Seismic Performance Analysis of Moment Frame Steel Structure

Rituja N. Patil[1], Dr. Pratibha Alandkar[2], Dr. Shailesh S. Angalekar[3]

[1]M.E. Structures student, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India
[2]Head of Department, Department of Civil Engineering, Rasiklal M. Dhariwal Sinhgad School of Engineering, Pune, Maharashtra, India
[3]Assistant Professor, Department of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India

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Abstract - *There are various steel structures that occur engineered by human. Though iron has been around for centuries, its usage in construction is more modern than you might think. It started during the time of the Industrial Revolution, which was marked by mass production and the invention of new materials, including modern steel. To begin, it's helpful to understand what structural steel is and how it's made. This grade of steel is utilized in a variety of applications. make structural steel shapes since it is formatted from a precise cross section. Yet, at the same time it follows definite standards for mechanical properties and chemical composition. Steel structures have been known to perform well under earthquake loads provided certain guidelines are followed in design.*

***Key Words*: Moment frame steel structure, Seismic Analysis, Earthquake, ETAB, Steel structure.**

1. INTRODUCTION

The section gives an introduction to the essential qualities of tremor-safe structure design, with a special focus on related supplementary features in contrast to structural design As earthquakes claim the lives of thousands of people and destroy property worth billions of dollars, it is vital to plan earthquake-resistant constructions on a constant basis. It's vital that structures are designed to withstand seismic tremor forces in order to reduce fatalities. A vital role is played by additional structure. The section serves as a prelude to the fundamental attributes of tremor-safe structure design, with a special emphasis on related supplementary features in contrast to structural design. It is critical to plan earthquake-resistant structures on a continuous basis, as shocks claim the lives of thousands of people and destroy property worth billions of dollars. It is critical that structures be proposed to counteract seismic tremor forces in order to reduce fatalities.

1.1 Lateral Load Resisting Systems

When lateral loads are applied to a tall building, it requires a lateral load resisting system to keep the structure stable. Wind and earthquake lateral loads are primarily applied to buildings. The horizontal loads applied to structures grow as they become taller. Furthermore, as the structure's height increases, the lateral load's effect gets more severe.

Moment Resisting Frames: Moment frames consist of a grid of vertical (i.e., columns) and horizontal (i.e. beams) members. To withstand lateral loads, axial forces, bending moments, and shear forces are formed in both beams and columns. To expect ductile behaviour, Sections of the beam and columns should be designed as under-reinforced sections; brittle shear failure must be avoided employing capacity design methodologies. Predominant flexural behaviour in beams and columns should be enabled when selecting the structural structure of the building. Small beams and columns generate huge pressures and are prone to brittle failure, therefore this can be accomplished by using relatively long frame members.

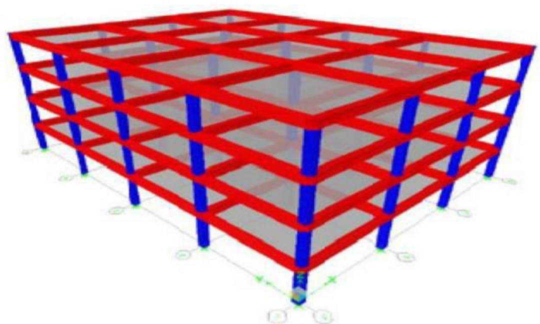

Figure 1. Moment Resisting Frame

1.2 Objective of study

Overall the key objectives dealt in this project are:

1) To verify loss of life and will limit economic loss during an earthquake.
2) To calculate the response of a building structure to earthquakes.
3) To design, build and maintain structures that are able to withstand earthquakes in compliance with steel building codes.
4) To suggest the resulting inter-story displacements are satisfactory.
5) To imply that a structure's ability to withstand earthquakes is determined by its displacement capacity rather than its initial yield strength.

1.3 Scope of the study

To achieve the objectives as stated above, the entire study has been conducted in three stages defining the scope of project. In first stage, the previous work done on steel structural model has been reviewed further, the second stage comprise of gathering analytical background on Analysis of irregular moment frame steel structure. Literature review on Design and analysis of irregular moment frame steel structure by Is-800 & AISC-341 is as well studied. A generalized solution based on present work to cover a wide range of applications in civil engineering has been then presented.

