Variation of Concrete and Steel Quantities for A T Shaped R.C Building Designed in All Seismic Zones using Static and Dynamic Analysis

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Abstract— One of the most destructive phenomena of a nature is a severe earthquake and it's after effect. It is highly impossible to prevent an earth quake from occurring, but the damage to the buildings can be controlled through proper design and detailing. Hence it is mandatory to do the seismic analysis and design to structures against collapse. Designing a structure in such a way that reducing damage during an earthquake makes the structure quite uneconomical, as the earth quake might or might not occur in its life time and is a rare phenomenon. The present IS code 1893:2002 doesn't provide information about the variation of percentage of steel and concrete from zone to zone. This project mainly focus on the variation of percentage in concrete and steel quantities when the building is designed for earthquake forces in all seismic zones as per IS 1893:2002 for both static and dynamic analysis. The building plan taken for this project is an irregular T shape with shear walls and the software used is STRUDS v11. It is observed in the results for beams, columns, shear walls and footing both concrete and steel quantities increase are increasing in static analysis compared to dynamic analysis.

Key words: Earthquakes, Dynamic Analysis, Static Analysis, Design, Concrete, Steel, STRUDS

I. INTRODUCTION

In The rapid development of software industry the people are migrated from rural area to cities. Due to this as one of the reason the cities are developing & spreading land areas. The people are very much interested to increase their economical status by increase their fixed assets. They are spending money on purchasing and constructing their own houses. Due to limited land area and high land costs, people are showing interested to apartment culture. The earthquake is one of the natural disasters occurring in our environment. Science was not yet reached to predict and to stop. Structural engineers are designing the structures to resist seismic forces by considering the guide lines given by codes. Generally Seismic analysis of structures is done by two methods, they are static analysis and dynamic analysis. I am considering both static and dynamic analysis to analysis my project G+6 floors R.C.C framed structures with shear walls. I am applying Frame Stiffness Method for Static Analysis and Response Spectrum Method for Dynamic Analysis for different seismic zones. Modal Combination method is applied as SRSS. The design of R.C.C elements such as slabs, beams, columns and footings are as per guide lines given by IS 456-2000, and ductile detailing of structure is by guideline given by IS 13920-1993 for beams, columns and shear walls.

II. LITERATURE SURVEY

Seismic analysis of the structures is carried out on the basis of lateral force assumed to act along with the gravity loads. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode of shape. In this study, an eight (G+6) storied RC building has been analyzed using the equivalent static method in STRUDS. The plan and elevation of the building taken for analysis is shown in Fig.1a. Three Dimensional view of the whole structure is shown in Fig.1b.Fig.2 is showing the structure subjecting to the vertical loading .In the earthquake analysis along with earthquake loads, vertical loads are also applied. For the earthquake analysis, IS 1893-2002 code was used .The total design seismic base shear (V_b) along any principal direction shall be determined by multiplying the design horizontal acceleration in the considered direction of vibration (A_h)and the seismic weight of the building.

Base shear in X Direction $V_b = A_h \times W$

A_h = design horizontal acceleration = (Z/2)*(I/R)*(Sa /g)

W = total seismic value of the building

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

Qi = V_b *(Wi*hi2/_Wi*hi2)

Where,

Qi is the design lateral forces at floor i,

Wi is the seismic weights of the floor i, and

hi is the height of the floor i, measured from base

The lateral force on each storey is again distributed based on the deflection and stiffness of the frame

A. Methodology

Response Spectrum Method Concept

The equation of motion can be rewritten as below for SDOF system

a + 2 xw v + w² u = - ag (t) (2)

Which involve only two parameter, frequency w = Ö/k/m and damping ratio x = C/2mw. The solution of equation 2 can be solved by Duhamel integral, using any numerical. Technique for any given forcing function and given constants T = 2p /w and x. The maximum response value Sd= max (u(t)) is obtained by scanning the entire history u(t), for its absolute maximum. This is function of period T and damping ratio x., i.e. Sd = Sd (T, x.). The computation may be repeated for a slightly different period T to obtain a new value Sa (T , x.). The results are plotted in a single graph as a function of T (or w) and repeated for different damping values. This is response spectra curve. (Figure 4a).The computational effort required to construct a response spectrum for a given forcing function can be large i.e. hundreds of data points mean integrating hundreds of times. But once it is constructed, no SDOF system needs to be analyzed again for this function, irrespective of its mass, stiffness, or damping as long as it fall within the frequency and damping range covered by the spectrum. Alternatively the maximum deformation may be expressed in terms of velocity or acceleration.

