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CAPACITY BASED DESIGN STUDY OF SEISMIC COEFFICIENT ANALYSIS & RESPONSE SPECTRUM ANALYSIS OF A MULTISTORIED BUILDING

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Abstract : Analysis and design of buildings for static forces is a routine affair these days because of availability of affordable computers and specialized programs which can be used for the analysis. On the other hand, dynamic analysis is a time consuming process and requires additional input related to mass of the structure, and an understanding of structural dynamics for interpretation of analytical results. Reinforced Concrete (RC) frame buildings are most common type of constructions in urban India, which are subjected to several types of forces during their lifetime, such as static forces due to dead and live loads and dynamic forces due to earthquake. Here the present study describes the effect of earthquake load which is one of the most important dynamic loads along with its consideration during the analysis of the structure. In the present study a multi-storied framed structure of (G+9) pattern is selected. Linear seismic analysis is done for the building by static method (Seismic Coefficient Method) and dynamic method (Response Spectrum Method) using STAAD-Pro as per the IS-1893-2002-Part-1. A comparison is done between the static and dynamic analysis, the results such as Bending moment, Nodal Displacements, Mode shapes are observed, compared and summarized for Beams, Columns and Structure as a whole during both the analysis.

Keyword: RCC Buildings, Equivalent Static Analysis, Response Spectrum, Displacement

I. INTRODUCTION

Structural analysis is mainly concerned with finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to weight of things such as people , furniture , wind snow etc .or some other kind of excitation such as earthquake , shaking of the ground due to a blast nearby ,etc. In essence all these loads are dynamic including the self- weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. If a load is applied sufficiently slowly, the inertia forces (Newton's second law of motion) can be ignored and the analysis can be simplified as static analysis. Structural dynamics, therefore, is a type of structural analysis which covers the behavior of structures subjected to dynamic (actions having high acceleration) loading. Dynamic loads include people, wind, waves, traffic, earthquake, and blasts. Any structure can be subjected to dynamic loading. Dynamic analysis can be used to find dynamic displacements, time history, and modal analysis.

In the present study, Response spectrum analysis is performed to compare results with Static analysis.

The criteria of level adopted by codes for fixing the level of design seismic loading are generally as follows:

Structures should be able to resist minor earthquakes (<DBE), without damage.

Structures should be able to resist moderate earthquakes (DBE) without significant structural damage but with some non-structural damage.

Structures should be able to resist major earthquakes (MCE) without collapse.

"Design Basis Earthquake (DBE)" is defined as the maximum earthquake that reasonable can be expected to experience at the site once during lifetime of the structure. The earthquake corresponding to the ultimate safety requirements are often called as "Maximum Considered Earthquake (MCE) ".generally," The (DBE) is half of (MCE)".

During an earthquake , Ground motion occur in a random fashion both horizontally and vertically , in all directions radiating from the epi-centre .The ground accelerations cause structures to vibrate and induce inertial forces on them. Hence structures in such locations need to be suitably designed and detailed to ensure stability, strength and serviceability with acceptable levels of safety under seismic effects.

The magnitude of the forces induced in a structure to a given ground acceleration of earthquake will depend amongst other things on the mass of the structure, the material , and type of construction , the damping, ductility and energy dissipation capacity of structure . By enhancing ductility, and energy dissipation capacity in the structure obtained or alternatively, the probability of collapse reduced.

1.1. Dynamic analysis methods

It is performed to obtain the design seismic forces and its distribution to different level along the height of the building and to various lateral load resisting elements for the regular buildings and irregular buildings also as defined in (is-1893 part-1-2000) in clause 7.8.1

1.1.1. Regular Building

1.1.2. Irregular Building

All framed building higher than 12m in Zone 4 and Zone 5 Those greater than 40m in Zone 2 and Zone 3

Civil engineering structures are mainly designed to resist static loads. Generally the effect of dynamic loads acting on the structure is not considered. This feature of neglecting the dynamic forces sometimes becomes the cause of disaster, particularly in case of earthquake. In case of earthquake forces the demand is for ductility. Ductility is an essential attribute of a structure that must respond to strong ground motions. Larger is the capacity of the structure to deform plasticity without collapse, more is the resulting ductility and the energy dissipation. This causes reduction in effective earthquake forces.

