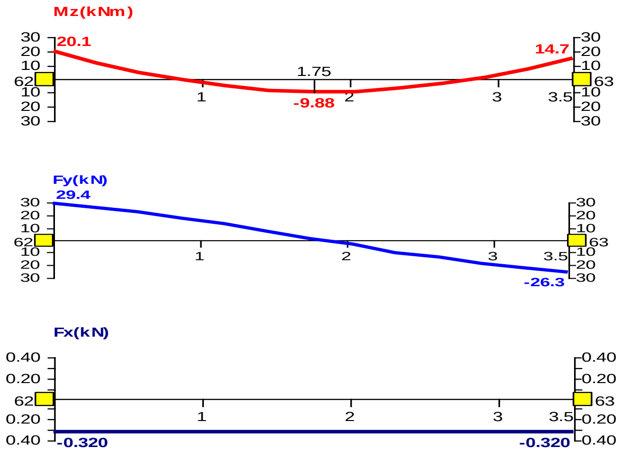



Fig 4:- SHEAR FORCE AND BENDING MOMENT

➢ *load Displacement Diagram:*

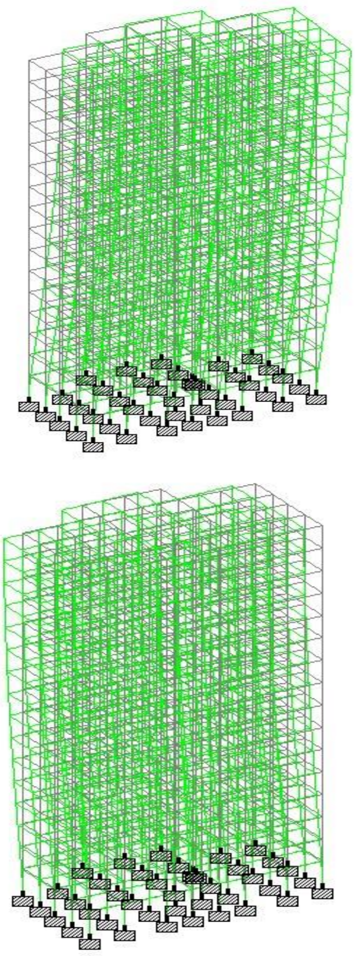


Fig 5:- DISPLACEMENT IN WIND X &-X

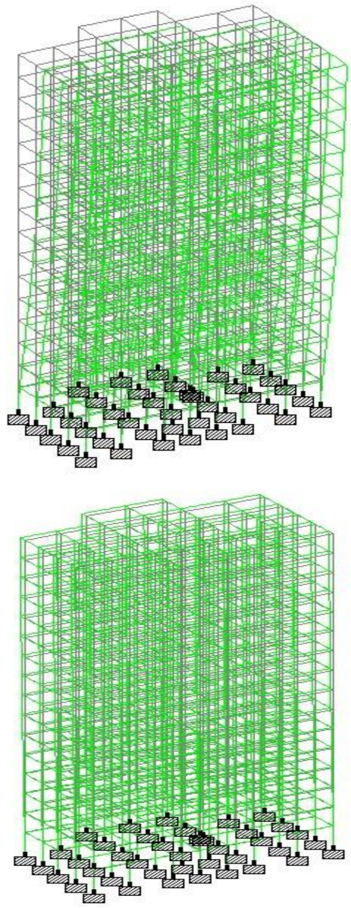


Fig 6:- DISPLACEMENT IN WIND Z&-Z

*C. Earthquake (Vijayawada)*

➢ *Static Results*

- *Beam Reinforcement Details& Column Reinforcement Details:*

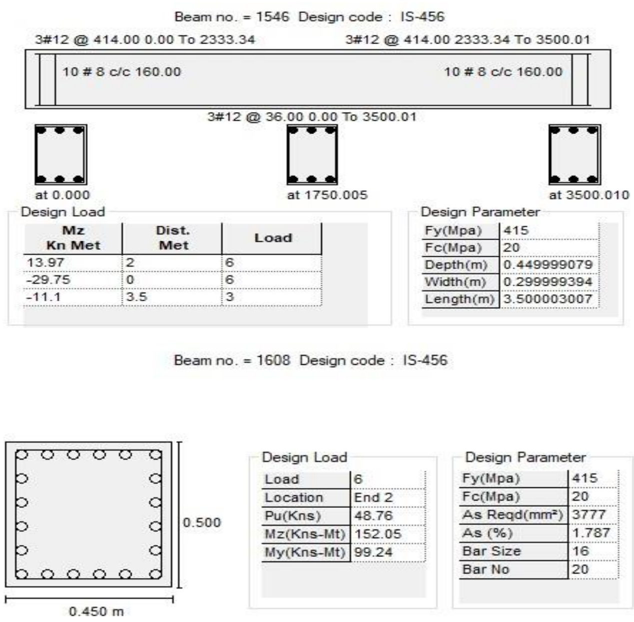



Fig 7

➢ *Shear Force And Bending Moment Graphs:*

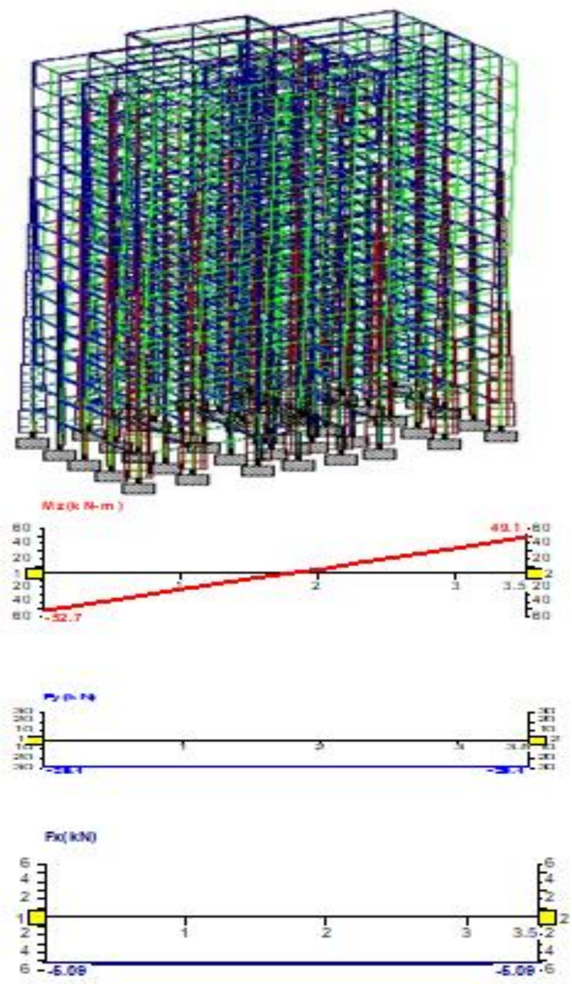