$$Sv = w\,Sd = 2p\,Sd / T \quad (3)$$

$$Sa = w\,Sv = w^2\,Sd = (2p/T)^2\,Sd \quad (4)$$

The acceleration spectrum also makes possible static consideration of the seismic excitation, which is totally dynamic phenomenon. Such a consideration offers significant advantage to the civil engineers whose training is mainly focused on static. The relation between the inertia forces and the restoring forces has the following form:

$$Vb = k\,(u - uo) = k\,u = -(c\,v + m\,a) \quad (5)$$

The base shear Vmax assumes its maximum value when the relative displacement also reaches its maximum value.

$$Vmax = k\,umax = M\,amax \quad (6) = kSd = M\,Sa$$

1) Methods for Modal Response Combination

Using the response spectrum method for MDOF system, the modal responses (Maxima) are obtained for each mode. The principal question is how these responses should be combined to get the best estimate of the total response. Response spectrum takes time out of the modal response equation and replaces it with the modal maxima. As these maxima do not occur at the same time, procedure has been evolved to combine the modal maxima in such a way as to approximate the total response.

2) Square root of the sum of squares (SRSS)

A reasonable estimate, based on probability theory is obtained by SRSS method in which the response is calculated as below:

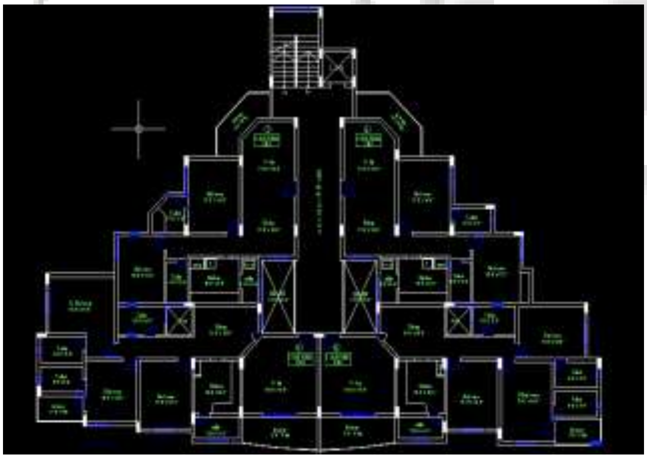

Fig. 1(a): Plan of the building

N ½

$R = (S\,|\,Rk^2\,|)$ (10)

k=1

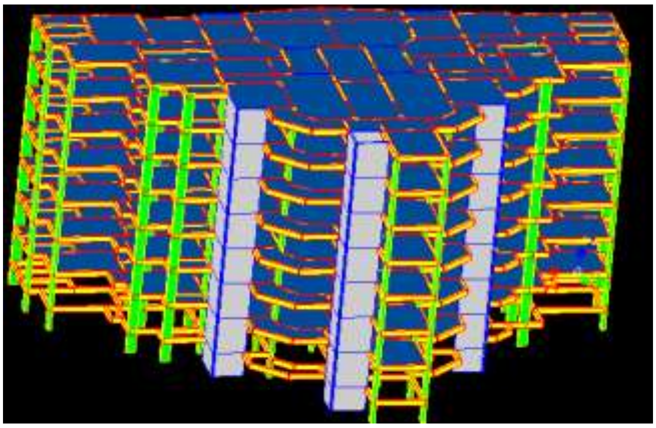

Fig. 2: Model of the building in 3D

B. Preliminary data for the problem taken:

Material and loading data is given below:

Grade of Concrete : M20
Grade of Steel : Fe415
Dead Load on Floors : 3.25 kN/sqm
Live load on Floors : 2 kN/sqm (25% for earthquake)
Floor Finish : 1 kN/sqm
Brick wall on peripheral beams: 230Thick
Brick wall on Internal beams: 115 Thick
Density of Concrete : 25 kN/cum
Density of Brick : 19 kN/cum

