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Design and Analysis of Multistorey Building (G+29) to Resist Earthquake Load on E-Tabs Software
Seismic Zone 2 Vs Seismic Zone 5

Abhishek Chanda & Shashank Gupta
M.tech, Civil Engineering Department Dr.K.N.Modi University Newai, Tonk, Rajasthan, India-304021
chandaabhishek93@yahoo.com
Assistant Professor, Civil Engineering Department Dr.K.N.Modi University Newai, Tonk, Rajasthan, India-304021
gupta.shashank.kay@gmail.com

Abstract— Structural Analysis is a branch which involves in the determination of behaviour of structures in order to predict the responses of real structures such as buildings, bridges, trusses etc. The behaviour of the structure changes according to various earthquake zones. In this paper we have taken two structures with same material specifications and are analysed under two different seismic zones of India. The analysis brings out different shear force and bending moment values at different zones. The different storey drifts are being plotted for different loads and load combinations. ETABS stands for Extended Three Dimensional Analysis of Building Systems. The main purpose of this software is to design multi-storeyed building in a systematic process.

Keywords-Structural analysis and design,different load combination,ETABS, zone 2 VS zone 5.

I. INTRODUCTION

A tall building is termed as multistory building when the height of the building goes above 100meters. India is a vast country with diversification of soil strata, the tectonic plates causing earthquakes of various magnitudes and the different wind speed in different locations. Here, in this paper we have designed a 30 storey multistory building with fixed support at the ground. The multistory building possesses various sub structural part i.e. beams, columns, slabs, walls and two lift walls diagonally placed. The floor to Floor height of the building is 4 m. The base height from ground floor to the first floor is 5m. The building is having a total height of 121m. All the design codes of steel and concrete are taken from Indian standards1893-part2:2002, IS 456:2000. The model is designed on ETABS software-2015. This software particularly deals with the design and analysis of a particular building or structures when exposed to loading. Various data is being extracted in the form of maximum bending moment, maximum shear force, and the reactions at various points and graphically presents the values of storey drift and many other physical data under various loading cases and load combination as well. ETABS basically stands for Extended Three Dimensional Analysis for Building System.

Since for a project to bring into essence there must be pros and corns to that. The advantages of these types of projects are they provide space for people to work and lives; it saves land and provides more accommodation in less cross sectional area. Moreover it facilitates human life with ease and leisure. As these are the advantages, there are many disadvantages for having such types of projects as well. The disadvantages being high cost of project, contribute more to noise and air pollution, makes life congested and misbalances the criteria of natural healthy environment.

II. LITERATURE REVIEW

Jan in 2004 [1] stated that when evaluating the seismic demands of tall buildings, engineers were more likely to adopt simplified non-linear static analytical procedures, instead of the more complicated non-linear response history analysis. Since the conventional procedure has some drawbacks in predicting the inelastic seismic demands of high-rise buildings.

Dharne Sidramappa Shivashaankar, Patil Raobahdur Yashwant[2] presents the various limitations in design and construction practices along with the feedback to overcome the limitations and make the structures safer to take the earthquake forces. The paper focuses on software used in the civil engineering for analysis and design, construction methods/practices, use of materials, types of structures, experiments for earthquake studies, quality control parameters etc.

Prashanth.P, Anshuman.S, Pandey .R .K, Arpan Herbert [3] present day leading design software's in the market. Many design company's use these software's for their project design purposes.

So, this project mainly deals with the comparative analysis of the results obtained from the design of a same structure but under different seismic zones. They can be either analysed by having different structures with same seismic zone and earthquake load or can be analyzed by having same structure under different seismic zones and variant earthquake load. In this paper the structural data and the specifications of building material remains the same but the analysis is carried out by placing the structure under two different seismic zones which are having the extreme earthquake specification data and the analysis is carried out.

III. PROBLEM DEFINATION

A. CASE

A 45mx45m multistory regular structure is taken to design and analyze under different seismic zone i.e. zone 2 and zone 5 on ETABS software and various results are plotted and compared.

B. PRELIMINARY DATA

Length x Width	45m x 45m
Number of stories	30(G+29)
Height of the structure	121m
Floor to floor height	4m
Standard code (steel)	IS 800:2007
Standard code (concrete)	IS 456:2000
Support condition	Fixed
Type and grade of beam	Concrete rectangular; M25
Type and grade of column	Concrete rectangular; M40
Grade of steel	HYSD415
Type of slab	Concrete
Type of wall	Masonry
Specification of beam	500mm x 300mm(1-15 story) 200mm x 200mm(16-30story)
Specification of column	600mm x 210mm(1-15 story) 300mm x 150mm(16-30 story)
Thickness of slab	250mm
Partition wall thickness	300mm
Wall thickness at outer periphery	500mm
Parking area (length x width)	75m x 15m
Beam specification (parking area)	600mm x 200mm
Column specification (parking area)	600mm x 300mm
Slab thickness (parking area)	200mm

C. LOAD CONSIDERATION

Loads acting on the structure are dead load (DL) which includes floor finish, water proofing, terrace finish and painting, the live load (LL), the Earthquake load for seismic zone 1 for model 1 and seismic zone 5 for model 2, the wind loading at two various locations with variant wind speed .