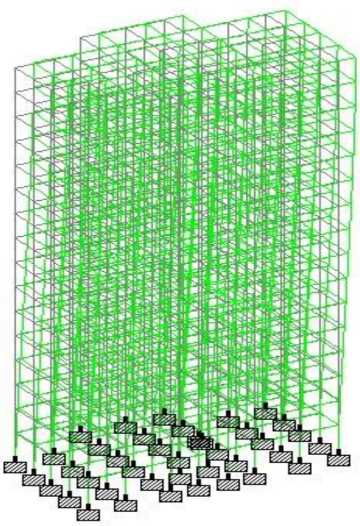
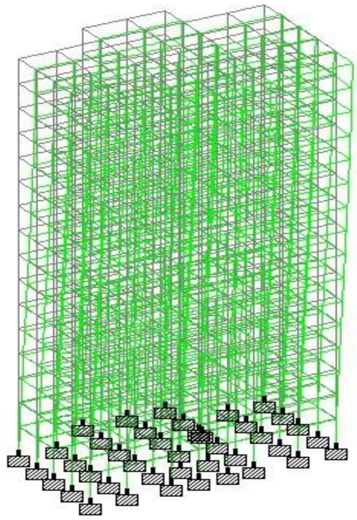


Fig 8

➢ *Displacement Due To Earthquake:*



DISPLACEMENT ALONG X



DISPLACEMENT ALONG Z

Fig 9

BASE SHEAR IN X DIRECTION (VB):

- ✓ * UNITS - KN METE *
- ✓ * TIME PERIOD FOR X 1893 LOADING = 0.89800 SEC *
- ✓ * SA/G PER 1893= 1.514, LOAD FACTOR= 1.000*
- ✓ * VB PER 1893= 0.0182 X 68618.14= 1247.05 KN *
- ✓ * VB Act Based on Clause 7.2.1 = 1247.05 KN *
- ✓ * VB Min based on Clause 7.2.2 = 480.33 KN *