2. METHODOLOGY

The core theme of suggesting seismic analysis on irregular steel moment frame structure has been accomplished by ETAB analytical investigation. The irregular steel moment frame structure modelled in ETAB, the moment frame structure contains G+6 floors and steel structure is in L-shaped model. On previous investigation on analysis of irregular steel moment frame structure model, it has been proved that an integrated approach by conducting analytical investigation by using ETAB software provides a reliable solution. Following design philosophies are used as:

2.1 Allowable stress design (ASD)

These theories made it possible to examine indeterminate structures and calculate the correct distribution of bending and shear stresses. The initial occurrence of yield stress in steel was thought to represent the start of failure. The nonlinearity and buckling constraints were overlooked. The most basic calculations involved ensuring that the stresses induced by the characteristic loads were less than a "allowable stress," which was a little portion of the yield stress. As a result, the permitted stress can be stated in terms of a "factor of safety," which is a margin for overload and other unknown circumstances that the structure can endure. As a result, the permissible stress is proportional to yield stress as follows: *Allowable stress = Yield stress/ Factor* Each part of a structure is tested for a variety of loading combinations as a matter of safety in general.

2.2 Load and Resistance Factor Design (LRFD)

Load and Resistance Factor Design is a significant advancement in the logical design of steel-framed structures. It combines structural reliability's strength and serviceability limit states with a modern probabilistic methodology. The method is specified after a historical introduction, and a generic LRFD format is established. The topic focuses on design sources of variability, limit states, and probabilistic load and resistance factor values.

2.3. Analysis of structural system

The proposed structural model is analyzed using ETABS software. The static analysis method is used to examine the models. Based on the type of study employed for the model, the software estimates the lateral load, which is then used to perform analysis on these models. The structure is subjected to lateral loads in this investigation, and analysis is performed.

3. MODELLING

The moment frame structure has G+6 floors and it is in L-shaped model.

3.1 Methodology

1 Seismic Analysis of Moment frame steel structure using ETABS 2018.
2 The steel structure is being analyzed based on Indian Standard Codes i.e. IS 456:2000 & IS 1893:2016.
3 The steel structure is being analyzed as per ASCE codes i.e. AISC 360-16 & AISC 341-16.

3.2 Description of Model

Physical properties of structural steel irrespective of its grade may be taken as:

- Unit mass of steel, p = 7850 kg/m3
- Modulus of elasticity, E = 2.0 x 105 N/mm2 (MPa)
- Poisson ratio, μ = 0.3
- Modulus of rigidity, G = 0.769 x 105 N/mm2 (MPa)
- Co-efficient of thermal expansion α = 12 x 10-6 /ºc

Table 1. Description of Moment frame steel model

1.	Plan	18m X 17.5m
2.	X-direction grid spacing	18m
3.	Y-direction grid spacing	17.5m
4.	Number stories	G+6
5.	Shape of the building	L-shaped
6.	Height of ground floor	3.6m
7.	Height of each storey	3m
8.	Support condition	Fixed
9.	Total height of building	33.6m

3.3 Model views in ETABS

Following are the views of models which are used for the research work in ETABS.

A two-dimensional, flattened image of a floor level is depicted in the overall floor plan. A plan view is a three-dimensional object projected orthographically across a horizontal plane.

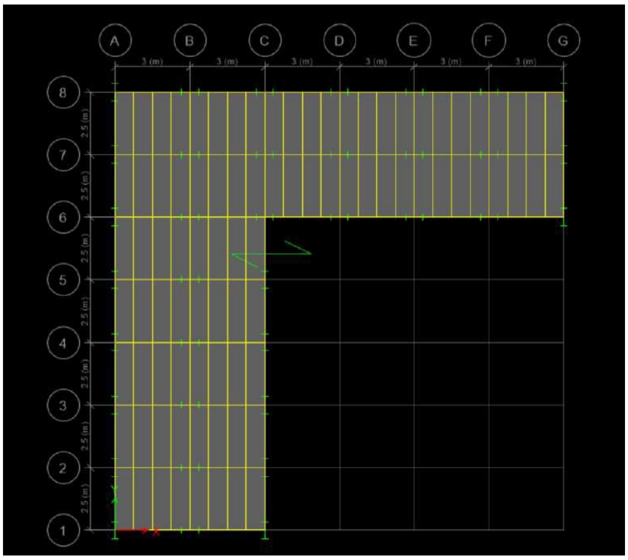

Figure 2. Plan view of moment frame structure

An elevation drawing is a projection drawing that depicts one side of the home in orthographic projection. An elevation drawing's goal is to represent the finished appearance of a certain side of the house as well as offer vertical height information. In most cases, four elevations are designed, one for each side of the house.

