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Comparitive Analysis of Earthquake Design of Steel Structure Static Vs Dynamic Anaysis

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Abstract- Earthquakes are one of the most devastating forces on the planet. The seismic waves that travel through the ground can demolish buildings, kill people, and cost billions of dollars in damage and restoration. According to the National Earthquake Information Centre, there are over 20,000 earthquakes every year on average, including 16 major disasters. The damage was caused by the collapse of buildings with people inside, as in previous earthquakes, prompting the development of earthquake-resistant constructions. Constructions intended to withstand earthquakes are known as earthquake-resistant structures. While no structure can be completely safe from earthquake damage, earthquake-resistant construction aims to build structures that perform better than their conventional equivalents during seismic activity. Building rules state that earthquake-resistant constructions must be able to withstand the greatest earthquake with a reasonable chance of occurring at their site. In this paper we are marking comparison between Static and dynamic analysis. It is concluded from paper Dynamic analysis is economical as compared to static analysis.

Keywords: EQX –Static Earthquake Force; RSX- Dynamic Earthquake Force; Dynamic- Dependent on time; Static – Dependent on Mass

I. INTRODUCTION

An earthquake is a sudden and transient motion of the earth's surface. According to geologists, the earth has suffered earthquakes for hundreds of millions of years, even before humans came into existence. Earthquakes are so far away unpredictable and unpreventable; the only alternative is to construct and build the building structures which by earthquake resistant. There are so many techniques to withstand earthquake, but they are costly are not used by ordinary people.

II. OBJECTIVE AND PROBLEM STATEMENT

1. Problem Statement

- The entire North –Eastern region & most parts of Indian Himalayan belt fall under the seismic zone IV & V.(Source : www.nidm.gov.in) Over the past two decades India is facing severe earthquake
- Increased construction activities along the earthquake-prone zones, Soil–Structure Interaction in its various avatars has come to prominence. It has been applied to modern structures like High-Rises, Bridges, Harbours, and Nuclear Power Plants and also to traditional historic structures.
- Now a days Unfortunately, the use of more accurate analysis methods has not use in PEB construction in India due to this research work is required in this field.
- Literature review is done to study previous research work done in this topic.

2. Objective

- Performance based seismic design of a steel structure by using dynamic analysis of Structure.
- Shortcoming and imperfection of conventional static analysis of seismic design for tall structure.
- Study of cut off mode shape & their behaviour.
- Different structural member modelling and the kind of dynamic analysis using staad pro software.
- The comparative results for both of static method & dynamic analysis are done.
- The main objective of this thesis to analyse the mass participation using staad software.

III. LITERATURE REVIEW

The chapter present literature review on the subject of seismic analysis in India and world. Requirement of dynamic analysis is increase in India now a days due to increase of earthquake occurrence in India. This chapter is divided I three part . Part 1 deals with architectural and planning aspects of project. Next section deals with seismic code use in world part 3 deals with major seismic zone in world.

1. Architectural and Planning Aspects

The wide range of structural damages observed during past earthquakes across the world is very educative in identifying structural configurations. (Source: TIU, 2008).

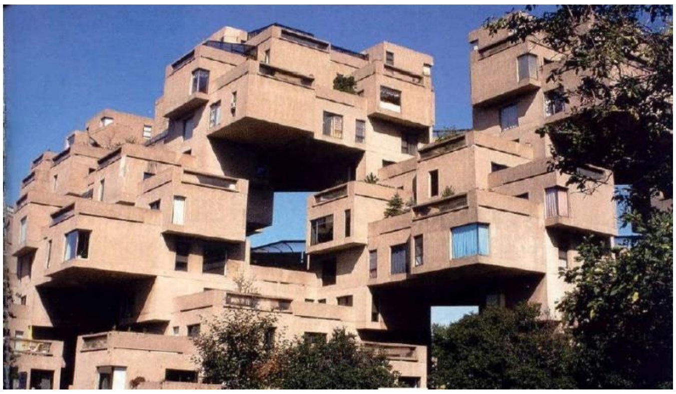

Fig.1: Montreal's Expo World' Fair (Un symmetrical Plan)

The effect of p-delta is mainly dependent on the applied load and building characteristics In addition to this it is also depends upon the height, stiffness and asymmetry of the building. The building asymmetry maybe unbalanced mass, stiffness, in plane. In the elastic or inelastic dynamic analyses, the effects of P-Delta sometimes increase the responses and sometimes decrease the responses. (Source : www.ijir.info | Volume 1 (Issue 2) | October – December, 2024)

The presence of setbacks in a building results in abrupt reductions of the floor area, which in turn results in change of mass and stiffness along the building height. This results in variation of dynamic characteristics of these buildings as compared with their regular counterparts. This aspect has been ignored by the seismic design codes in formulating the seismic design methodologies that are reflected in poor seismic performance of setback structures during past earthquakes (Spyropoulos, 1982; Penelis et al., 1989; Penelis and Kappos, 1997; Varadharajan et al. 2012a).