BASE SHEAR IN Z DIRECTION (VB):

- ✓ * UNITS - KN METE *
- ✓ * TIME PERIOD FOR Z 1893 LOADING = 1.13400 SEC *
- ✓ * SA/G PER 1893= 1.199, LOAD FACTOR= 1.000*
- ✓ * VB PER 1893= 0.0144 X 68618.14= 987.52 KN *
- ✓ * VB Act Based on Clause 7.2.1 = 987.52 KN *
- ✓ * VB Min based on Clause 7.2.2 = 480.33 KN *

*D. Response Spectrum Results*

➢ *Beam Reinforcement Details& Column Reinforcement Details:*

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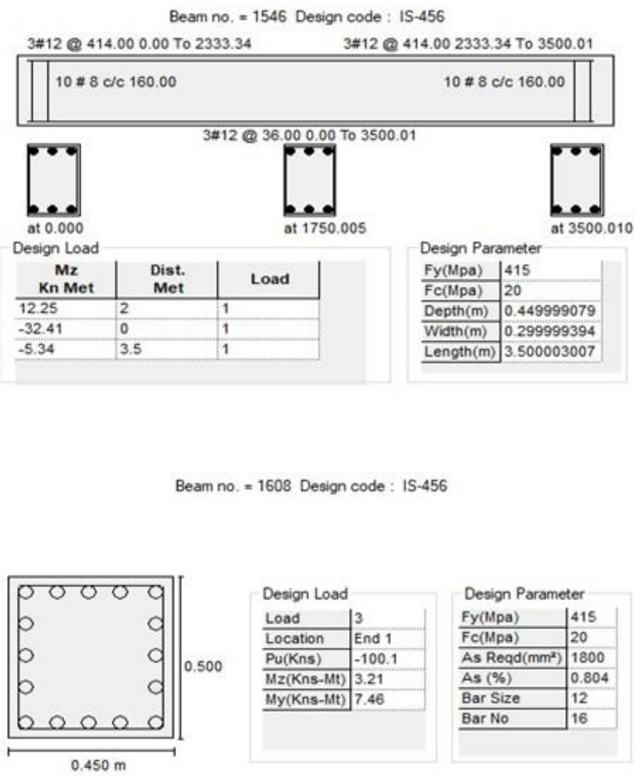



Fig 10

➢ *Displacement Due To Earthquake*

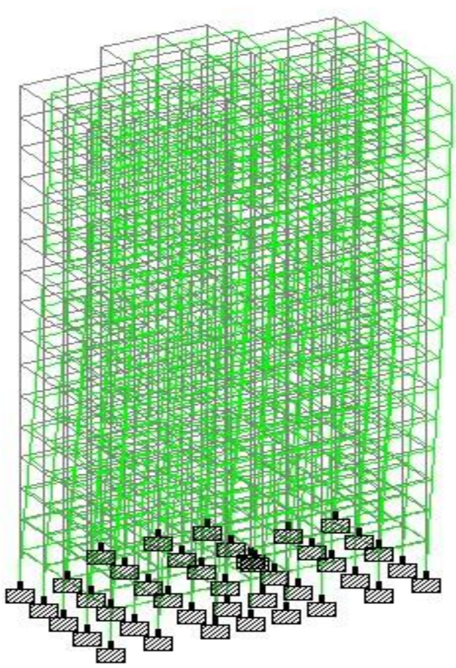
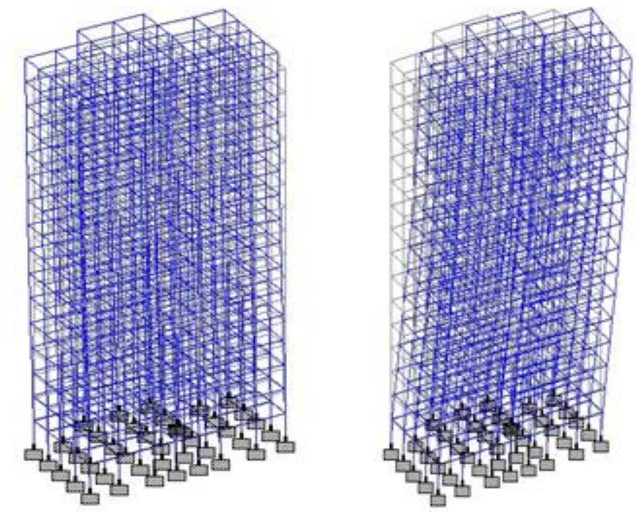
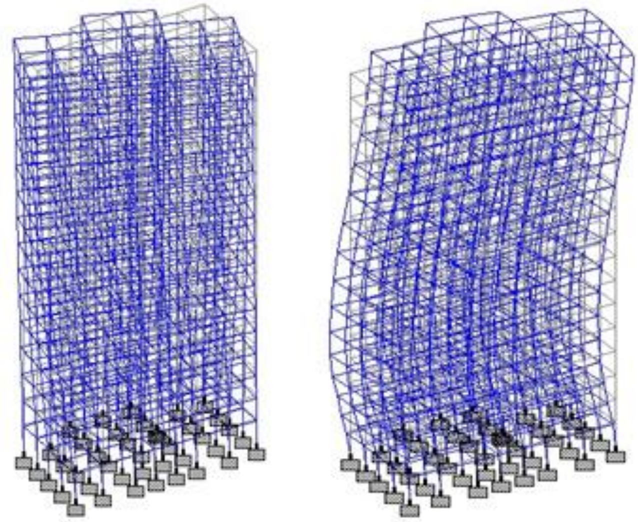