2. METHODS OF ANALYSIS

2.1. Code-based Procedure for Seismic Analysis

Main features of seismic method of analysis based on Indian standard 1893(Part 1):2002 are described as follows

- Equivalent static lateral force method
- Response spectrum method
- Square roots of sum of squares (SRSS method)
- Complete Quadratic combination method (CQC)
- Elastic time history methods

2.2. By IS code method for dynamic analysis

2.3. By STAAD PRO software Method-for static and dynamic analysis both

2.3.1. Equivalent *Static Analysis*

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low-to medium-rise buildings. It begins with an estimation of base shear load and its distribution on each story calculated by using formulas given in the code. Equivalent static analysis can therefore work well for low to medium-rise buildings without significant coupled lateral- torsional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances**.**

2.3.2. *Response Spectrum Method*

The representation of the maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. The maximum response plotted against of un-damped natural period and for various damping values and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement. For this purpose response spectrum case of analysis have been performed according to IS 1893.

3. MODELLING AND ANALYSIS

For the analysis of multi storied building following dimensions are considered which are elaborated below.

In the current study main goal is to compare the Static and Dynamics Analysis (Rectangular) building.

3.1. Static and Dynamic Parameters

Design Parameters: Here the Analysis is being done for G+9 (rigid joint regular frame) building by computer software using STAAD-Pro.

Design Characteristics: The following design characteristic are considered for **multistory rigid jointed plane frames**

Table 3.1 Detail of model

Sr. No	Particulars	Dimension/Size/Value
1	Model	G+9

Design Data of RCC Frame Structure

1	Seismic Zone	IV
2	Floor height	3 m
3	Plan size	22.98 x 15.67 m
4	Size of columns	0.9 x 0.9 m
5	Size of beams	0.5 x 0.7 m
6	Walls	1) External Wall =0.23 m 2) Internal Wall =0.115 m
7	Thickness of slab	150 mm
8	Type of soil	Type-II, Medium soil as per IS-1893
9	Material used	Concrete M-30 and Reinforcement Fe-415
10	Static analysis	Equivalent Lateral force method
11	Dynamic analysis	Response spectrum method
12	Earthquake load	as per IS-1893-2002
13	Specific weight of RCC	25 KN/m²
14	Specific weight of infill	20 KN/m²
15	Software used	STAAD-Pro for both static and dynamic analysis

Table – 2

Zone Categories

Seismic Zone	II	III	IV	V
Seismic intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

