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Comparison of Earthquake Analysis Results of a Structure using ETABS Software and Manual Calculation

Rajat Danej[1], **Siddharth Verma**[2]

[1]IES IPS Academy, Department of Civil Engineering, Rajendra Nagar, A.B. Road, Indore, Madhya Pradesh, India

[2]IES IPS Academy, Department of Civil Engineering, Rajendra Nagar, A.B. Road, Indore, Madhya Pradesh, India

Abstract: ***ETABS (Extended Three-dimensional Analysis of Building Systems) is the present-day leading software for analysis and design of buildings especially Reinforced cement concrete buildings. Many design companies are using this software for their projects. This project mainly deals with the comparison of the lateral loads to stories obtained from manual calculation and from the analysis on ETABS of a10-story building. Analysis is carried out by equivalent static analysis method as per IS 1893 (Part 1): 2002 guidelines. For the analysis of the structure, the dead load and live load are considered. Further lateral loads to storiesare determined on each story and compared to the loads obtained from the manual calculation.***

Keywords: ETABS, Building, Lateral loads, Analysis

1. Introduction

Earthquake analysis or seismic analysis is a part of structural analysis and is the calculation of how a structure will respond during an event of earthquake. Earthquake causes shaking of the ground. So, any structure resting on it will experience movement at its base. Although the base of the structure moves with the ground, the roof has a tendency to remain on its original position. This tendency to continue to stay in the previous position is known as inertia. But the roof is also dragged because it is connected to the columns. In a building, since columns are flexible, the motion of the roof is different from that of the base due to the back and forth movement of the ground. This creates a lateral load on the building and a shear force at the base, as if these forces were being applied in the opposite direction. Therefore, it is necessary to evaluate these forces in order to design the structure capable of resisting these loads.

1.1 Types of Seismic Analysis

There are six types of seismic analysis namely:
1) Equivalent static analysis
2) Response spectrum analysis
3) Linear dynamic analysis
4) Nonlinear static analysis
5) Nonlinear dynamic analysis
6) Time history method

1.2 Equivalent static analysis

The equivalent static lateral force method is a simplified technique to substitute the effect of dynamic loading of an expected earthquake by a static force distributed laterally on a structure for design purposes. The total applied seismic force, V is generally evaluated in two horizontal directions parallel to the main axes of the building. It assumes that the building responds in its fundamental lateral mode. For this to be true, the building must be low rise and must be fairly symmetric to avoid torsional movement during ground motions. The structure must be able to resist effects caused by seismic forces in either direction, but not in both directions simultaneously.

2. Types of Load Used

Following types of loads are used
1) Dead load (DL): Dead loads are defined as the loads that are relatively constant over time, including the weight of the structure itself and immovable objects such as walls, floor finish, etc. Dead loads are also known as permanent or static loads.
2) Live load (LL): Live loads, or imposed loads are loads of temporary or short duration or of a moving load.
3) Earthquake load (EQ): Earthquake load is load due to the inertia force produced in the building because of seismic excitations.

3. Problem Formulation

A 40 m in X direction and 20 m in Y direction and a 10-story building is modelled in ETABS. The height each story is 3 m except for the bottom story which have a height of 4 m. At the top parapet wall of 1 m height is taken. The dimension of each room is taken as 5 m × 4 m. The floor finish load is taken as 1 kN/m^2 and the live load is taken as 2 kN/m^2.

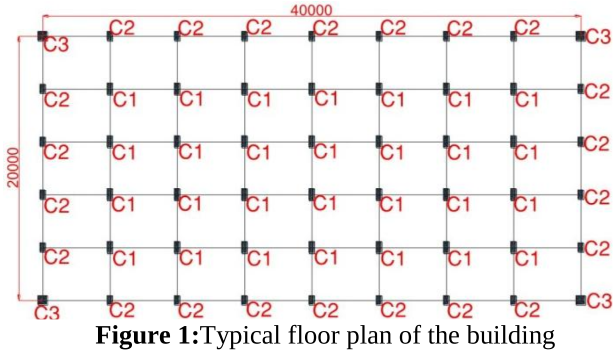

Figure 1: Typical floor plan of the building

3.1 Member Specification

- Beam size = 230 mm × 500 mm
- Slab size = 140 mm
- Exterior wall thickness = 230 mm
- Interior wall thickness = 115 mm
- Column size

S.NO.	Column Group	1^{st} – 5^{th} Story	6^{th} – 10^{th} Story
1	C_1	900 × 400	500 × 400
2	C_2	700 × 400	500 × 400
3	C_3	700 × 700	500 × 700

4. Load Calculations

4.1 Slab

Self-Weight per m^2 of slab = 0.14 × 25 = 3.5 kN/m^2
Total Dead Load per m^2 on slab = 3.5 + 1 = 4.5 kN/m^2
Total Dead Load on slab = 4.5 × 20 × 40 = 3600 kN

4.2 Beam

Self-weight of beam per m = 0.23 × 0.5 × 25 = 2.875 kN/m
Length of beam = (20 × 9) + (40 × 6) = 420 m
Self-weight of beam = 2.875 × 420 = 1207.5 kN

4.3 External Wall

Length of external wall = (40 × 2) + (20 × 2) = 120 m
Self-weight of external wall = 0.23 × 20 × 120 = 552 kN/m height.