Fig 11

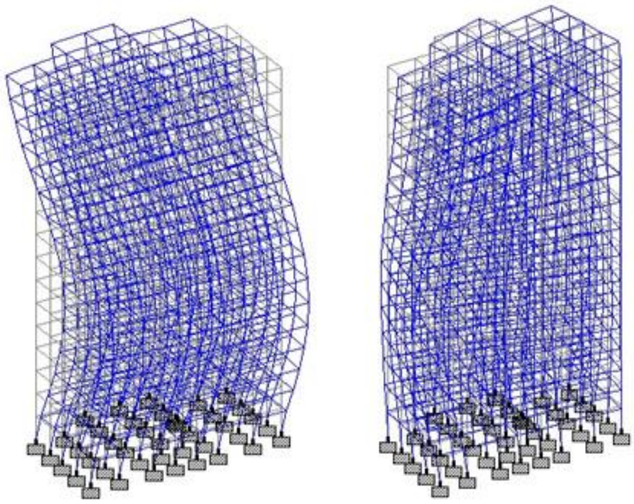
➢ *Mode Shapes*



MODE 1 & MODE 2



MODE 3 & MODE 4



MODE 5 & MODE 6

Fig 12

➢ *Peak Story Shear*

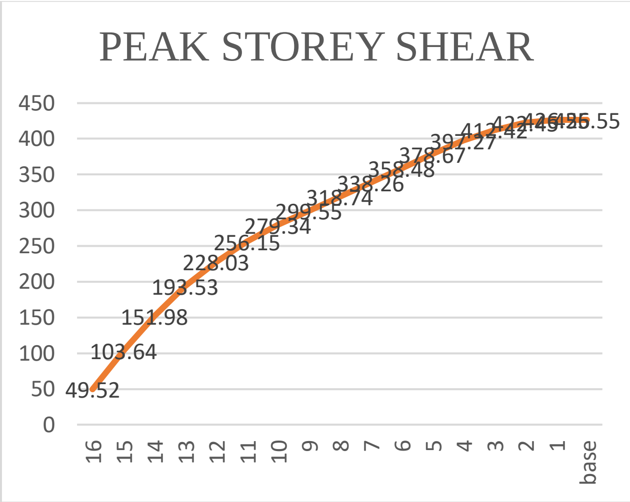



Fig 13

➢ *Mode Participation Factor*

| Mode | Frequency Hz | Period seconds | Participation X % | Participation Y % | Participation Z % |
|---|---|---|---|---|---|
| 1 | 0.635 | 1.574 | 8.006 | 0 | 70.359 |
| 2 | 0.637 | 1.569 | 68.239 | 0 | 8.225 |
| 3 | 0.738 | 1.355 | 2.923 | 0 | 0.002 |
| 4 | 1.95 | 0.513 | 7.307 | 0 | 3.495 |
| 5 | 1.954 | 0.512 | 3.105 | 0 | 8.102 |
| 6 | 2.227 | 0.449 | 0.307 | 0 | 0 |