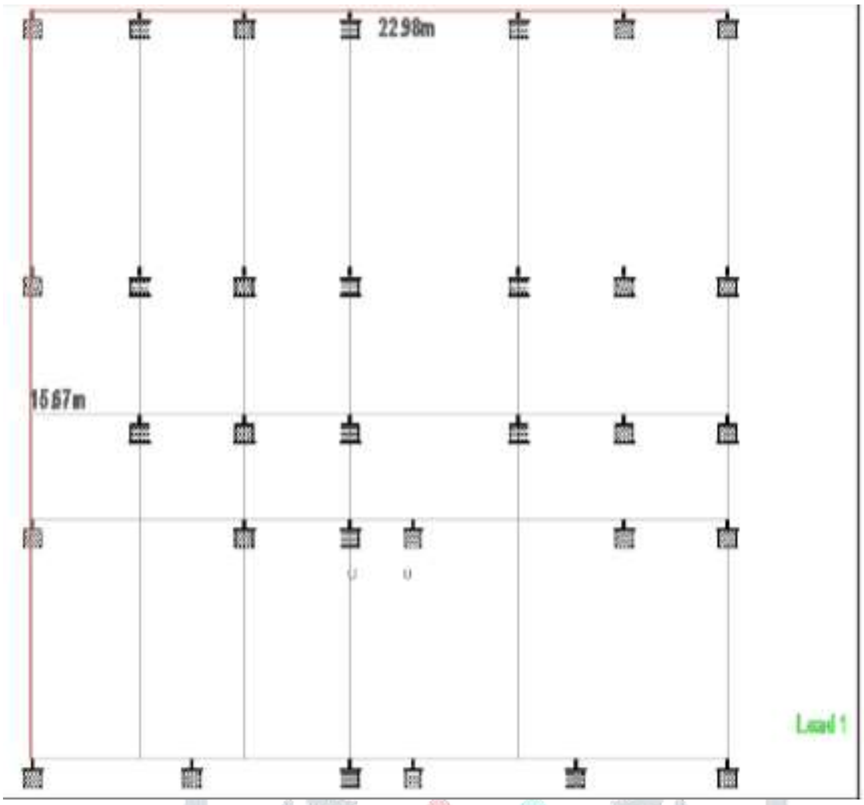

Figure 3.1(a) Plan of Regular Building

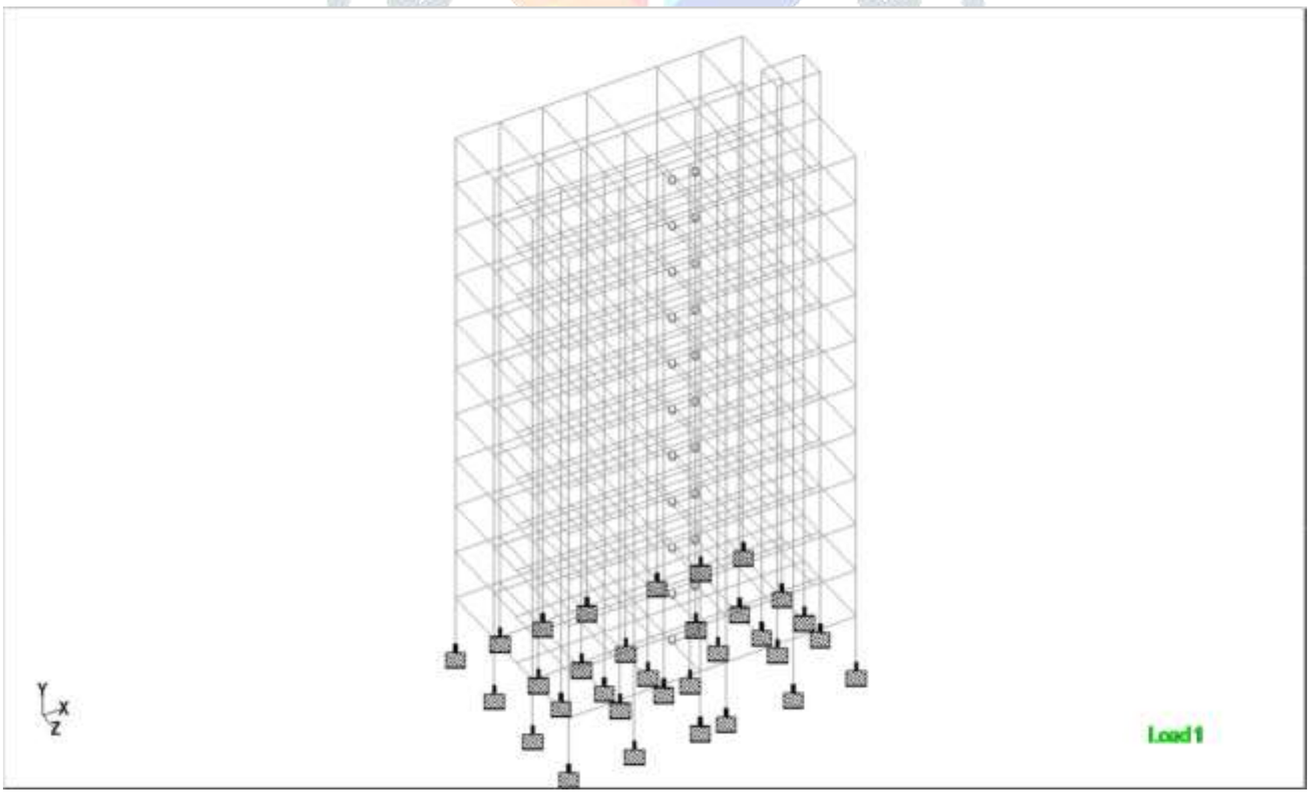