Now the loading is being subjected to the structure in accordance with different seismic loading at different zones. In India the revision of zone 1 and zone 2 are combined and are determined as zone 2. The location selected for the first model is Jaipur, where the soil type is of medium 2 and the soil is alluvial soil. For the second model for zone 5 considerations we take Bhuj, where the soil type is hard soil and the strata are of sedimentary rocks.

- Live load=3kn/m²
- Dead load=7kn/m²(includes floor finish, water proofing, terrace finish and painting)
- Earthquake load(IS:1893 PART1-2002)

Properties	Model 1	Model 2
Location	JAIPUR	BHUJ
Zone	2	5
Zone factor	0.10	0.36
Soil type	Medium	Hard and rocky
Response reduction factor	5	5
Importance factor	1	1
Damping	5%	5%
Time period	0.008 sec	0.008 sec

- Wind load(IS:875PART3-1987)

Properties	Model 1	Model 2
Basic wind speed	47m/sec	50m/sec
Risk coefficient, k1	1.07	1.08
Terrain category	2	2
Class	C	C
K2	1.21	1.21
K3	1	1
Cpe	1.2	1.2

D. ACTUAL ANALYSIS

A grid system of 45m x45m is taken and the properties of beams and columns are assigned.

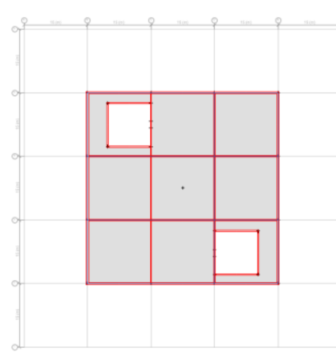

Fig 3.1.Plan view of both models.

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Fig 3.2. Elevation of G+29 story building

Fig 3.3. 3-D view of the building

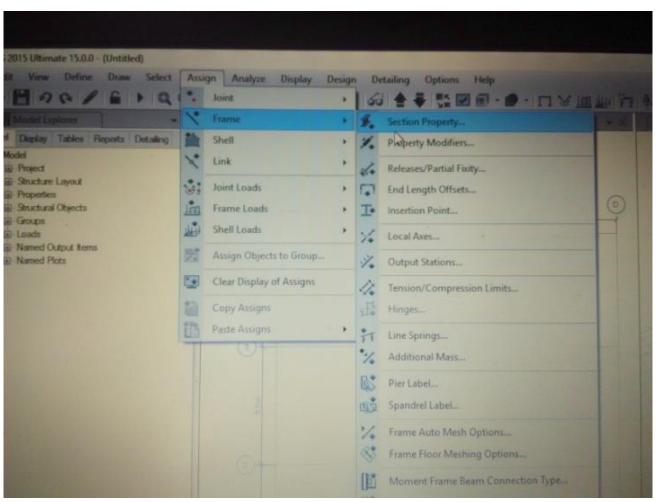

Fig 3.4. Selection of beam and column

The material of beam and column is taken as rectangular concrete structure. The grade of beam is M25 and that of column is M40. The theoretical explanation says that the beams and columns of the structure towards the foundation should be heavy as compared to that in the top. So the beams from 1-15 storey are of size 500mm x300mm and from16-30 storey is 200mm x200mm.In similar way the columns from1-15 storey are of size 600mm x 210mm and that from 16-30 storey are 300mm x 150mm.

After the columns and beams are designed the slabs and walls are to be designed. The slab thickness of slab is taken to be 250 mm for all stories and the wall sections are divided into two- the partition wall and the outer wall periphery. The wall thickness of outer walls is taken to be 500mm and that of the partition walls are taken to be 300mm.

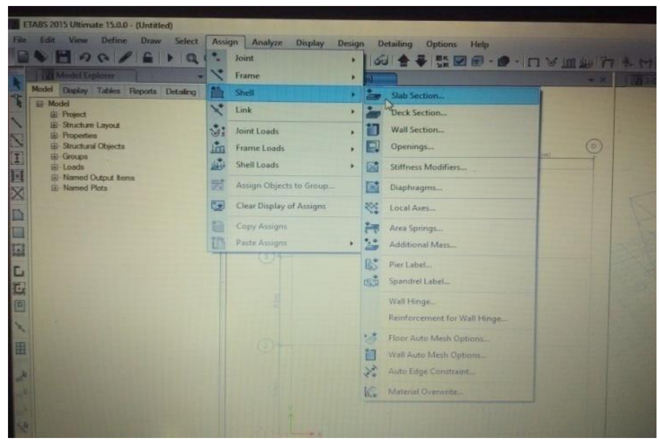

Fig 3.5.Selection of walls and slabs.

After the walls and slabs are designed the lift wall is to be designed. Preliminary the building had only one lift wall but since the design would gather all the stiffness at that area, an identical lift wall is also designed and placed diagonally to distribute the stiffness equally. The lift wall had a thickness of with height opening of 2m and width opening of 1.5m. The dimensions of lift wall are taken to be 10m x10m.