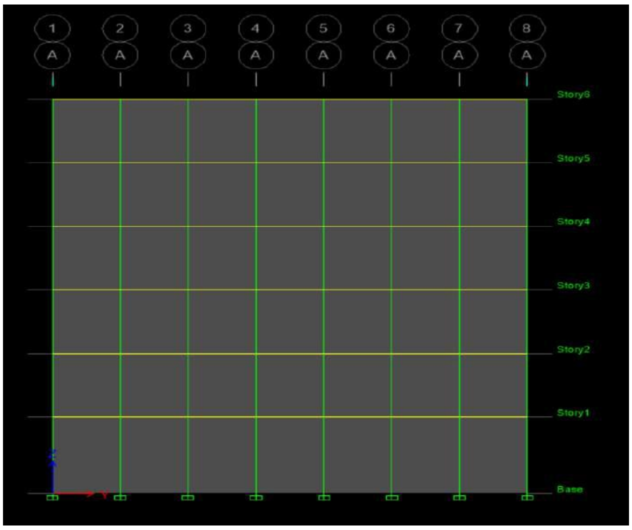

Figure 3. Elevation of moment frame structure

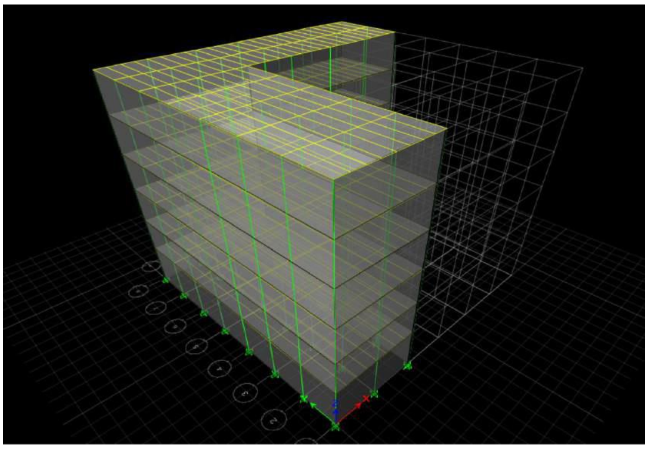

Figure 4. 3D-view of moment frame structure

4. STRUCTURAL ANALYSIS PROCESS

Structural analysis is the process of determining the effects of loads on physical structures and their components. Any structures that must endure loads, such as structures, bridges, aircraft, and ships, are subjected to this type of inspection. Structural analysis is a method of calculating a structure's deformations, internal forces, stresses, support responses, accelerations, and stability using applied mechanics, materials science, and applied mathematics. The study's findings are used to confirm a structure's suitability for the purpose of its intended function, frequently without the need for physical inspections. As a result, structural analysis is an important aspect of the engineering design of the structure.

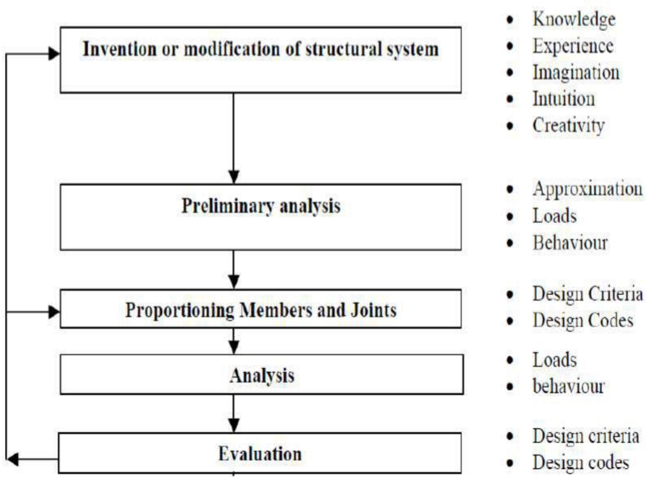

Chart 1. Flowchart for Structural Analysis

5. ANALYTICAL ITERPRETATION

5.1 Interpretations as per analysis using Indian Standard codes

Interpretation of Torsion: Torsion is the state of strain in a material that has been twisted by an applied torque. When a structural element is exposed to a twisting force, something happens. Torsion produces shear stresses and is the same as tension and compression when they are applied at right angles. When you wring a wet towel, you can see how torsion-induced compression squeezes the water out.