Figure 3.1(b) Model of Regular Building

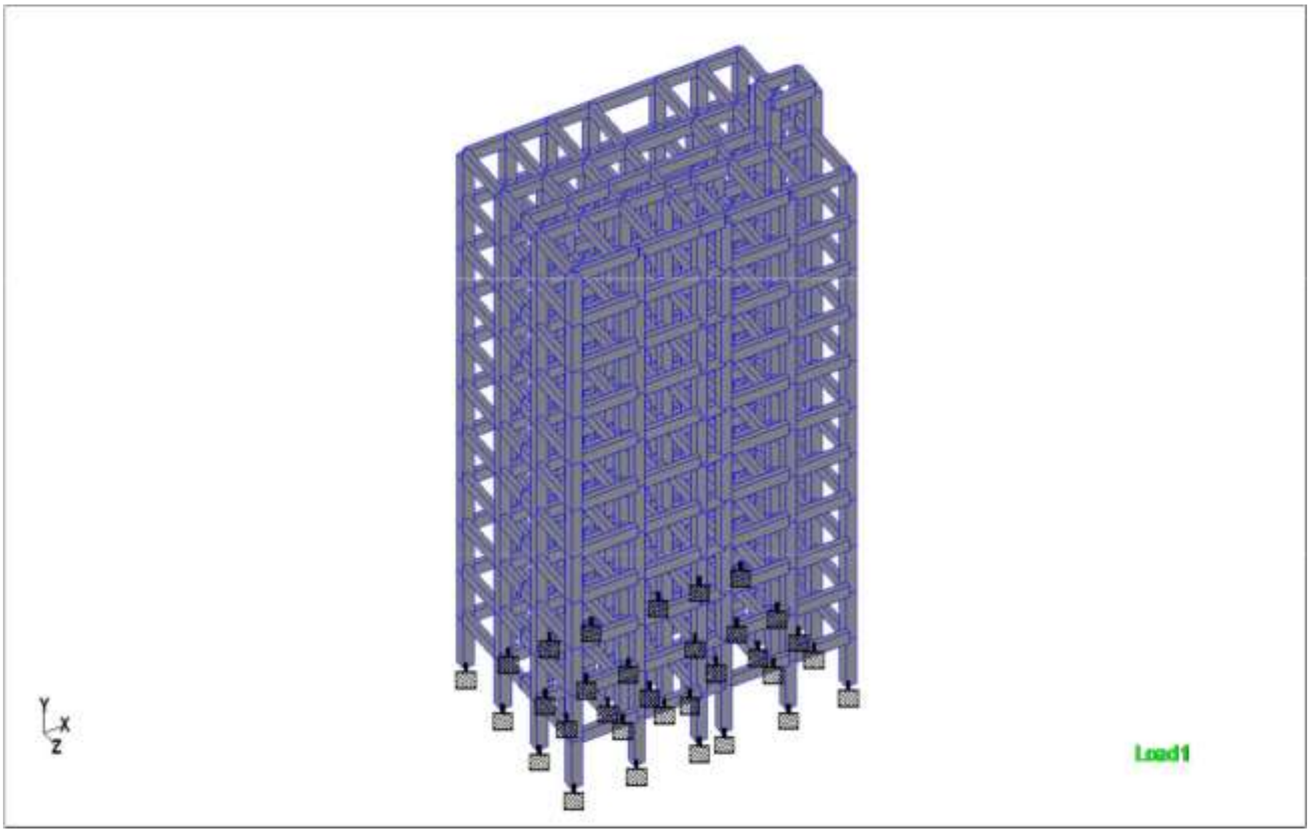

Figure 3.1(c) 3-D Model of Regular Building(with sections)