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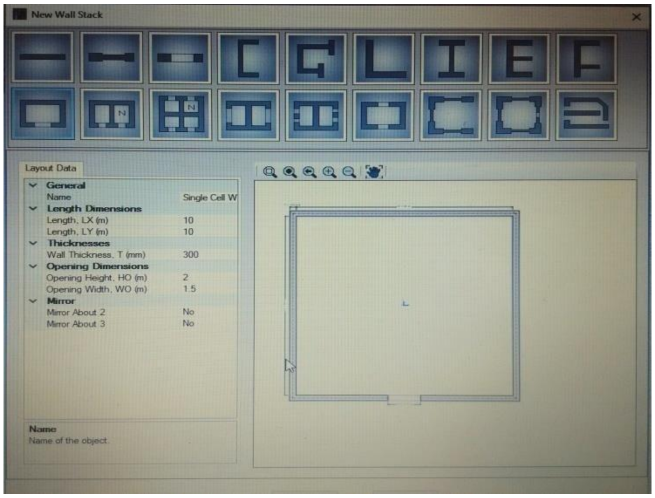

Fig 3.6. Selection of lift wall

IV. LOAD CALCULATION

A. SELF WEIGHT

1) COLUMN

a) COLUMN FROM 1-15 STOREY

B xDxDensity=0.6 x 0.21 x 25=3.15kn

b) COLUMN FROM 16-30 STOREY

BxDxDensity=0.3 x 0.15 x 25 =1.1125kn

c) COLUMN OF PARKING AREA

BxDxDensity=0.6 x 0.3 x 25=4.5kn

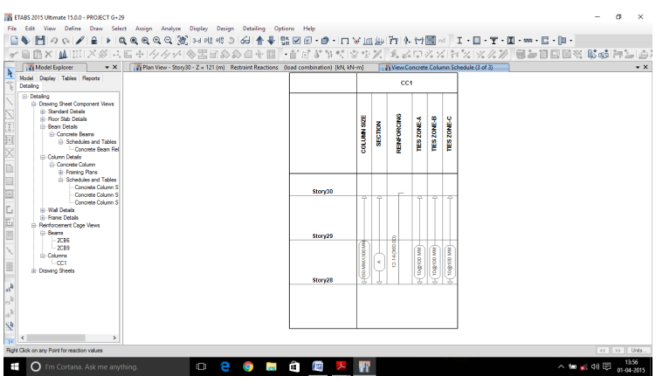

Fig 4.1 Column schedule

2) BEAM

a) BEAM FROM 1-15 STOREY

BxDxDensity=0.5 x 0.3 x 25=3.75kn

b) BEAM FROM 16-30 STOREY

BxDxDensity=0.2 x 0.2 x 25=1kn

c) BEAM OF PARKING AREA

BxDxDensity=0.6 x 0.2 x 25=3kn

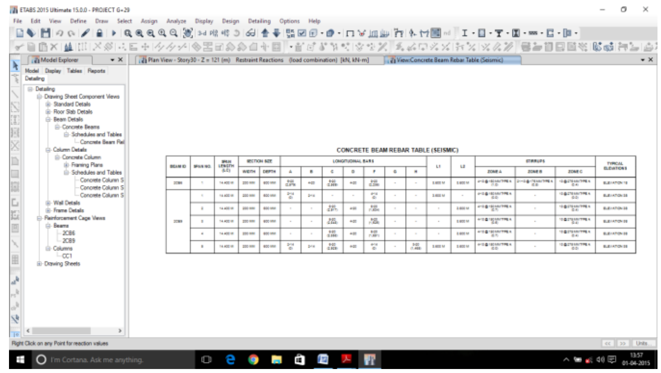

Fig 4.2 Beam details

3) SLAB

a) SLAB FROM 1-30 STOREY

Thickness=250MM=0.25 x 25=6.25kn

b) SLAB OF PARKING AREA

Thickness=200mm=0.20 x 25 =5kn

4) BRICK WORK

BRICKWORK OF PARTITION WALL

Thickness=300mm=0.3x19+2x0.012x20=6.18kn/m²

a) Brickwork of partitionwall at floor

Height of wall x brick wall of partition wall
=4 x 6.18=24.72kn/m

b) Brickwork of partitionwall at parking

Height x brick work of partition wall
=5 x 6.18= 30.9kn/m

BRICKWORK OF OUTER WALL PERIPHERY

Thickness=500mm=0.5x19+2x0.012x20=9.98kn/m²

a) Brickwork of outerwall at floor

Height of wall x brick work at outer wall
=4 x 9.98=39.92kn/m

b) Brickwork of outerwall at parking

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Height of wall x brick work at outer wall

=5 x 9.98=49.9kn/m.