III. EARTHQUAKE LOAD REPORT

A. Floor wise Dist of Base Shear in X Direction

	zone-II	zone-III	zone-IV	zone-V
floor8	80.08	128.128	192.193	288.289
floor7	184.478	295.164	442.746	664.119
floor6	165.202	264.324	396.485	594.728
floor5	139.174	222.678	334.018	501.026
floor4	110.701	177.122	265.683	398.524
floor3	83.318	133.308	199.962	299.943
floor2	60.908	97.453	146.179	219.271
floor1	10.157	16.25	24.375	36.564

Table 1: Floor wise Dist of Base Shear in X Direction

IV. ANALYSIS RESULTS

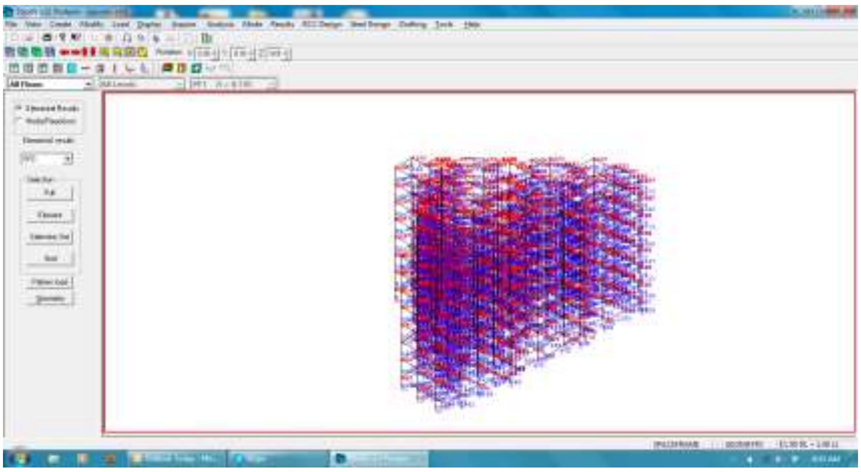

Fig. 3: Model of the building after analysis results in space frame

A. Member Forces Report:

Structure Type: Space Frame
Element No: 1

Load Combin ation	No de	Fx kN	Fy kN	Fz k N	Mx kN. m	My kN. m	Mz kN. m
1.50 DL + 1.50 EQL X+	Firs t	- 2.58 2	- 0.1 71	- 0. 28 2	0.0 02	7.2 72	- 0.1 47
	Sec ond	2.58 2	0.1 71	12 .8 19	- 0.0 02	13. 886	- 0.4 05

Table 2: Element

V. RESULTS AND DISCUSSION

1) Variation of volume of concrete in footings and the increase in percentage difference in all seismic zones is represented in the Table 1 and Fig.4. For static analysis it is observed that in footings, variations are 12.56% between zone II and III, 23.91% between zone III and IV, and 36.3% between gravity zone IV and V respectively. For dynamic analysis it is observed that in footings, variations are 13.36% between zone II and III, 23.69% between zone III and IV, and 27.97% between gravity zone IV and V respectively. Therefore, the volume of concrete in footings is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Volume of concrete in footings (Cu m)				**Percentage Difference between**		
Analys is Type	**Zo ne- II**	**Zone - III**	**Zone - IV**	**Zon e- V**	**II& III**	**III& IV**	**IV &V**
Static Ana	10 3.5 4	116. 55	144. 43	186. 67	12.5 6	23.9 1	36.2 3
Dynam ic Ana	94. 49	107. 12	132. 51	169. 57	13.3 6	23.6 9	27.9 7