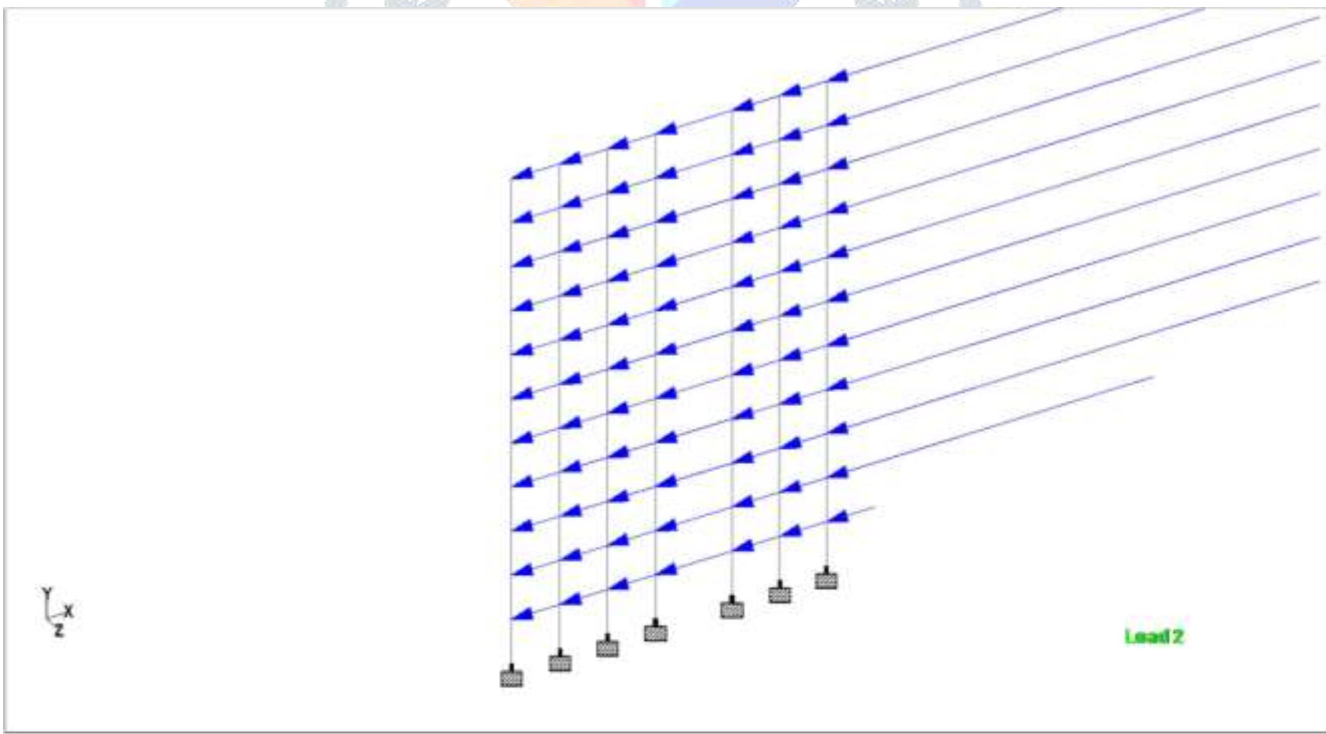

Figure 3.1(d) Earthquake Loading (Dynamic Loading)