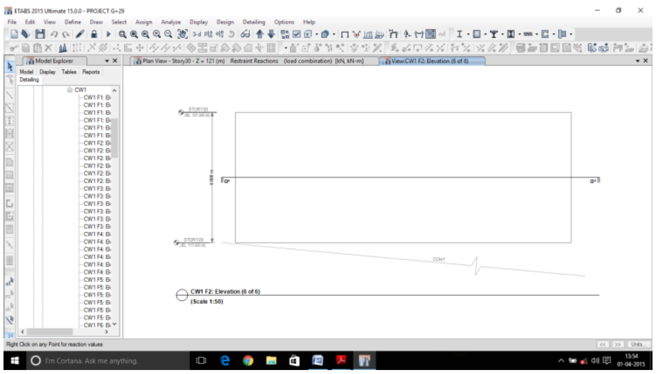

Fig 4.3 Wall layout

B. DEAD LOAD

1) COLUMN

a) COLUMN FROM 1-15 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.6 x 0.21 x 4 x 16 x 25=201.6kn

b) COLUMN FROM 16-30 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.3 x 0.15 x 4 x 16 x 25=72kn

c) COLUMN OF PARKING AREA

B x D x Height of storey x No. of column on each floor x Density
=0.6 x 0.3 x 5 x 13 x 25=292.5kn

d) DEAD LOAD OF COLUMN AT ROOF

=½(dead load of column of storey 1-15 + dead load of column of storey 16-30)
=½(201.6+72) =136.8kn

2) BEAM

a) BEAM FROM 1-15 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.5 x 0.3 x 15 x 24 x 25=1350kn

b) BEAM FROM 16-30 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.2 x 0.2 x 15 x 24 x 25=360kn

c) BEAM OF PARKING AREA

B x D x Length of beam x No. of beam on each floor x Density
=0.6 x 0.2 x 15 x 22 x 25=990kn

3) SLAB

a) SLAB FROM 1-30 STOREY

L x B x Thickness x No. of slab x Density
=45 x 45 x 0.25 x 1 x 25=12656.25kn

b) SLAB OF PARKING AREA

L x B x Thickness x No. of slab x Density
=45 x 15 x 0.25 x 1 x 25=4218.75kn

4) BRICK WORK WALL

a) Brickwork of partitionwall at floor

L x Thickness x storey height x no. of walls x density
=45 x 0.3 x 4 x 4 x 20=4320kn

b) Brickwork of partitionwall at parking

L x Thickness x storey height x no. of walls x density
=45 x 0.2 x 5 x 1 x 20=900kn

c) Brickwork of outerwall at floor

L x Thickness x storey height x no. of walls x density
=45 x 0.5 x 4 x 4 x 20=7200kn

d) Brickwork of outerwall at parking

L x Thickness x storey height x no. of walls x density
=45 x 0.25 x 5 x 2 x 20=2250kn

C. LIVE LOAD

Live load is considered 3kn/m² on each floor. Each floor has dimension of 45m x45m. Thus live load on each floor can be calculated as

=45 x 45 x 3=6075kn

As per IS 1893:2002 (pg no. 24) Clause no. 7.3.1, Table no.8, only 25% live load is considered in seismic weight calculations.

25% of live load = 0.25x 6075 = 1518.75 KN

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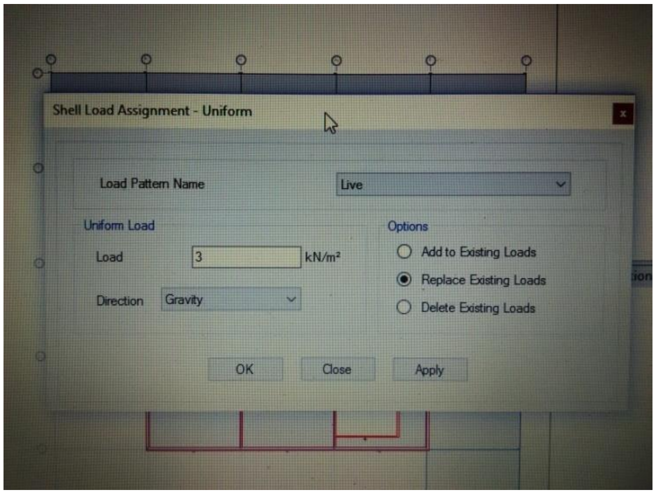

Fig 4.4(a). Assign of live load

The live load is assigned as shell loads in the slabs and is assigned as frame load in beam and column. Similarly, the dead load, the earthquake loads and the wind loads are being assigned in both x and y direction. The software also includes the eccentricity value which is by default taken as 0.05.

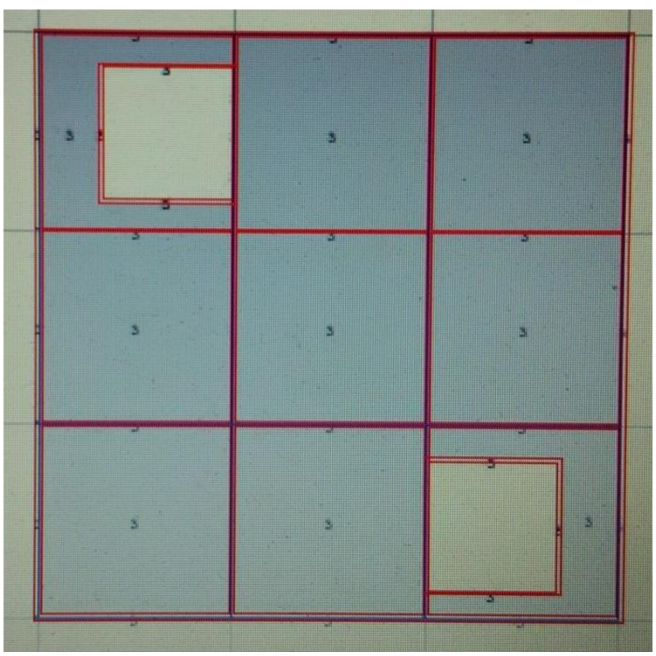

Fig 4.4(b). Live load is assigned

In similar manner the loads are defined for various buildings and the load combination is selected.