Table 1: Variation of volume of concrete in footings

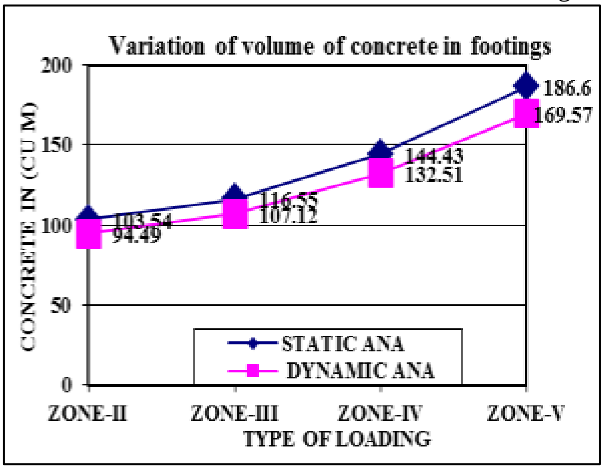

Fig. 4: Variation of volume of concrete in footings

2) Variation of weight of steel in footings and the increase in percentage difference in all seismic zones is represented in the Table 2 and Fig.5. For static analysis it is observed that in footings, variations are 10.88% between zone II and zone III, 19.69% between zone III and zone IV, and 27.47% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in footings, variations are 7.44% between zone II and Zone III, 16.09% between zone III and zone IV, and 25.32% between gravity zone IV and zone V respectively. Therefore, the weight of steel in footings is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Weight of Steel in footings (T)				**Percentage Difference between**		
Analysi s Type	**Zo ne- II**	**Zon e- III**	**Zon e- IV**	**Zon e- V**	**II& III**	**III& IV**	**IV &V**
Static Ana	2.4 5	2.72	3.25	4.15	10.8 8	19.6 9	27.4 7
Dynami c Ana	2.3 7	2.55	2.96	3.71	7.44	16.0 9	25.3 2

Table 2: Variation of weight of steel in footings

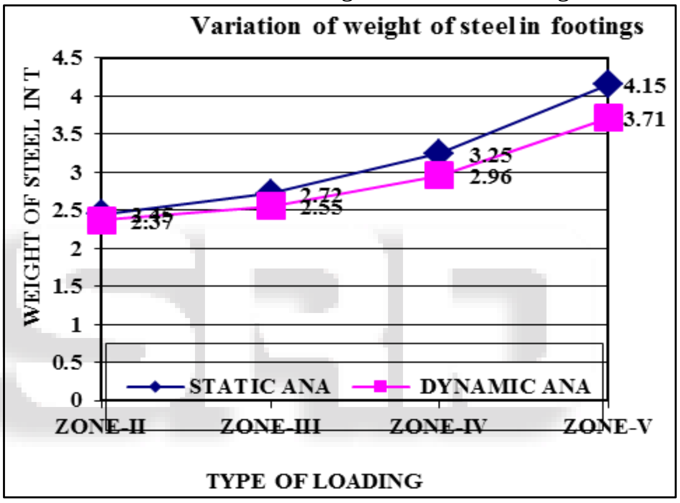

Fig. 5: Variation of weight of steel in footings

3) Variation of weight of steel in shear walls and the increase in percentage difference in all seismic zones is represented in the Table 3 and Fig 6. For static analysis it is observed that in shear walls, variations are 14.25% between zone II and zone III, 37.63% between zone III and zone IV, and 45.46% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in shear walls, variations are 2.6% between zone II and Zone III, 17.23% between zone III and zone IV, and 29.23% between gravity zone IV and zone V respectively. Therefore, the weight of steel in shear walls is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Weight of Steel in shear walls (T)				**Percentage Difference between**		
Analysi s Type	**Zo ne- II**	**Zone - III**	**Zon e- IV**	**Zon e- V**	**II& III**	**III& IV**	**IV &V**
Static Ana	4.0 7	4.65	6.4	9.31	14.2 5	37.6 3	45.4 6
Dynami c Ana	3.9 2	4.02	4.72	6.1	2.6	17.2 3	29.2 3