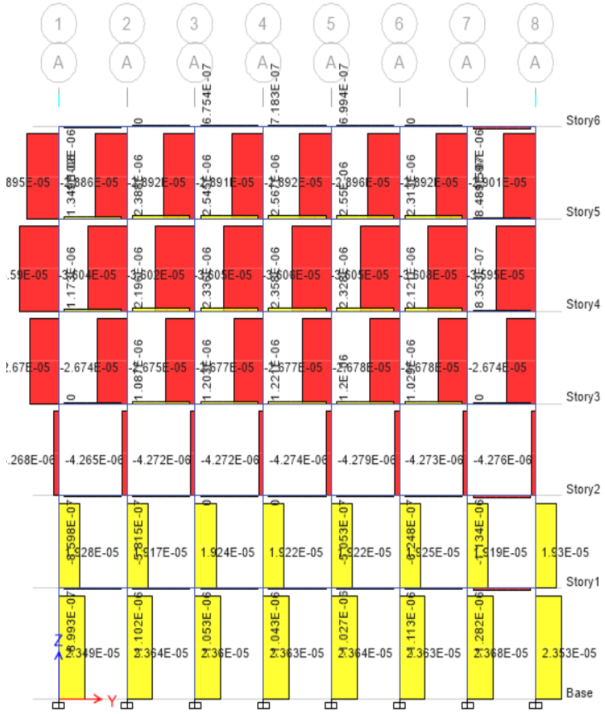

Figure 5. Torsion diagram at elevation A

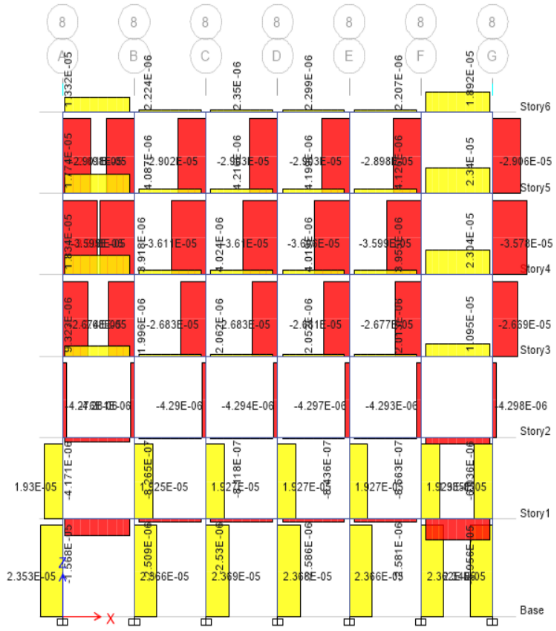

Figure 6. Torsion diagram at elevation 8

5.2. Interpretations as per analysis using ASCE codes

Interpretation of Torsion: The state of strain in a material that has been twisted by an applied torque is known as torsion. When a structural element is exposed to a twisting force, something happens. Torsion produces shear stresses and is the same as tension and compression when they are applied at right angles. When you wring a wet towel, you can see how torsion-induced compression squeezes the water out.

The torsion diagrams that result from the analysis of the moment frame structure are as follows:

Figure 7. Torsion diagram at elevation A

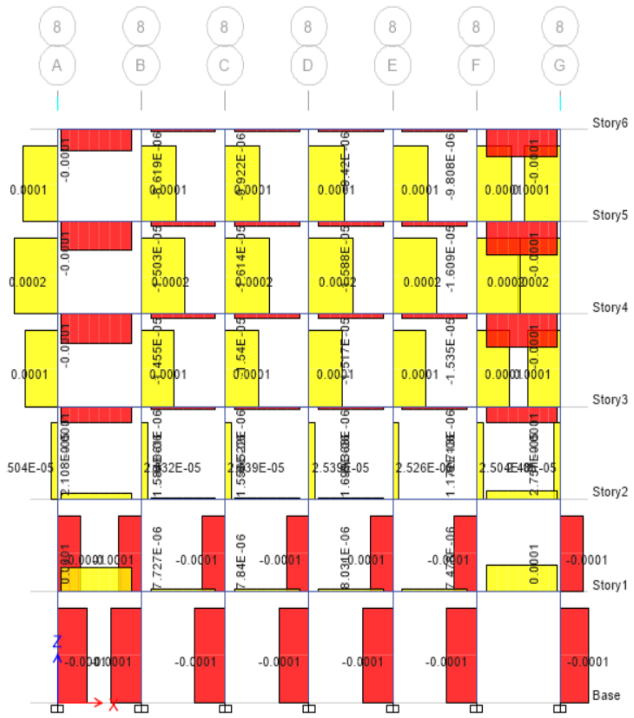

Figure 8. Torsion diagram at elevation 8

6. RESULTS

6.1. Modal Participating Mass Ratios

In modal analysis, the modal mass participation ratio is a regularly used statistic to assess the relative relevance of modes. The inherent frequencies and mode shapes of the proposed model are calculated using modal analysis. It's the sole analysis that doesn't require any input excitation or loads, which makes sense because natural frequencies are unaffected by excitation loads, as previously stated. Natural frequency depends only on two things mass and stiffness.

6.2. Modal participation mass ratio table as per Indian Standard code

Table 2. Modal participation mass ratio table as per Indian Standard code

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
		sec												
Modal	1	1.387	0.003	0.8	0	0.003	0.8	0	0.1448	0.0006	0.0443	0.1448	0.0006	0.0443
Modal	2	1.13	0.661	0.0216	0	0.6641	0.8216	0	0.0034	0.1288	0.1557	0.1482	0.1294	0.1999
Modal	3	1.011	0.176	0.0279	0	0.8401	0.8494	0	0.0041	0.0323	0.6395	0.1523	0.1617	0.8394
Modal	4	0.44	0.0003	0.0946	0	0.8404	0.9441	0	0.6498	0.0016	0.0057	0.802	0.1633	0.8451
Modal	5	0.353	0.0824	0.0019	0	0.9228	0.946	0	0.0138	0.5235	0.0196	0.8158	0.6868	0.8647
Modal	6	0.318	0.02	0.0028	0	0.9427	0.9488	0	0.0206	0.1354	0.0779	0.8363	0.8222	0.9426
Modal	7	0.242	0.0001	0.0308	0	0.9428	0.9796	0	0.0757	0.0001	0.0015	0.9121	0.8223	0.9442
Modal	8	0.189	0.0291	0.0004	0	0.9719	0.98	0	0.0011	0.0706	0.0062	0.9132	0.8929	0.9503
Modal	9	0.172	0.0063	0.001	0	0.9782	0.981	0	0.0025	0.0149	0.0276	0.9156	0.9078	0.9779
Modal	10	0.159	0.000009928	0.0126	0	0.9782	0.9936	0	0.0612	0.0000424	0.0008	0.9768	0.9078	0.9787
Modal	11	0.121	0.0125	0.0002	0	0.9907	0.9938	0	0.0009	0.0568	0.0025	0.9778	0.9646	0.9811
Modal	12	0.117	0.0001	0.0048	0	0.9907	0.9985	0	0.0157	0.0004	0.0001	0.9935	0.965	0.9813

The below line graph represents the modal cases verses torsion representation. The X- axis represent modal cases value and Y-axis represent torsion value. The given values are as per seismic analysis of steel moment frame structure buy using Indian Standard codes.

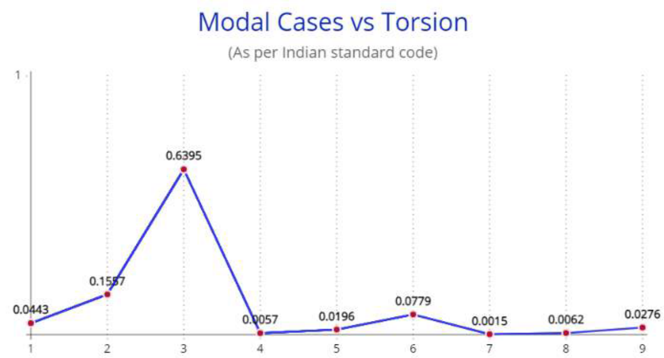

Chart 2. Modal cases vs torsion according to the Indian Standard Code

6.3. Modal participation mass ratio table as per ASCE code

The model should be reviewed against the performance requirements of the mass participation factor to judge the dynamic characteristics. According to the code, UBC-97 section 1631.5.2 and ASCE 7-10 section 12.9.5, the total number of modes included in the analysis must contain at least 90% of the structure's participating mass or at least 90% of the structure's participation mass must be attained. There is no minimum number of modes that must be considered in the analysis, but it must be sufficient to meet the 90% target.