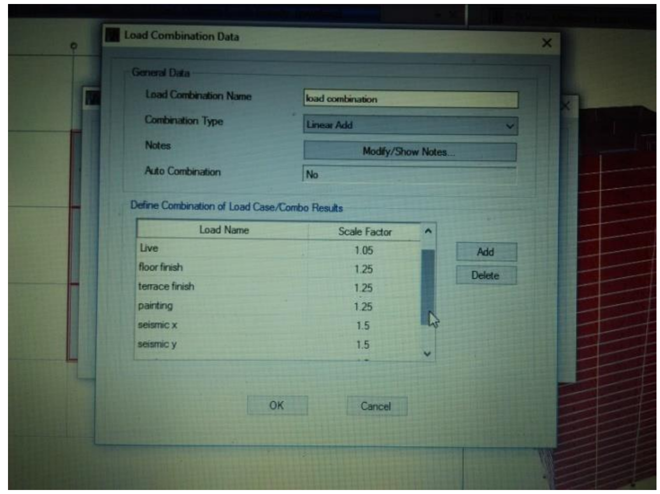

Fig 4.5. Load combination

For zone 2, the Z value is taken to be 0.10 and for zone 5 the Z value is taken to be 0.36. The importance factor for both the model is taken to be 1 and the response reduction factor R is taken to be 5 in both cases as the building is of SMRF frames. The value of time period is being calculated as per IS 1893:2002

$$Ta = \frac{0.09}{\sqrt{d}}$$

The SI unit for Ta is in seconds. The value of Ta is inserted for calculating Seismic load and wind load.

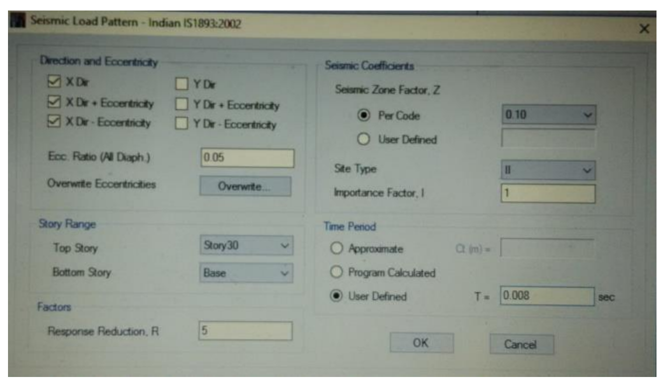

Fig 4.6. Seismic load applied for zone 2(Jaipur)

The wind load is also designed for both x and y direction where the value of Cpe for both leeward and external coefficient is determined and the value of K1 (Risk factor coefficient) and K3 (Topography coefficient) are determined.

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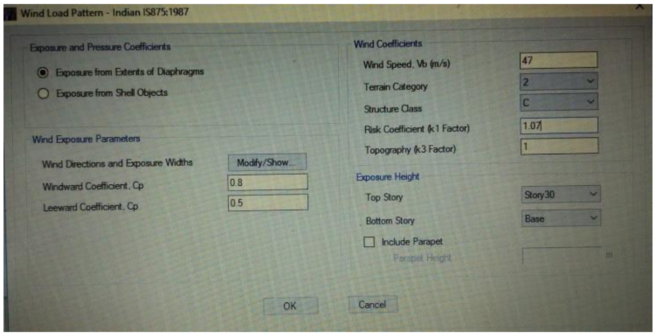

Fig 4.7. Wind load applied for zone 2(Jaipur)

D. LUMP MASS

Total plan area=45 x 45= 2025m²

Equivalent load at roof level= dead load x plan area+weight of beam at each floor + weight of column at each floor =7x2025+2700+566.1=17,441.1kn

Equivalent load at each floor=equivalent weight at each floor except the roof x plan area+ weight of beam at each floor + weight of column at each floor

Equivalent weight at each floor except the roof=DL+25%LL=7 + 0.25 x 3=7.75kn

Therefore,
Equivalent weight at each floor except the roof=7.75 x 2025+2700+566.1=18959.85Kn

E. SEISMIC WEIGHT OF BUILDING

=Equivalent load at roof level + Equivalent load at each floor x number of story
= 17441.1 + 18959.85 x 30
=5, 86,236.6 KN

F. DESIGN BASE SHEAR

1) BASE SHEAR FOR ZONE 2(Location Jaipur)

As per IS 1893:2002, The total design lateral force or design seismic base Shear (VB) along any principal direction shall be determined by the following expression:

$$v_b = A_h \times W$$

Where,
A_h = Design horizontal acceleration spectrum Value
w = Seismic weight of the building

As per IS 1893:2002,

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where,
Z =0.10, As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for zone 2.
I= 1, As per IS 1893:2002, Importance factor, It is depends on the functional use of the structure.
R= 5, As per IS 1893:2002, Response reduction factor
Sa/g = Average response acceleration coefficient.