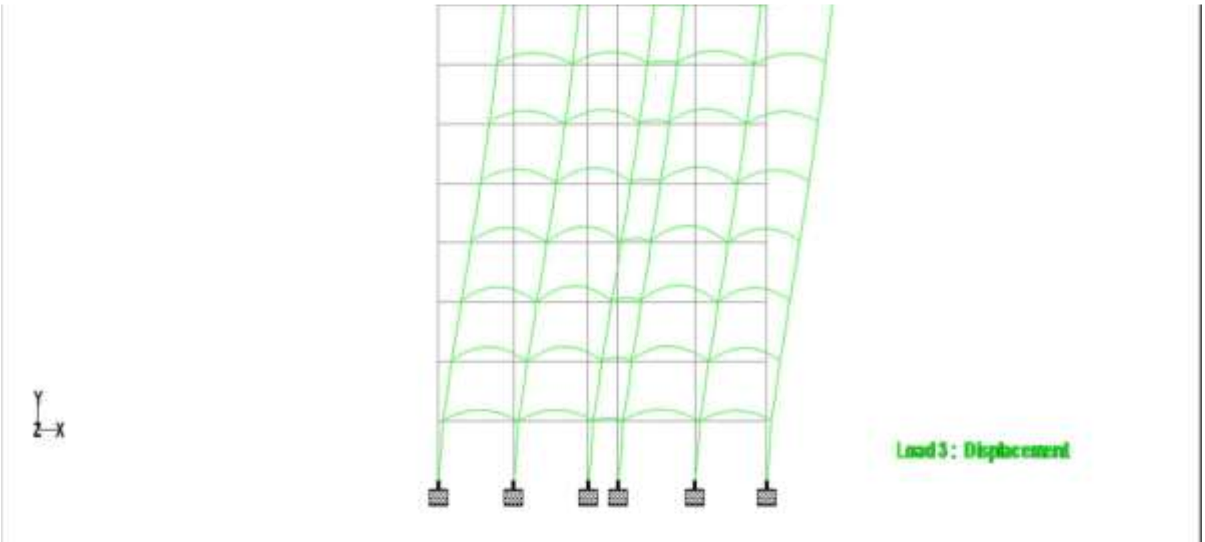

Figure 3.1(e) Response Spectrum Loading (Dynamic Loading)