Table 8

➢ *Earthquake(Vishakhapatnam)*

*E. Static Results*

➢ *Beam Reinforcement Details& Column Reinforcement Details:*

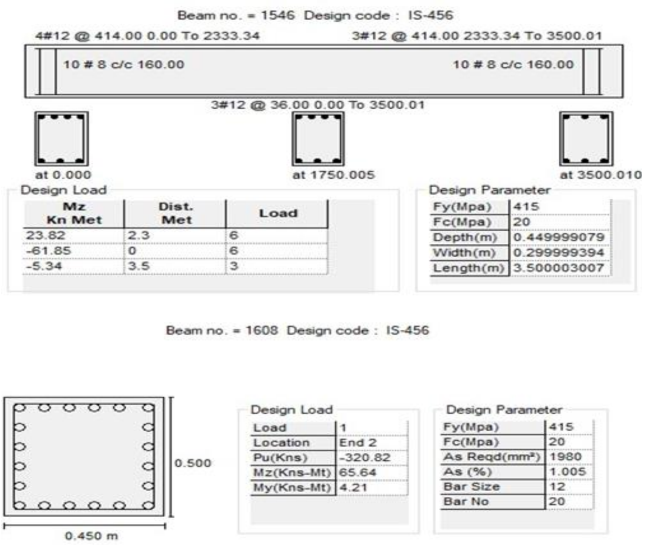



Fig 14

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➢ *Shear Force And Bending Moment Graphs:*

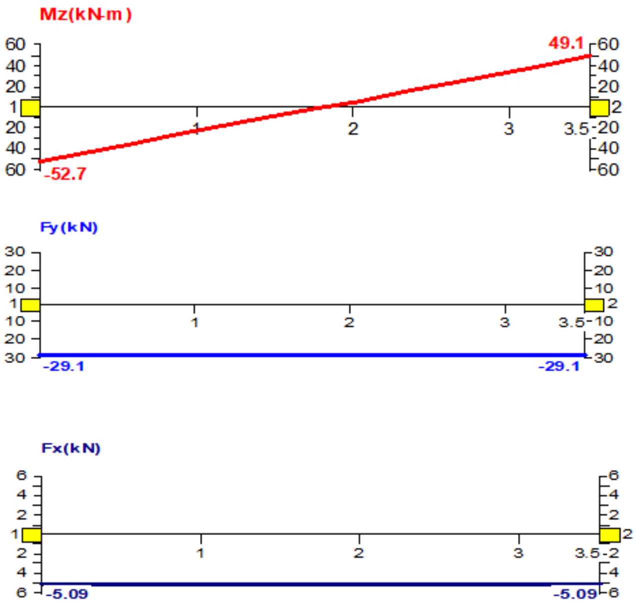
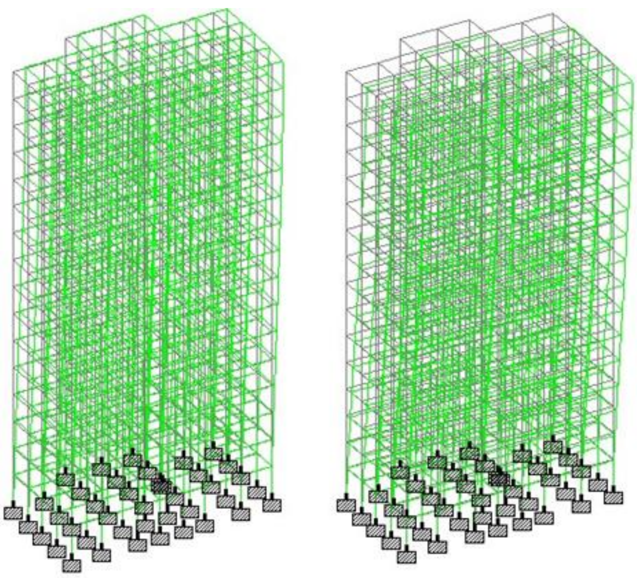



Fig 15

➢ *Displacement Due To Earthquake*



DISPLACEMENT ALONG X & Z

Fig 16

BASE SHEAR IN X DIRECTION (VB):