1. Overview of Seismic codes use in World

Seismic codes and standards serve as the bedrock of structural resilience in earthquake-prone regions, underpinning the safety and durability of buildings and infrastructure. By meticulously defining design parameters, construction methodologies, and testing protocols, these regulations act as a shield against the devastating impact of seismic events.

- **ACI 318:** Published by the American Concrete Institute (ACI), ACI 318 presents the Building Code Requirements for Structural Concrete, offering comprehensive guidelines for the design and construction of reinforced concrete buildings to withstand seismic forces.
- **ASCE 7:** The American Society of Civil Engineers (ASCE) publishes ASCE 7, which provides the standard Minimum Design Loads and Associated Criteria for Buildings and Other Structures. This standard includes provisions for seismic design, ensuring the resilience of concrete structures in earthquake-prone regions.
- **Eurocode 8:** Encompassed within the European standard EN 1998-1, Eurocode 8 furnishes guidelines for the seismic design of buildings across Europe. It addresses the design of new structures as well as the assessment and retrofitting of existing buildings to enhance seismic resilience.
- **NZS 1170:** The New Zealand standard for structural design actions, NZS 1170, incorporates provisions for seismic design, catering to the unique seismic challenges faced in the region and ensuring the structural integrity of concrete buildings.
- **IS 1893:** Published by the Bureau of Indian Standards (BIS), IS 1893 provides guidelines for seismic design in India, offering tailored recommendations to address the seismic risks prevalent in the subcontinent.
- **GB 50011:** The Chinese standard for seismic design of buildings, GB 50011, furnishes design principles and requirements aimed at enhancing the seismic resistance of reinforced concrete structures in China.

2. Major Seismic Hazard Zones

Pacific Ring of Fire: Revered as the most prolific seismic belt on Earth, the Pacific Ring of Fire spans the vast expanse from the western coast of North America, traversing South America, Japan, Southeast Asia, and Oceania. Characterized by intense tectonic activity along the Pacific Plate's boundaries, this zone is notorious for its frequent earthquakes and volcanic eruptions. Mediterranean and Middle East: The collision of the African and Eurasian plates engenders significant seismicity across the Mediterranean and Middle Eastern regions. From Turkey and Greece in the west to Iran and Pakistan in the east, this zone witnesses recurrent earthquakes, underscoring the geological intricacies shaping the landscape.

Himalayas: Nestled amidst the majestic peaks of the Himalayan range, this seismically active region bears witness to the relentless convergence of the Indian and Eurasian plates. Major earthquakes, such as the devastating 2015 event in Nepal, underscore the region's susceptibility to seismic hazards.

Alaska: Situated at the juncture of the Pacific and North American plates, Alaska emerges as a crucible of seismic activity within the United States. Subduction zones and transform faults delineate the state's geological fabric, fostering a landscape rife with seismic hazards.

IV. METHOD OF EARTHQUAKE ANALYSIS

1.Equivalent Static Analysis of Structure

The equivalent lateral force for an earthquake is a unique concept used in earthquake engineering. The concept is attractive because it converts a dynamic analysis into partly dynamic and partly static analyses for finding the maximum displacement (or stresses) induced in the structure due to earthquake excitation. For seismic resistant design of structures, only these maximum stresses are of interest , not the time history of stresses.

VB = m a
VB = (W/g) a
VB = W (a/g)
VB = W Ah
Ah = Basic horizontal seismic coefficient
VB = Base shear
W = Total weight of the structure
a = Acceleration induced at the base during earthquake
g = Acceleration due to gravity
This method is one of the simplest approaches for estimating seismic forces. It is widely used for structures with a regular, symmetric configuration and relatively limited height. For such structures, the contribution of the first mode is typically dominant, with the modal participating mass ratio of the first mode shape often exceeding 70-80%, making it acceptable to consider only the first mode shape of the structure.