Table 3. Modal participation mass ratio table as per ASCE code

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
		sec												
Modal	1	0.589	0.0836	0.5778	0	0.0836	0.5778	0	0.1156	0.0164	0.1777	0.1156	0.0164	0.1777
Modal	2	0.528	0.5177	0.2138	0	0.6014	0.7916	0	0.0406	0.0995	0.1143	0.1562	0.1159	0.292
Modal	3	0.443	0.2456	0.0524	0	0.8469	0.844	0	0.0084	0.0452	0.5496	0.1646	0.1611	0.8415
Modal	4	0.186	0.0103	0.0751	0	0.8572	0.9191	0	0.469	0.0682	0.0239	0.6336	0.2294	0.8654
Modal	5	0.168	0.064	0.0253	0	0.9212	0.9445	0	0.1672	0.4176	0.0143	0.8008	0.6469	0.8797
Modal	6	0.14	0.0283	0.0052	0	0.9495	0.9497	0	0.0387	0.1932	0.0677	0.8396	0.8401	0.9474
Modal	7	0.102	0.0032	0.0231	0	0.9527	0.9728	0	0.0583	0.0078	0.0064	0.8979	0.848	0.9538
Modal	8	0.093	0.02	0.0077	0	0.9727	0.9805	0	0.0189	0.0492	0.0045	0.9168	0.8972	0.9583
Modal	9	0.078	0.009	0.0015	0	0.9817	0.982	0	0.0036	0.0215	0.0224	0.9204	0.9187	0.9807
Modal	10	0.069	0.0012	0.009	0	0.9829	0.991	0	0.0433	0.006	0.0026	0.9637	0.9247	0.9833
Modal	11	0.062	0.0079	0.003	0	0.9908	0.994	0	0.0146	0.0383	0.0018	0.9783	0.963	0.9851
Modal	12	0.052	0.0006	0.0034	0	0.9914	0.9974	0	0.0112	0.0022	0.0004	0.9894	0.9652	0.9855

The above line graph represents the modal cases verses torsion representation. The X- axis represent modal cases value and Y-axis represent torsion value. The given values are as per seismic analysis of steel moment frame structure by using ASCE codes.

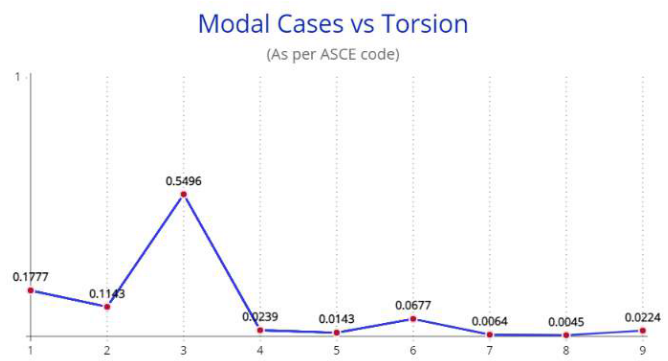

Chart 3. Modal cases vs torsion as per ASCE code

7. CONCLUSIONS

The major conclusions drawn from this study are:

- The seismic performance analysis conducted on both model which firstly, analyze by Indian Standard code and further analyze by ASCE codes.
- As per IS1893:2016 (Part 1) Table – 5 concluded that the period of natural oscillation is less than the first two modes of translation in each of the major plan directions; which is satisfied after structural analysis of both models.
- After structural analysis of moment frame steel structure by both codes Indian as well as ASCE, which gives separate results.
- Shear forces, bending moment, and torsion are all included in the analysis.
- The analysis of moment frame steel structure having maximum values of shear forces, Torsion and bending moment by analyzing Indian Standard codes, which cause to reduce the life of steel structure.
- Finally, ETAB is a versatile software that can accurately decide analytical outcomes against lateral forces.
- It does a static as well as a dynamic study of the structure and provides reliable results.

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