Table 3: Variation of weight of steel in shear walls

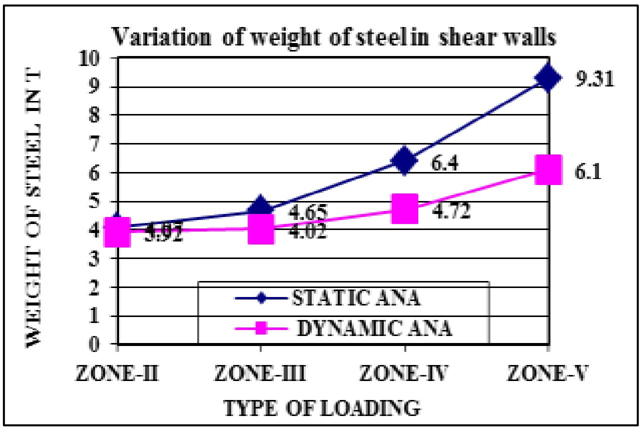

Fig. 6: Variation of weight of steel in shear walls

4) Variation of volume of concrete in columns and the increase in percentage difference in all seismic zones is represented in the Table 4 and Fig.7. For static analysis it is observed that in columns, variations are zero between zone II and zone III, 0.4% between zone III and zone IV, and 2.38% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in columns, variations are zero between zone II and Zone III, 0.4% between zone III and zone IV, and 2.38% between gravity zone IV and zone V respectively. Therefore, the volume of concrete in columns is same in seismic zone II & III, zone III and IV in static analysis compared to dynamic analysis. However the variation is very small in zone IV and V in static analysis compared to dynamic analysis.

	Volume of concrete in columns (Cu m)				Percentage Difference between		
Analysis Type	Zone-II	Zone - III	Zone-IV	Zone- V	II& III	III& IV	IV &V
Static Ana	137.15	137.15	137.76	140.84	0	0.4	2.38
Dynamic Ana	136.61	136.61	137.15	138.39	0	0.4	0.9

Table 4: Variation of volume of concrete in columns

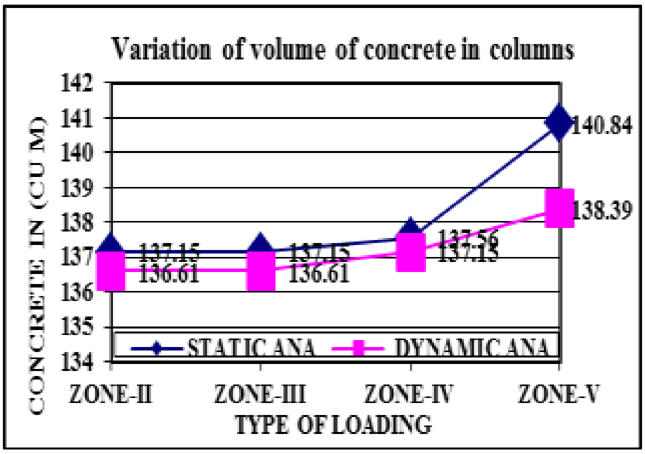

Fig .7 Variation of volume of concrete in columns

5) Variation of weight of steel in columns and the increase in percentage difference in all seismic zones is represented in the Table 5 and Fig.8. For static analysis it is observed that in columns, variations are 6.6% between zone II and zone III, 16.6% between zone III and zone IV, and 20.44% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in columns, variations are 1.27% between zone II and Zone III, 2.05% between zone III and zone IV, and 12% between gravity zone IV and zone V respectively. Therefore, the weight of steel in columns is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Weight of Steel in columns (T)				Percentage Difference between		
Analysis Type	Zone-II	Zone-III	Zone-IV	Zone- V	II& III	III& IV	IV &V
Static Ana	19.01	20.26	23.62	28.45	6.6	16.6	20.44
Dynamic Ana	19.223	19.46	19.87	22.25	1.27	2.05	12