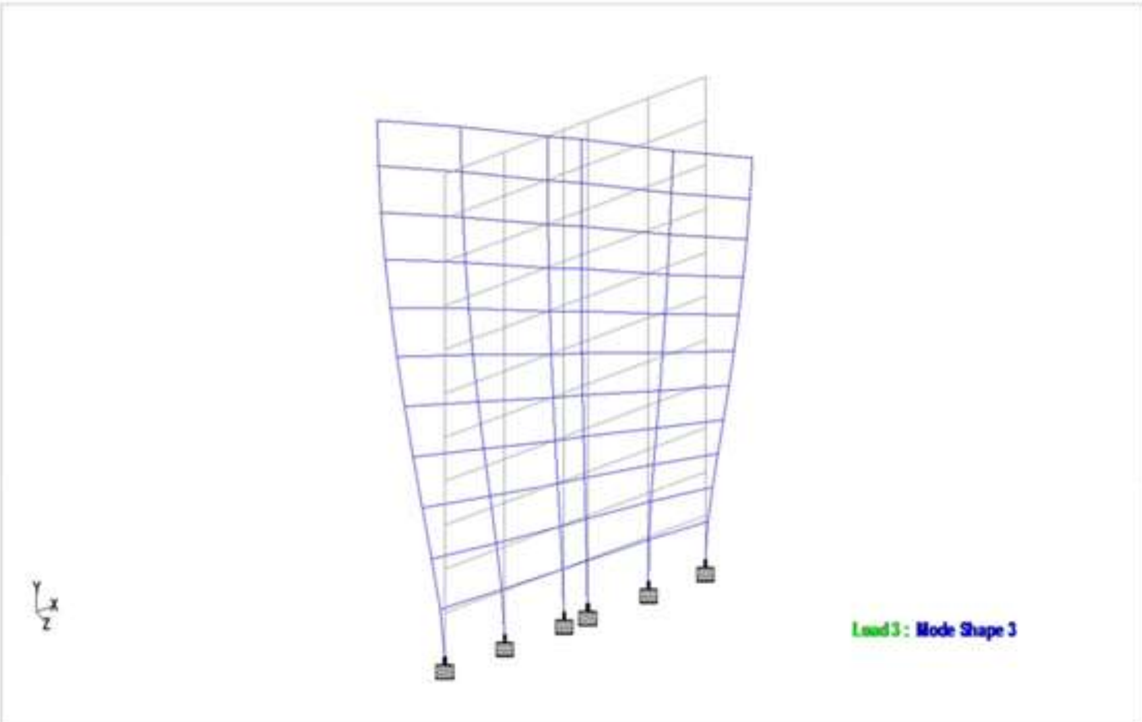

Figure 3.1(f) Response Spectrum Loading (Mode Shape)

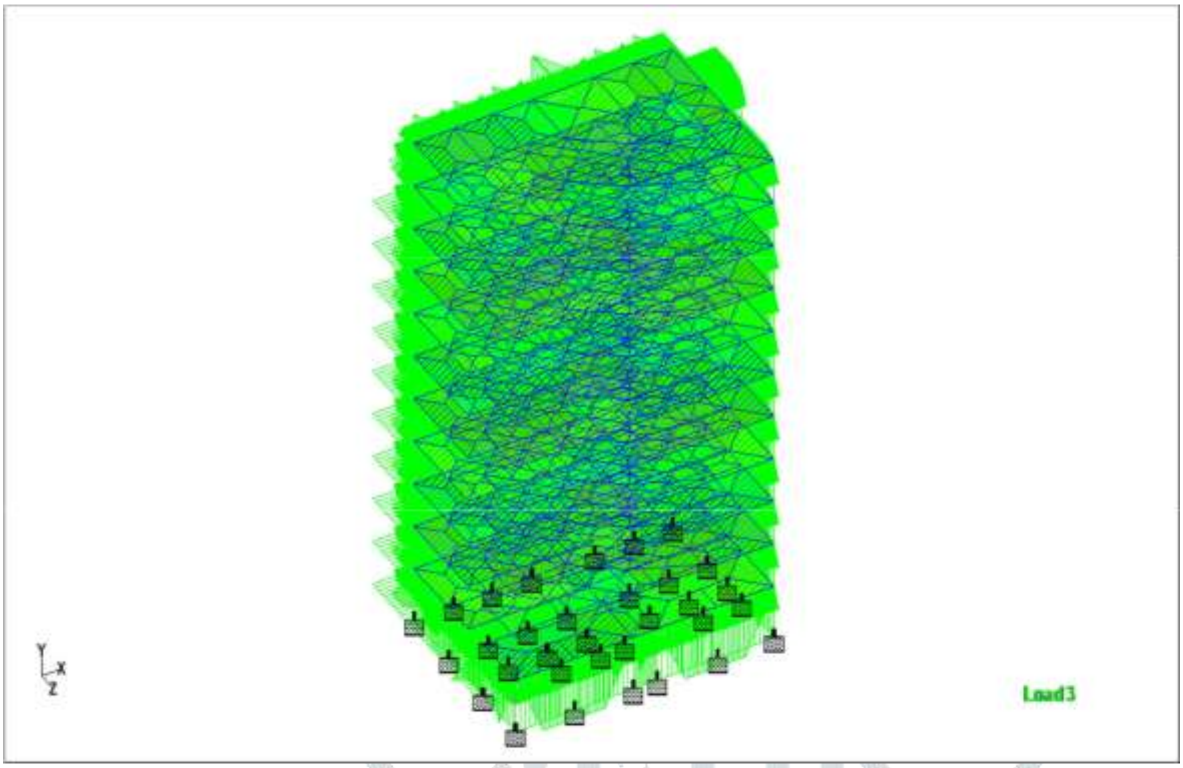

Figure 3.1(g) Deflection diagram (Dynamic Loading)

4. RESULTS AND DISCUSSIONS

The above RCC frame structure is analyzed both statically and dynamically and the results are compared for the following three categories namely Beam Stresses, Axial Forces, Torsion, Displacements and Moment at different nodes and beams and the results are tabulated as a shown below.