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

Fig 4.8(a). Determination of Sa/g for medium soil

For determination of average response acceleration coefficient, it is required to calculate time period. As per IS 1893:2002, time period T is given by

$$Ta = \frac{0.09}{\sqrt{d}}$$

Where,
d=Base dimension of the building in meter = 45 m
Ta = 0.008 sec
Sa/g = 1.12

Now, Design horizontal acceleration spectrum Value can be calculated.

$$A_h = \frac{0.10}{2} \times \frac{1}{5} \times 1.12 = 0.0112$$

Now base shear,

$$v_b = A_h \times W$$
$$v_b = 0.0112 \times 5,86,236.6 = 6565.84KN$$

2) BASE SHEAR FOR ZONE 5(Location Bhuj)

As per IS 1893:2002, The total design lateral force or design seismic base Shear (VB) along any principal direction shall be determined by the following expression:

$$v_b = A_h \times W$$

Where,
A_h = Design horizontal acceleration spectrum Value
w = Seismic weight of the building

As per IS 1893:2002,

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$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where,
Z =0.36, As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for zone 5.
I= 1, As per IS 1893:2002, Importance factor, It is depends on the functional use of the structure.
R= 5, As per IS 1893:2002, Response reduction factor
Sa/g = Average response acceleration coefficient.

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

Fig 4.8(b). Determination of Sa/g for hard soil

For determination of average response acceleration coefficient, it is required to calculate time period. As per IS 1893:2002, time period T is given by

$$Ta = \frac{0.09}{\sqrt{d}}$$

Where,
d=Base dimension of the building in meter = 45 m
Ta = 0.008 sec
Sa/g = 1.12
Now, Design horizontal acceleration spectrum Value can be calculated.

$$A_h = \frac{0.36}{2} \times \frac{1}{5} \times 1.12 = 0.04032$$

Now base shear,

$$v_b = A_h \times W$$

$$v_b = 0.04032 \times 5{,}86{,}236.6 = 23{,}637.059712KN$$

V. ANALYSIS AND COMPARISION

After all the loads are assigned the model is being checked for various Errors and Warnings. Previously at the time of design the steel column of ISMB600 was being used and checked but column when subjected to the dead and live load failed the shear check capacity and failed. Due to that reason the steel columns are being replaced by rectangular columns and the model passed the design check.

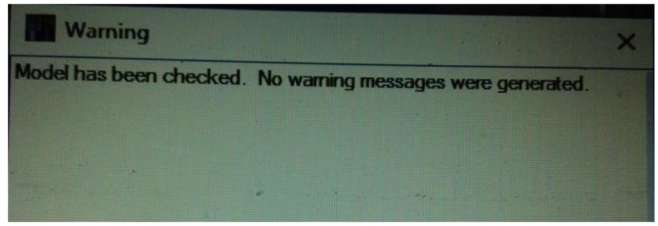

Fig 5.1. Model checking

After the model is checked and all the members under load are passed the model is being analyzed for different loads and the type of members are checked. After the members clearly pass the design check the various criteria are being compared for the model of zone 2 and zone 5.

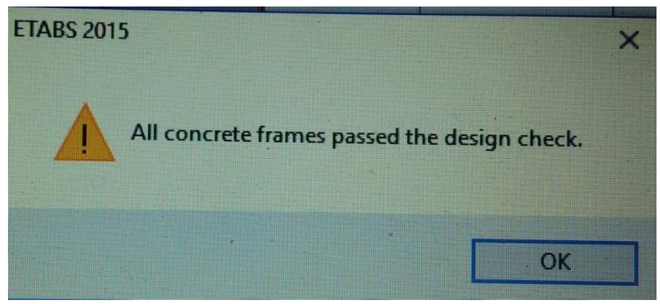

Fig 5.2(a). All concrete members passed the design check

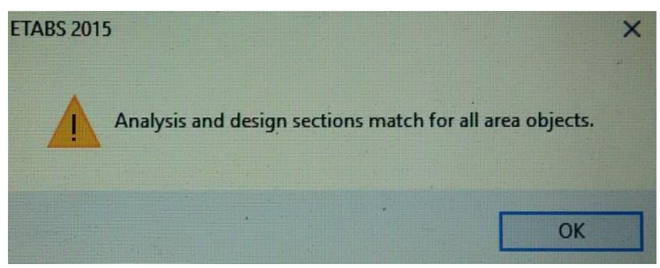

Fig 5.2(b). Both the lift wall passed the design check

After all the members pass the design check after load application, there are following few comparisons shown graphically and diagrammatically for the model having same structural composition but the lateral load i.e. the wind load and the seismic load differ zone wise following which the result for different data's gets distinguished.