Table 5: Variation of weight of steel in columns

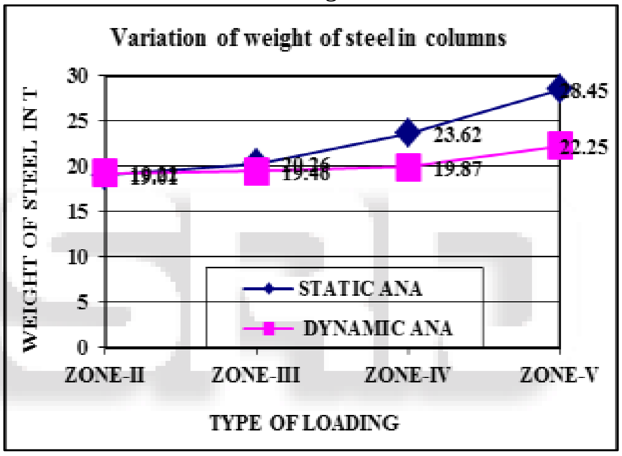

Fig. 8: Variation of weight of steel in columns

6) Variation of volume of concrete in beams and the increase in percentage difference in all seismic zones is represented in the Table 6 and Fig.9. For static analysis it is observed that in beams, variations are 0.37% between zone II and zone III, 0.67% between zone III and zone IV, and 1.7% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in beams, variations are 0.1% between zone II and Zone III, 0.24% between zone III and zone IV, and 0.56% between gravity zone IV and zone V respectively. Therefore, the volume of concrete in beams is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Volume of concrete in beams (Cu m)				Percentage Difference between		
Analysis Type	Zone-II	Zone-III	Zone-IV	Zone- V	II& III	III& IV	IV &V
Static Ana	314.33	315.49	317.61	323.02	0.37	0.67	1.7
Dynamic Ana	314.04	314.34	315.10	316.89	0.1	0.24	0.56

Table 6: Variation of volume of concrete in beams

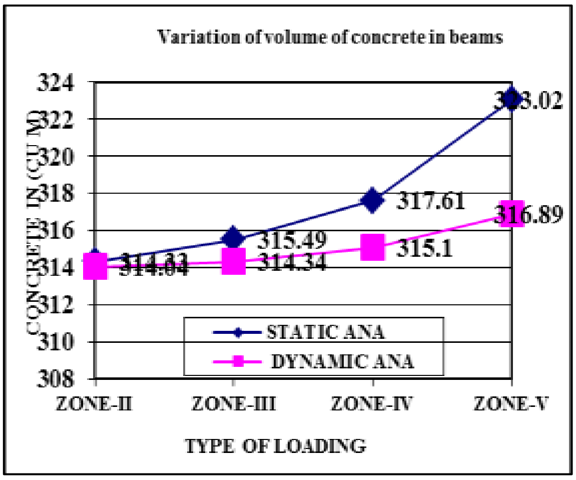

Fig. 9: Variation of volume of concrete in beams

7) Variation of weight of steel in beams and the increase in percentage difference in all seismic zones is represented in the Table 7 and Fig.10. For static analysis it is observed that in beams, variations are 10.53% between zone II and zone III, 12.75% between zone III and zone IV, and 20.5% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in beams, variations are 5.26% between zone II and Zone III, 5.53% between zone III and zone IV, and 11.16% between gravity zone IV and zone V respectively. Therefore, the weight of steel in beams is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

	Weight of Steel in beams (T)				**Percentage Difference between**		
Analysis Type	**Zone-II**	**Zone-III**	**Zone-IV**	**Zone- V**	**II& III**	**III& IV**	**IV &V**
Static Ana	40.40	44.65	50.35	60.64	10.53	12.75	20.5
Dynamic Ana	38.17	40.18	42.40	47.14	5.26	5.53	11.16

Table 7: Variation of weight of steel in beams

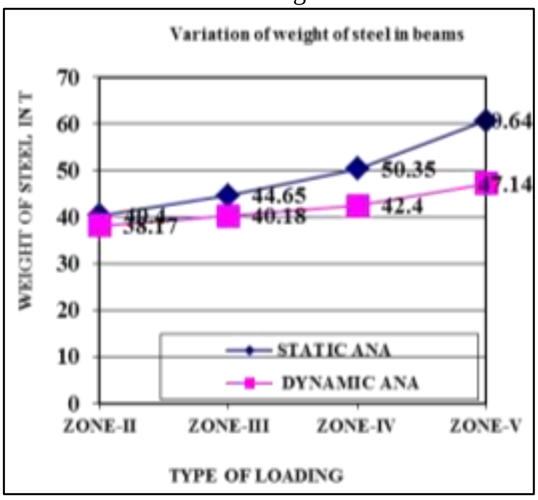

Fig. 10: Variation of weight of steel in beams in all seismic

VI. CONCLUSIONS

The following conclusions can be made based on the design of RC building designed for earthquake forces in all the zones for both static and dynamic analysis.