II. DYNAMIC ANALYSIS

Response Spectrum Method

In response spectrum analysis, the eigen modes of the structure are combined with the corresponding accelerations from the response spectrum. By weighting the mode shapes with their effective modal masses and applying the accelerations, a structural state—including resulting deformations and internal forces—can be derived without the need to create equivalent loads. The results from the individual modes are then combined using standardized combination techniques, with the most common being the SRSS (Square Root of the Sum of the Squares) rule. Structures possess multiple degrees of freedom, leading to several mode shapes.

Time-History Analysis

This method involves applying time-dependent ground motion records (accelerograms) to a structural model to simulate its response over time. It provides detailed results, including displacements, accelerations, and internal forces at each time step. The analysis can be either linear or nonlinear, depending on the way the material behaviour and structural response are accounted for during the loading process. In the linear case, the structure is modelled assuming linear elastic behaviour, while in the nonlinear case, the analysis accounts for both material and geometric nonlinearities.

Seismic analysis methods range from simple static approaches to highly detailed dynamic simulations, each serving specific design needs and structural complexities

V. STATIC AND DYNAMIC ANALYSIS OF STEEL STRUCTURE

1. Model 1 for G+20 Story Steel Structure

In this project, a G+20 Story building was studied. The structure was modelled and analysed in Staad Pro 2024 Version. The seismic performance of the structure was carried out by linear static analysis.

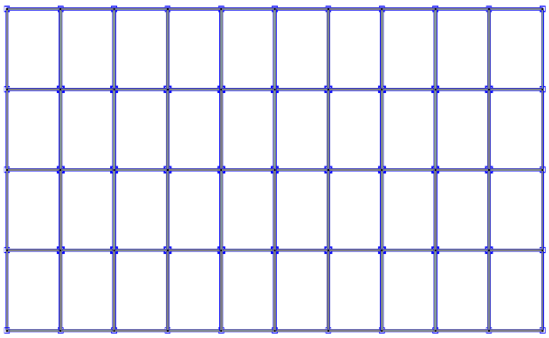

Fig 2. Plan of G+20 Steel Structure

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Table 1. Design Data of Steel Frame Structure

S. NO.	PARTICULARS	DIMENSION
1	Model	G+20
2	Floor Height	3 m
3	Plan Size	75 m x 45 m
4	Size of Column	
	1st Floor to 10th Floor inner Core	1000 x 1000 x 32
	1st Floor 4th Floor Periphery Column	750 x 750 x 25 mm
	4th Floor to 20th Floor	750 x 750 x 22 mm
5	Size of Beams in Z-Dir	Web - 1000 x 10 mm Flange - 400 x 20 mm
	Size of Beams in x-Dir	Web - 1000 x 8 mm Flange - 300 x 16 mm
6	Walls	225 mm thick
7	Thickness of Slab	0.190 m including floor Finish
8	Type of Soil	Medium Soil
9	Seismic Zone	IV
	Response Reduction Factor (R)	4
	Importance Factor (I)	1.2
	Damping	5 %
	ST	3
11	Material Used	Steel 345 Mpa

Table 2. Design Data of Load Application

S. NO.	LOADING	KN/M2
1	Dead Load on Each Floor	4.75
2	Dead Load on Roof including Floor Finish	6.75
3	Collateral Load False Ceiling	1
4	Floor Live Load	5
	Roof Live Load	3

2. Model 2 for G+2 Story Steel Structure

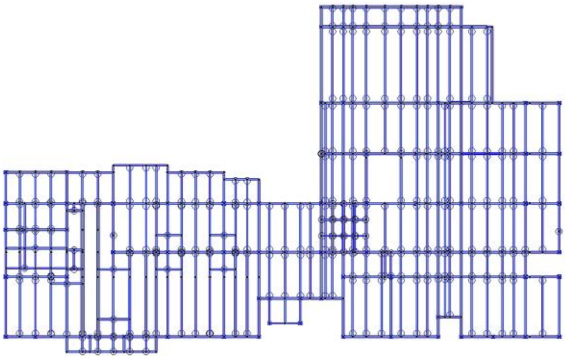

Fig 3. Plan of G+2 Steel Structure

Table 3. Design Data of Steel Frame Structure

S. NO.	PARTICULARS	DIMENSION
1	Model	G+2
2	Floor Height	5.18 m + 4.87 m + 4.66 m
3	Plan Size	59 m x 25 m
4	Size of Column	
	1st Floor to 2nd Floor inner Core	375 x 375 x 14 mm
	2nd Floor 3rd Floor Periphery Column	375 x 375 x 14 mm
5	Size of Beams in Z-Dir	Web - 550 x 6 mm Flange - 275 x 14 mm
	Size of Beams in x-Dir	Web - 400 x 5 mm Flange - 175 x 12 mm
6	Walls	225 mm thick
7	Thickness of Slab	0.150 m including floor Finish
8	Type of Soil	Medium Soil
9	Seismic Zone	IV
	Response Reduction Factor (R)	4
	Importance Factor (I)	1.0
	Damping	5 %
	ST	3
11	Material Used	Steel 345 Mpa