- ✓ * UNITS - KN METE*
- ✓ * TIME PERIOD FOR X 1893 LOADING = 0.89800 SEC *
- ✓ * SA/G PER 1893= 1.514, LOAD FACTOR= 1.000 *
- ✓ * VB PER 1893= 0.0182 X 68618.14= 1247.05 KN *
- ✓ * VB Act Based on Clause 7.2.1 = 1247.05 KN*
- ✓ * VB Min based on Clause 7.2.2 = 480.33 KN

BASE SHEAR IN Z DIRECTION (VB):

- ✓ * UNITS - KN METE *
- ✓ * TIME PERIOD FOR Z 1893 LOADING = 1.13400 SEC *
- ✓ * SA/G PER 1893= 1.199, LOAD FACTOR= 1.000*
- ✓ * VB PER 1893= 0.0144 X 68618.14= 987.52 KN *
- ✓ * VB Act Based on Clause 7.2.1 = 987.52 KN *
- ✓ * VB Min based on Clause 7.2.2 = 480.33 KN

*F. Response Spectrum Results*

➢ *Beam Reinforcement Details& Column Reinforcement Details*

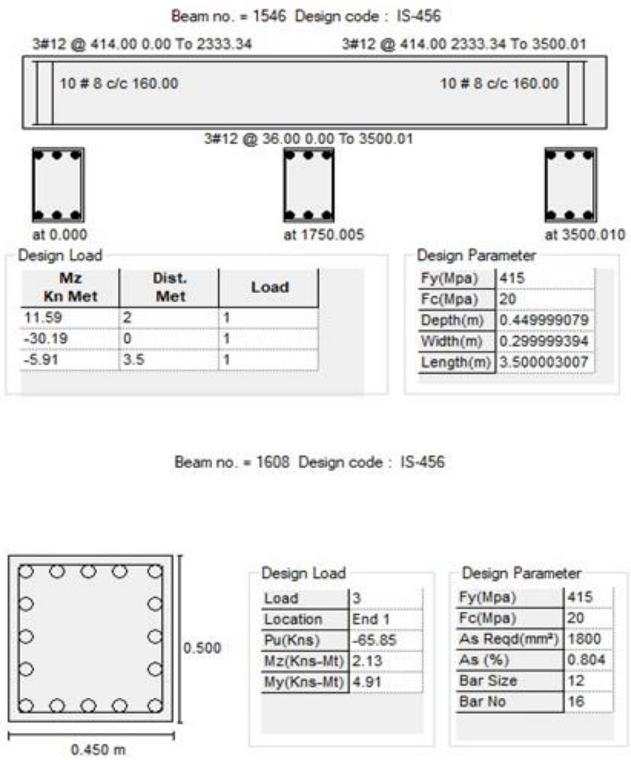
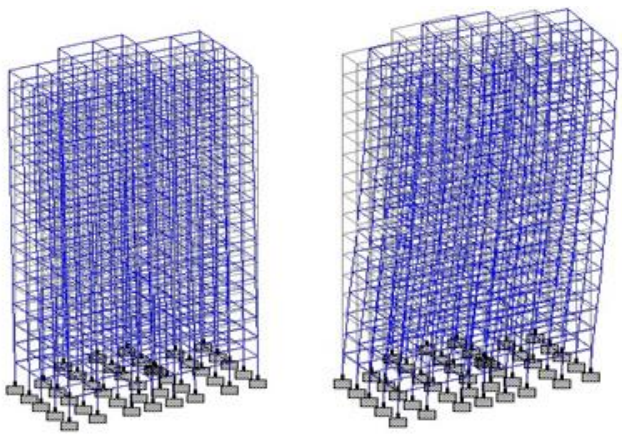
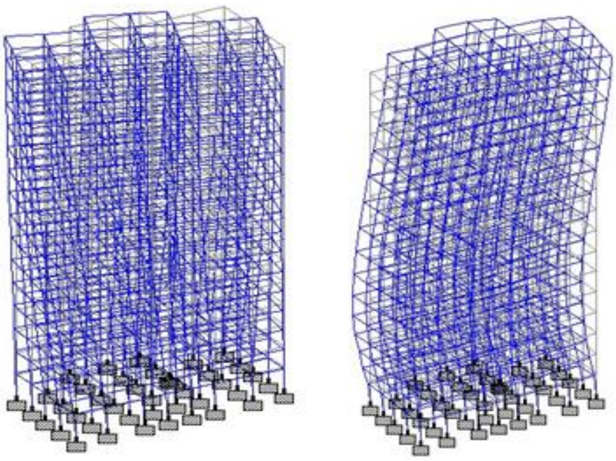