4.4 Internal Wall

Length of internal wall = (40 × 4) + (20 × 7) = 300 m
Self-weight of internal wall = 0.115 × 20 × 300 = 690 kN/m height.

4.5 Columns

For 1^{st} to 5^{th} storey
C_1 = 0.9 × 0.4 × 25 × 28 = 252 kN/m height
C_2 = 0.7 × 0.4 × 25 × 22 = 154 kN/m height
C_3 = 0.7 × 0.7 × 25 × 4 = 49 kN/m height

For 6t to 10^{th} storey
C_1 = 0.5 × 0.4 × 25 × 28 = 140 kN/m height
C_2 = 0.5 × 0.4 × 25 × 22 = 110 kN/m height
C_3 = 0.5 × 0.7 × 25 × 4 = 35 kN/m height

4.6 Live Load Percent in Seismic Load

As per table 8 of IS 1893 (Part 1): 2002, percentage of imposed load to be considered in seismic weight calculations is 25% of the live load if the live load is less than or equal to 3 kN/m^2. Therefore, Live load = 20 × 40 × 2 × 0.25 = 400 kN

5. Manual Seismic Load Calculation

Seismic weight of parapet wall, W_{s11}
External Wall = 552 × 0.5 = 276 kN

Therefore W_{s11} = 276 kN

Seismic weight of storey 10^{th}, W_{s10}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1 + 1.5) = 1380 kN
4) Internal Wall = 690 × (1.5) = 1035 kN
5) Columns = 1.5 × (140 + 110 + 35) = 427.5 kN
6) Live Load = 0 kN as per clause 7.4.3. IS 1893 (Part 1): 2002

Therefore W_{s10} = 7650 kN

Seismic weight of storey 9^{th}, W_{s9}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (140 + 110 + 35) = 855 kN
6) Live Load = 400 kN

Therefore W_{s9} = 9788.5 kN

Seismic weight of storey 8^{th}, W_{s8}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (140 + 110 + 35) = 855 kN
6) Live Load = 400 kN

Therefore W_{s8} = 9788.5 kN

Seismic weight of storey 7^{th}, W_{s7}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (140 + 110 + 35) = 855 kN
6) Live Load = 400 kN

Therefore W_{s7} = 9788.5 kN

Seismic weight of storey 6^{th}, W_{s6}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (140 + 110 + 35) = 855 kN
6) Live Load = 400 kN

Therefore W_{s6} = 9788.5 kN

Seismic weight of storey 5^{th}, W_{s5}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = [1.5 × (140 + 110 + 35)] + [1.5 × (252 + 154 + 49)] = 1110 kN
6) Live Load = 400 kN

Therefore W_{s5} = 10043.5 kN

Seismic weight of storey 4th, W_{s4}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (252 + 154 + 49) = 1365 kN
6) Live Load = 400 kN

Therefore W_{s4} = 10298.5 kN

Seismic weight of storey 3rd, W_{s3}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (252 + 154 + 49) = 1365 kN
6) Live Load = 400 kN

Therefore W_{s3} = 10298.5 kN

Seismic weight of storey 2nd, W_{s2}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5 + 1.5) = 1656 kN
4) Internal Wall = 690 × (1.5 + 1.5) = 2070 kN
5) Columns = 3 × (252 + 154 + 49) = 1365 kN
6) Live Load = 400 kN

Therefore W_{s2} = 10298.5 kN

Seismic weight of storey 1st, W_{s1}
1) Slab = 3600 kN
2) Beam = 1207.5 kN
3) External Wall = 552 × (1.5) = 828 kN
4) Internal Wall = 690 × (1.5) = 1035 kN
5) Columns = 3.5 × (252 + 154 + 49) = 1592.5 kN
6) Live Load = 400 kN

Therefore W_{s1} = 8663 kN

Hence, Seismic weight of building, $W = \sum W_{si}$ = 96682 kN as per IS 1893 (Part 1): 2002, clause No. 7.4.2