Table 4. Design Data of Load Application

S. NO.	LOADING	KN/M2
1	Dead Load on Each Floor	4.2
2	Dead Load on Roof including Floor Finish	4.2
3	Collateral Load False Ceiling	1.12
4	Floor Live Load	4.5
	Roof Live Load	4.5

3. Model 3 Warehouse Steel Structure

In this project, a warehouse building was studied. The structure was modelled and analysed in Staad Pro 2024 Version. The seismic performance of the structure was carried out by linear static analysis.

A Steel framed structure is basically an assembly of slabs, beams, columns and foundation inter connected to each other as a unit. The load transfer mechanism in these structures is from slabs to beams, from beams to columns, and then ultimately room columns to the foundation, which in turn passes the load to the soil. In this structural analysis study, The building is 168.5 m x 101.44 m in plan.

Clear height 14.15 m is assumed.

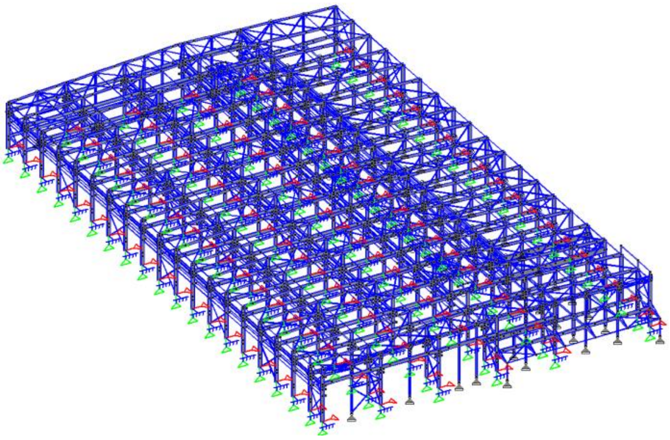

Fig 4. 3D View of warehouse structure

S. NO.	PARTICULARS	DIMENSION
1	Model	Warehouse
2	Floor Height	2.9 m + 10.9 m + 14.16 m (Clear ht.)
3	Plan Size	168.5 m x 101.4 m c/c
4	Size of Column	Web – 1000x8 Flange – 375 x20 mm
	Intermediate Column	Web – 850x10 Flange – 395 x28 mm
	End wall Column	Web – 750x8 Flange – 275x20
5	Size of Beams in X-Dir	Web - 1000 x 12 mm Flange - 395 x 20 mm Web - 1000 x 12 mm Flange - 275 x 32 mm
	Size of Beams in Z-Dir	Web - 500 x 5 mm Flange - 150 x 10 mm
6	Walls	225 mm thick
7	Thickness of Slab	0.150 m including floor Finish
8	Type of Soil	Medium Soil
9	Seismic Zone	IV
	Response Reduction Factor (R)	4
	Importance Factor (I)	1.0
	Damping	5 %
	ST	3
11	Material Used	Steel 345 Mpa

Table 5. Design Data of Steel Frame Structure

S. NO.	LOADING	KN/M2
1	Dead Load on Each Floor	3.75
2	Dead Load due to Floor Finish	0.18
3	Collateral Load False Ceiling	1.12
4	Floor Live Load on Paint shop area	4
	Floor live load on 6.4 m Level	10

VI. RESULT AND DISCUSSION

This chapter includes the analysis and result for the Static and Dynamic analysis by staad model output. This chapter is divided in 3 section , section one deals with G+2 Story unsymmetrical mezzanine structure, section 2 deals with Warehouse structure and section three deals wit G+20 story high rise structure.