1) For static analysis it is observed that in footings, variations are 12.56% between zone II and III, 23.91% between zone III and IV, and 36.3% between gravity zone IV and V respectively. For dynamic analysis it is observed that in footings, variations are 13.36% between zone II and III, 23.69% between zone III and IV, and 27.97% between gravity zone IV and V respectively. Therefore, the volume of concrete in footings is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.
2) For static analysis it is observed that in footings, variations are 10.88% between zone II and zone III, 19.69% between zone III and zone IV, and 27.47% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in footings, variations are 7.44% between zone II and Zone III, 16.09% between zone III and zone IV, and 25.32% between gravity zone IV and zone V respectively. Therefore, the weight of steel in footings is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.
3) For static analysis and dynamic analysis it is observed that volume of concrete in shear wall is same in seismic zone II & III, zone III and IV because of the constant size of shear wall.
4) For static analysis it is observed that in shear walls, variations are 14.25% between zone II and zone III, 37.63% between zone III and zone IV, and 45.46% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in shear walls, variations are 2.6% between zone II and Zone III, 17.23% between zone III and zone IV, and 29.23% between gravity zone IV and zone V respectively. Therefore, the weight of steel in shear walls is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis
5) For static analysis it is observed that in columns, variations are zero between zone II and zone III, 0.4% between zone III and zone IV, and 2.38% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in columns, variations are zero between zone II and Zone III, 0.4% between zone III and zone IV, and 2.38% between gravity zone IV and zone V respectively. Therefore, the volume of concrete in columns is same in seismic zone II & III, zone III and IV in static analysis compared to dynamic analysis. However the variation is very small in zone IV and V in static analysis compared to dynamic analysis
6) For static analysis it is observed that in columns, variations are 6.6% between zone II and zone III, 16.6% between zone III and zone IV, and 20.44% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in columns, variations are 1.27% between zone II and Zone III, 2.05% between zone III and zone IV, and 12% between gravity zone IV and zone V respectively. Therefore, the weight of steel in columns is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.
7) For static analysis it is observed that in beams, variations are 0.37% between zone II and zone III, 0.67% between zone III and zone IV, and 1.7% between

gravity zone IV and zone V respectively. For dynamic analysis it is observed that in beams, variations are 0.1% between zone II and Zone III, 0.24% between zone III and zone IV, and 0.56% between gravity zone IV and zone V respectively. Therefore, the volume of concrete in beams is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

8) For static analysis it is observed that in beams, variations are 10.53% between zone II and zone III, 12.75% between zone III and zone IV, and 20.5% between gravity zone IV and zone V respectively. For dynamic analysis it is observed that in beams, variations are 5.26% between zone II and Zone III, 5.53% between zone III and zone IV, and 11.16% between gravity zone IV and zone V respectively. Therefore, the weight of steel in beams is increasing in seismic zones II, III, IV and V in static analysis compared to dynamic analysis.

FUTURE ENHANCEMENTS

1) The volume of work undertaken in this study is limited to comparison of seismic response parameters in a building with different shear wall locations using linear analysis. The study could be extended by including various other parameters such as torsional effects and soft storey effects in a building. Non linear dynamic analysis may be carried out for further study for better evaluation of structural response under seismic forces.
2) The volume of work undertaken in this study is limited to Eq Load, but it can be checked for wind load also.
3) The present investigations were made for M20 grade, but it can be recommended to researcher for higher strength concrete to check it.

REFERENCES

[1] IS 456: 2000, “Indian Standard for Plain and Reinforced Concrete – Code of Practice,” Bureau of Indian Standards, New Delhi.
[2] IS 875: Part 1: 1987, Indian Standard Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Bureau of Indian Standards, New Delhi, India.
[3] IS 1893 (Part 1): 2002, “Indian Standard Criteria for Earthquake Resistant Design of Structures, “Bureau of Indian Standards, New Delhi.
[4] IS 4326: 1993, “Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings,” Bureau of Indian Standards, New Delhi.
[5] IS 13920: 1993, “Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces,” Bureau of Indian Standards, New Delhi.
[6] Duggal S.K. ‘Earthquake Resistance Design of Structures’, Oxford University Press, New Delhi, 2007.