Zone Factor, Z as per Table 2, IS 1893 (Part 1): 2002
Assuming severe seismic intensity (Zone IV), Z = 0.24

Importance Factor, I = 1, as per table 6, IS 1893 (Part 1): 2002

Response reduction factor, R as per table 7, IS 1893 (Part 1): 2002
R = 5, taking special RC moment-resisting frame (SMPF)

The approximate fundamental natural period of vibration (T_a), in seconds of all buildings with brick infill panels as per 7.6.2 IS 1893 (Part 1): 2002

$$T_a = \frac{0.09 \times h}{\sqrt{d}}$$

For x direction, $T_{a(x)} = \frac{0.09 \times 31}{\sqrt{40}} = 0.4411$ second

For y direction, $T_{a(y)} = \frac{0.09 \times 31}{\sqrt{20}} = 0.6239$ second

As per 6.4.5 IS 1893 (Part 1): 2002, for medium soil site (Type II), Spectral Acceleration Coefficient (S_a/g), is given as

For x direction,

$$\frac{S_a}{g} = 2.5, \text{ as } 0.10 \leq T \leq 1.55$$

For y direction,

$$\frac{S_a}{g} = 1.36/T = 1.36/0.6239 = 2.179, \text{ as } 0.55 \leq T \leq 4.00$$

The design horizontal seismic coefficient A_h as per 6.4.2 of IS 1893 (Part 1): 2002
For x direction

$$A_{h(x)} = \frac{Z\, I\, S_a}{2\, R\, g} = \frac{0.24}{2} \times \frac{1}{5} \times 2.5 = 0.0600$$

For y direction

$$A_{h(y)} = \frac{Z\, I\, S_a}{2\, R\, g} = \frac{0.24}{2} \times \frac{1}{5} \times 2.175 = 0.0523$$

Design seismic Base Shear as per Clause 7.5.3 of IS 1893 (Part 1): 2002

Design seismic base shear along x direction,
$V_{B(x)} = A_{h(x)}W = 0.06 \times 96682 = 5800.920$ kN

Design seismic base shear along x direction,
$V_{B(y)} = A_{h(y)}W = 0.0523 \times 96682 = 5056.082$ kN

Vertical distribution of base shear to different floor levels as per 7.7.1, IS 1893 (Part 1): 2002

$$Q_i = V_B \frac{W_i h_i^2}{\sum W_j h_j^2}$$

Table 1: Earthquake load in x and y direction

Story	W_{si} (kN)	h_i (m)	$W_{si}h_i^2$ (kN-m²)	Q_{ix} (kN)	Q_{iy} (kN)
11	276	32	28.262 × 10^4	45.946	40.047
10	7650	31	375.165 × 10^4	1195.170	1041.711
9	9788.5	28	767.418 × 10^4	1247.605	1087.412
8	9788.5	25	611.781 × 10^4	994.583	866.878
7	9788.5	22	473.763 × 10^4	770.205	671.310
6	9788.5	19	353.365 × 10^4	574.472	500.709
5	10043.5	16	257.114 × 10^4	417.995	364.324
4	10298.5	13	174.045 × 10^4	282.948	246.617
3	10298.5	10	102.985 × 10^4	167.424	145.927
2	10298.5	7	50.463 × 10^4	82.039	71.505
1	8663	4	13.861 × 10^4	22.534	19.641
Total	96682.0		3568.22 × 10^4		

6. ETABS Analysis Results

Table 2: Earthquake load in x direction

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
Story11	32	Top	45.8007	0
Story10	31	Top	1191.7453	0
Story9	28	Top	1228.1907	0
Story8	25	Top	979.1061	0
Story7	22	Top	758.2198	0
Story6	19	Top	565.5317	0
Story5	16	Top	409.8795	0
Story4	13	Top	277.5683	0
Story3	10	Top	164.2416	0
Story2	7	Top	80.4784	0
Story1	4	Top	22.038	0
Base	0	Top	0	0

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Table 3: Earthquake load in y direction

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
Story11	32	Top	0	39.9376
Story10	31	Top	0	1039.1857
Story9	28	Top	0	1070.9657
Story8	25	Top	0	853.7673
Story7	22	Top	0	661.1574
Story6	19	Top	0	493.136
Story5	16	Top	0	357.4093
Story4	13	Top	0	242.0358
Story3	10	Top	0	143.2164
Story2	7	Top	0	70.176
Story1	4	Top	0	19.2168
Base	0	Top	0	0