Fig 17

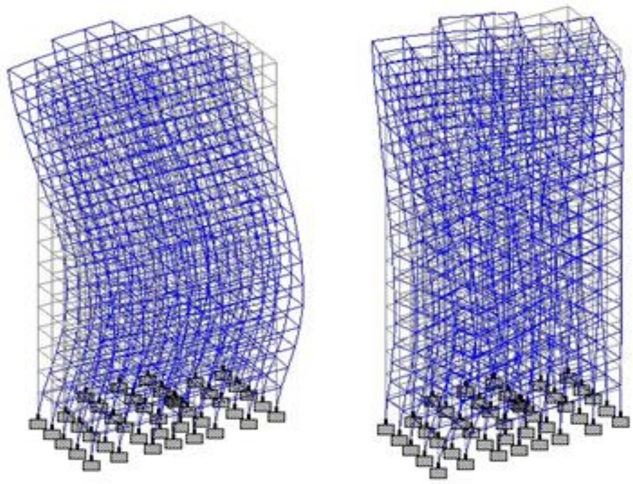
➢ *Mode Shapes*



MODE 1&MODE 2



MODE 3&MODE 4



MODE 5 & MODE 6

Fig 18

➢ *Mode Participation Factor*

| Mode | Frequency Hz | Period seconds | Participation X % | Participation Y % | Participation Z % |
|---|---|---|---|---|---|
| 1 | 0.605 | 1.653 | 7.872 | 0 | 70.498 |
| 2 | 0.607 | 1.647 | 68.562 | 0 | 8.086 |
| 3 | 0.706 | 1.416 | 2.731 | 0 | 0.001 |
| 4 | 1.857 | 0.538 | 7.209 | 0 | 3.619 |
| 5 | 1.861 | 0.537 | 3.228 | 0 | 7.98 |
| 6 | 2.129 | 0.47 | 0.281 | 0 | 0 |

Table 9

➢ *Peak Story Shear*

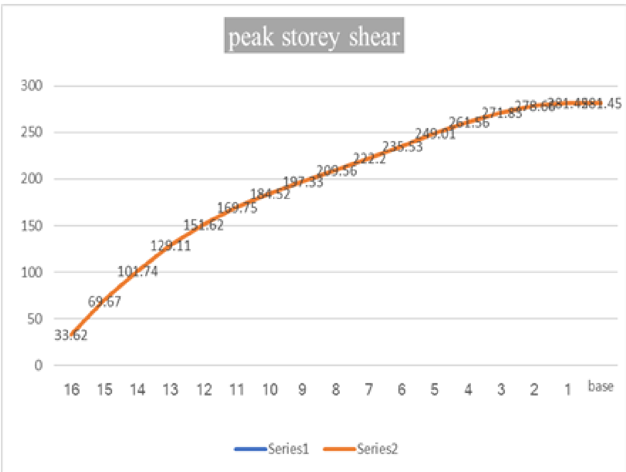



Fig 19

## V. CONCLUSION

The present study is preliminary in nature and further work is required before arriving at any optimal construction solution for the two major cities in Andhra Pradesh. However, based on the analysis carried out the following preliminary conclusion can be listed:

- wind effect is same for the both cities i.e Vijayawada, Vishakhapatnam.
- While the construction is going on the wind effect is more in Vishakhapatnam than Vijayawada because that Vishakhapatnam is a coastal area
- Vijayawada displace the highest vulnerability to earthquake while Vishakhapatnam is moderately effected
- Displacement, node displacement, deflection, shear force and bending moment everything is verified against failure and the structure is safe against the lateral loads
- Using STAAD.Pro software, the design considerations has been taken as per the new codes, the design is safe in all conditions.

## REFERENCES

[1]. Dr. J.S. Kalyana Rama, Reeti Sarkar, Ranjit patil "influence of wind and earthquake on a single modification high rise structure in four metro cities of india" – IJRET
[2]. IS 875: Part-3 : wind loads on buildings and structures
[3]. IS 1893: Part-1: Earthquake loads on buildings and structures