1.Result Analysis of G+2 Unsymmetrical Mezzanine Structure

Table 6. Difference in Story Displacement

Story	Elevation	EQX	RSX	%
Base	0	0	0	
1	5.18	8.411	1.442	**82.855784**
2	10.05	16.944	4.166	**75.413126**
3	14.71	21.64	7.326	**66.146026**

Table 7. Difference in Story Shear (KN)

Story	Elevation	EQX	RSX	%
1	3	30.196	36.378	**20.4**
2	6	23.664	25.458	**7.58**
3	9	15.623	14.072	**9.92**

Table 8. Difference in Story Moment

Story	Elevation	EQX	RSX	%
1	3	99.054	117.784	**18.91**
2	6	53.34	55.235	**3.55**
3	9	27.366	23.267	**14.98**

2.Result Analysis of G+20 Mezzanine Structure

Table 9. Difference in Story Displacement (mm)

Story	Elevation	EQX	RSX	%

Base	0	0	0	
1	3	1.481	1.442	**2.6333558**
2	6	4.322	4.166	**3.6094401**
3	9	7.687	7.326	**4.6962404**
4	12	11.275	10.605	**5.9423503**
5	15	14.971	13.864	**7.3942956**
6	18	18.701	17.046	**8.8497941**
7	21	22.437	20.136	**10.255382**
8	24	26.217	23.171	**11.618416**
9	27	30.091	26.186	**12.977302**
10	30	33.991	29.127	**14.30967**
11	33	37.885	31.942	**15.686947**
12	36	41.698	34.617	**16.98163**
13	39	45.388	37.147	**18.156782**
14	42	48.929	39.525	**19.219686**
15	45	52.295	41.745	**20.174013**
16	48	55.458	43.799	**21.023117**
17	51	58.388	45.678	**21.768172**
18	54	61.054	47.371	**22.411308**
19	57	63.422	48.865	**22.952603**
20	60	65.458	50.143	**23.396682**
21	63	67.127	51.189	**23.743054**
22	66	68.402	51.993	**23.989065**
23	69	69.358	52.609	**24.14862**

Table 10. Difference in Story Moment (KN-M)

Story	**Elevation**	**EQX**	**RSX**	**%**
1	3	488.575	534.727	**-9.4462467**
2	6	311.863	322.41	**-3.3819337**
3	9	252.432	249.892	**1.0062116**
4	12	228.303	217.422	**4.7660346**
5	15	217.646	198.237	**8.917692**
6	18	205.386	185.32	**9.7698967**
7	21	196.754	175.545	**10.77945**
8	24	198.996	176.892	**11.107761**
9	27	210.365	184.219	**12.428874**
10	30	197.008	172.896	**12.239097**
11	33	192.709	158.144	**17.93637**
12	36	174.9	147.433	**15.704403**
13	39	160.57	137.934	**14.097278**
14	42	146.773	129.032	**12.087373**
15	45	131.62	120.371	**8.5465735**
16	48	114.787	110.967	**3.327903**
17	51	96.151	100.218	**-4.2298052**
18	54	75.584	88.335	**-16.869972**
19	57	52.942	75.274	**-42.182011**
20	60	28.064	59.94	**-113.58324**
21	63	0.771	42.574	**-5421.9196**
22	66	28.01	33.172	**-18.429132**
23	69	45.873	37.453	**18.355024**

3.Result Analysis Warehouse Structure

Table 10. Difference in Story Displacement in mm

Elevation	**EQX**	**RSX**	**%**
1	0	0	
7	7.453	6.39	**14.262713**
25	1.382	1.241	**10.202605**
51	0.848	0.765	**9.7877358**
57	4.562	4.001	**12.297238**
73	6.146	5.357	**12.837618**
78	6.747	5.865	**13.072477**
83	7.065	6.129	**13.248408**
104	7.391	6.357	**13.989988**

Table 11. Difference in Story Shear in kn

Beam No.	EQX	RSX	%
1	42.478	39.759	**6.4**
22	50.938	44.251	**13.1**
48	42.478	39.759	**6.4**
64	50.449	43.636	**13.5**
80	50.449	43.636	**13.5**
85	50.449	43.636	**13.5**
90	35.058	34.118	**2.7**
115	35.058	34.118	**2.7**

Table 12. Difference in Story Moment in kn-m

Story	Elevation	EQX	RSX	%
1	3	204.892	184.743	**9.8**
2	6	168.953	143.878	**14.8**
3	9	88.077	75.432	**14.4**
4	12	34.799	33.128	**4.8**
5	15	135.696	120.4	**11.3**
6	18	186.145	164.036	**11.9**
7	21	103.719	98.769	**4.8**
8	24	33.604	30.536	**9.1**

VI. CONCLUSION

1. Displacement in static analysis is on higher side as compared to dynamic analysis.
2. Moment in dynamic analysis is higher side on bottom floor level but it is less as compared to static analysis at peak story.
3. Shear force value in static analysis is higher than dynamic analysis but at some story level dynamic shear force is higher side.
4. Axial force in dynamic analysis is high as compared to dynamic analysis at bottom level but it decreases going up ward.
5. As per our observation dynamic analysis is economical as compared to static analysis.

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