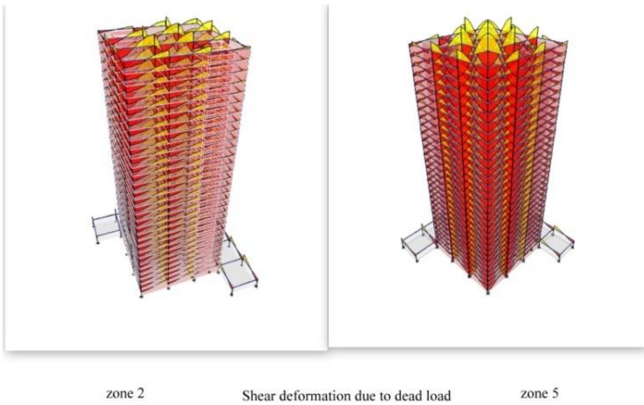

Fig 5.3. Shear deformation due to load combination zone 2 vs. zone 5

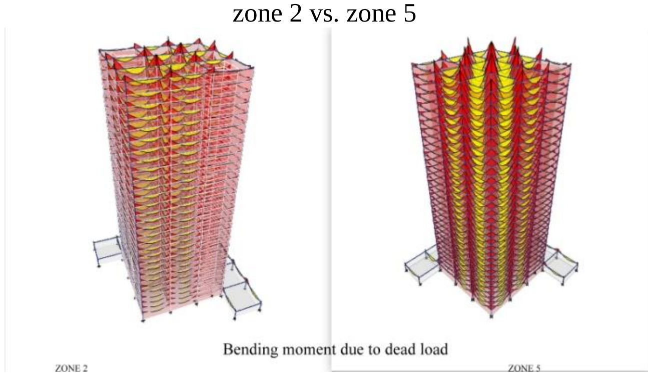

Fig 5.4. Bending moment due to load combination zone 2 vs. zone 5

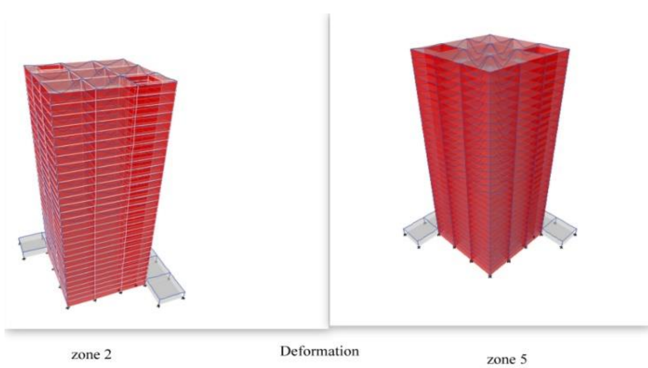

Fig 5.5. Deformation due to load combination zone 2 vs. zone 5

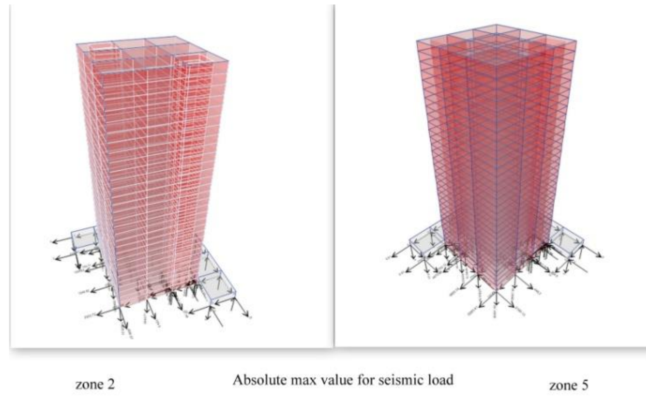

Fig 5.6. Reaction forces due to seismic load zone 2 vs. zone 5

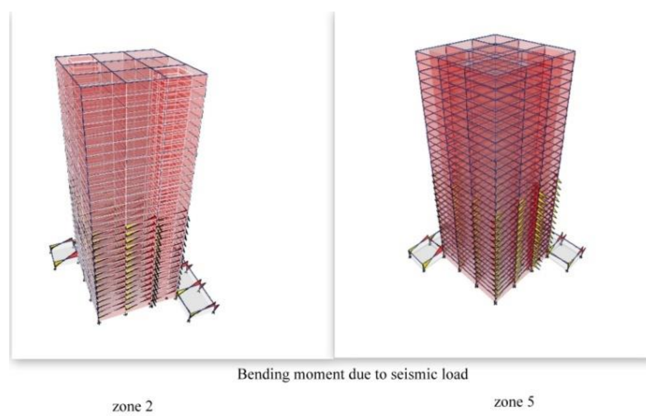

Fig 5.7. Bending moment due to seismic load zone 2 vs. zone 5

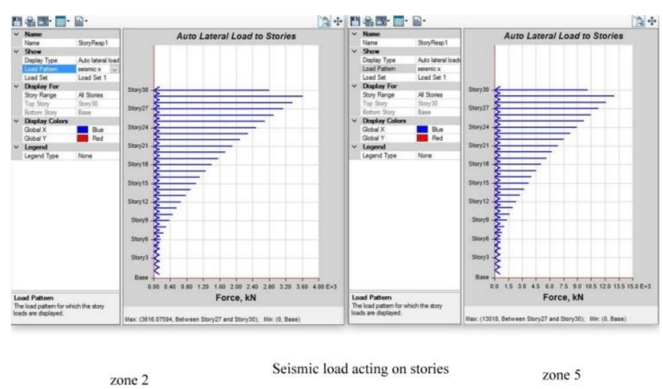

Fig 5.8. Seismic load acting on Stories zone 2 vs. zone 5

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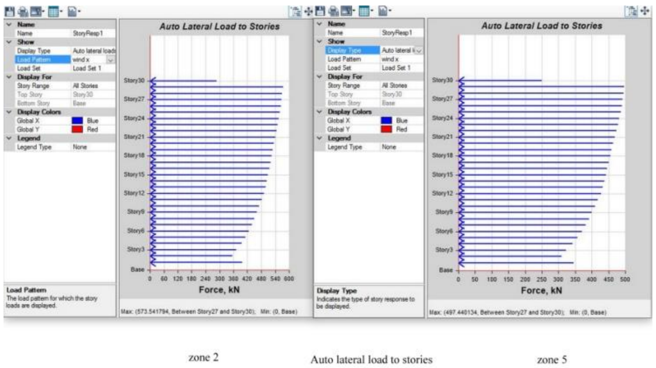

Fig 5.9. Wind load acting on stories
$v_b = 47m/sec \ vs \ v_b = 50m/sec$

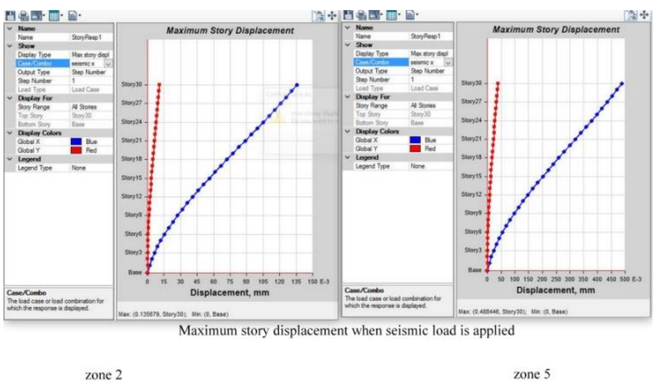

Fig 5.10. Maximum storey displacement
zone 2 vs. zone 5

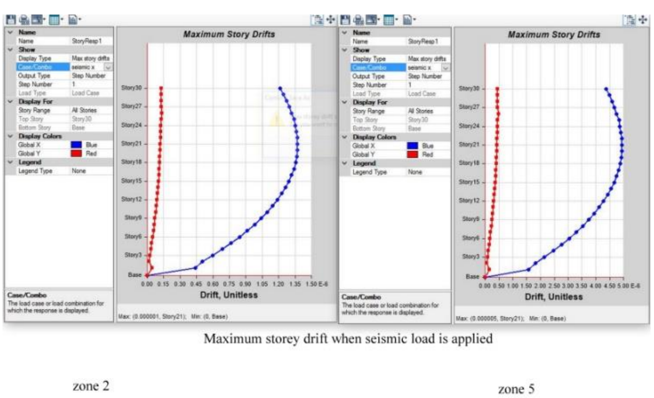

Fig 5.11. Maximum story drift
zone 2 vs. zone 5

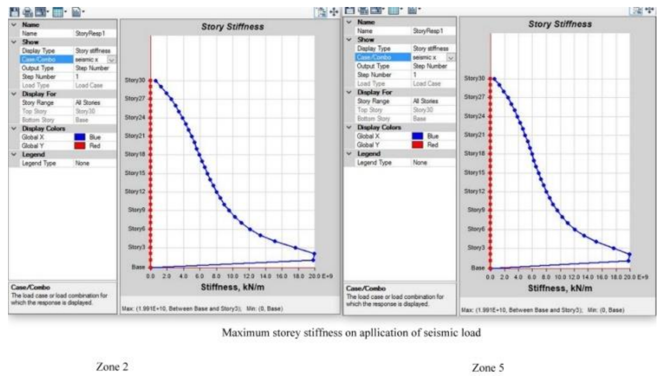

Fig 5.12. Maximum storey stiffness
zone 2 vs. zone 5

VI. CONCLUSION

Based on the design and analysis of (G+29) multistory building on ETABS software following conclusions is being drawn:

1. Initially steel columns were being used but it failed the design check so the concrete columns were being introduced.
2. The steel columns with Girder plate or a section from ISHB could have been used but we would have made the project costly.
3. From the data compared from 2 different seismic zones the one with seismic zone 5 shows more deformation and also shows a high Value of shear force and bending moment.
4. The maximum wind load effecting the stories is 573.54 KN for zone 2 and 497.44 KN for zone 5.
5. The maximum seismic load acting on the storey is 3616.0754KN for zone 2 and 13018KN for zone 5.
6. The maximum storey displacement under seismic load is 135mm in zone 2 and 488mm in zone 5.
7. The maximum storey drift under seismic load is 1.35 for zone 2 and 5 for zone 5 at storey number 21.
8. The maximum stiffness of the building lies between base and storey number 3 and is same for both models either in zone 2 or zone 5.

9. The bending moment due to seismic load are shown maximum from base to the storey number 15 since the weight of the column and the beams are heavy.
10. Our project deals with provision of earthquake resistant structure which is also economic.
11. There is a gradual increase in the value of lateral forces from bottom to top floor in software analysis.
12. By using ETABS, the analysis and design work can be completed within the stipulated time.

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