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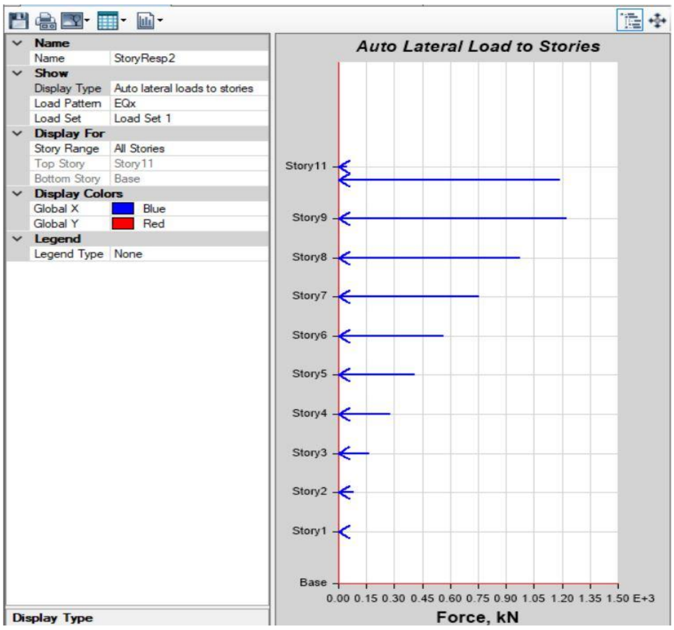

Chart 1: Earthquake load in x direction

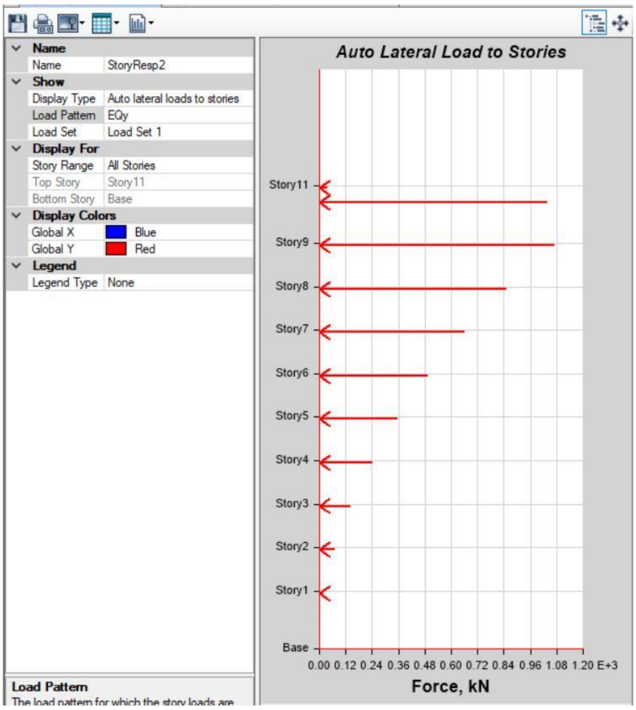

Chart 2: Earthquake load in y direction

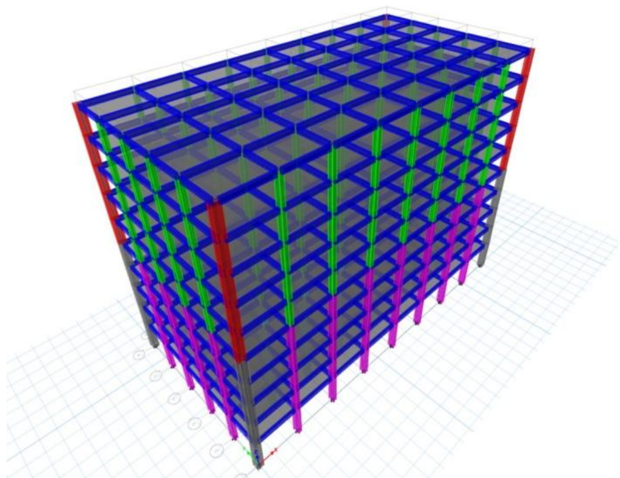

Figure 2: 3-D view of the model in ETABS

7. Conclusions

1) The preparation of this project has provided an excellent opportunity to emerge ourselves in analyzing a multistory building for seismic loads.
2) This project has given an opportunity to re-collect and co-ordinate the methods of analysis and engineering principles.
3) Analysis was done by using ETABS software and manually as per IS 1893 (Part 1): 2002. The lateral load to stories obtained in both the cases are approximately same.
4) By using ETABS software the analysis work can be completed within the stipulated time.

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Author Profile

Rajat Danej, B.E (Civil Engineering), Institute of Engineering & Science (IES) IPS Academy, Graduate Student

Siddharth Verma, B.E (Civil Engineering), Institute of Engineering & Science (IES) IPS Academy, Graduate Student