4.1. Comparison of Moment for Vertical Members

Table 4.1 Comparison of Bending Moment

COLUMN NUMBER	*L/C*	*STATIC ANALYSIS (KN-M)*	*L/C*	*DYNAMIC ANALYSIS (KN-M)*
949	*9*	*204.49*	*10*	*313.6*
917	*9*	*292.37*	*10*	*433.17*
885	*9*	*371.82*	*10*	*574.08*
853	*9*	*426.2*	*10*	*691.36*
821	*9*	*462.21*	*10*	*787.2*
789	*9*	*484.15*	*10*	*862.07*

4.2. Comparison of Axial Forces for Vertical Members

Table 4.2. Comparison of Axial Forces

COLUMN NUMBER	*L/C*	*STATIC ANALYSIS (KN)*	*L/C*	*DYNAMIC ANLYSIS (KN)*
9947	*9*	*119.9*	*10*	*127.3*
915	*9*	*295.5*	*10*	*305.5*
883	*9*	*468.8*	*10*	*479.7*
851	*9*	*639.1*	*10*	*649.6*
819	*9*	*806.7*	*10*	*815.03*
787	*9*	*971.647*	*10*	*976.007*

4.3. Comparison of Torsion for Vertical Members

Table 4.3 Comparison of Torsion

COLUMN NUMBER	*L/C*	*STATIC ANALYSIS (KN-m)*	*L/C*	*DYNAMIC ANLYSIS (KN-m)*
946	*EQ+X*	*-6.036*	*RE*	*17.347*
914	*EQ+X*	*-7.936*	*RE*	*30.23*
882	*EQ+X*	*-8.47*	*RE*	*35.247*
850	*EQ+X*	*-8.642*	*RE*	*54.816*
818	*EQ+X*	*-8.65*	*RE*	*65.58*
786	*EQ+X*	*-8.48*	*RE*	*74.72*

EQ+X = Earthquake Loading in X-Direction(+). RE= Response Spectrum Loading.

4.4. Comparison of Displacements for Vertical Member

Table 4.4 Comparison of Displacements

COLUMN NUMBER	*L/C*	*STATIC ANALYSIS (mm)*	*L/C*	*DYNAMIC ANALYSIS (mm)*
949	*9*	*41.56*	*10*	*70.892*
917	*9*	*39.715*	*10*	*68.33*
885	*9*	*37.138*	*10*	*64.62*
853	*9*	*33.848*	*10*	*59.72*
821	*9*	*29.959*	*10*	*53.67*
789	*9*	*25.617*	*10*	*46.6*

4.5. Comparison of Nodal-Displacements in Z-Direction

Table 4.5 Comparison of Nodal-Displacements

NODE NUMBER	*L/C*	*STATIC ANALYSIS (mm)*	*L/C*	*DYNAMIC ANALYSIS (mm)*
430	*9*	*44.7*	*10*	*80.6*
391	*9*	*42.7*	*10*	*77.8*
352	*9*	*39.8*	*10*	*73.6*
313	*9*	*36.1*	*10*	*68.07*
274	*9*	*31.8*	*10*	*61.2*
235	*9*	*27.1*	*10*	*53.1*
196	*9*	*22.2*	*10*	*44.1*
157	*9*	*17.06*	*10*	*34.4*
118	*9*	*11.8*	*10*	*24.2*
79	*9*	*6.9*	*10*	*14.1*

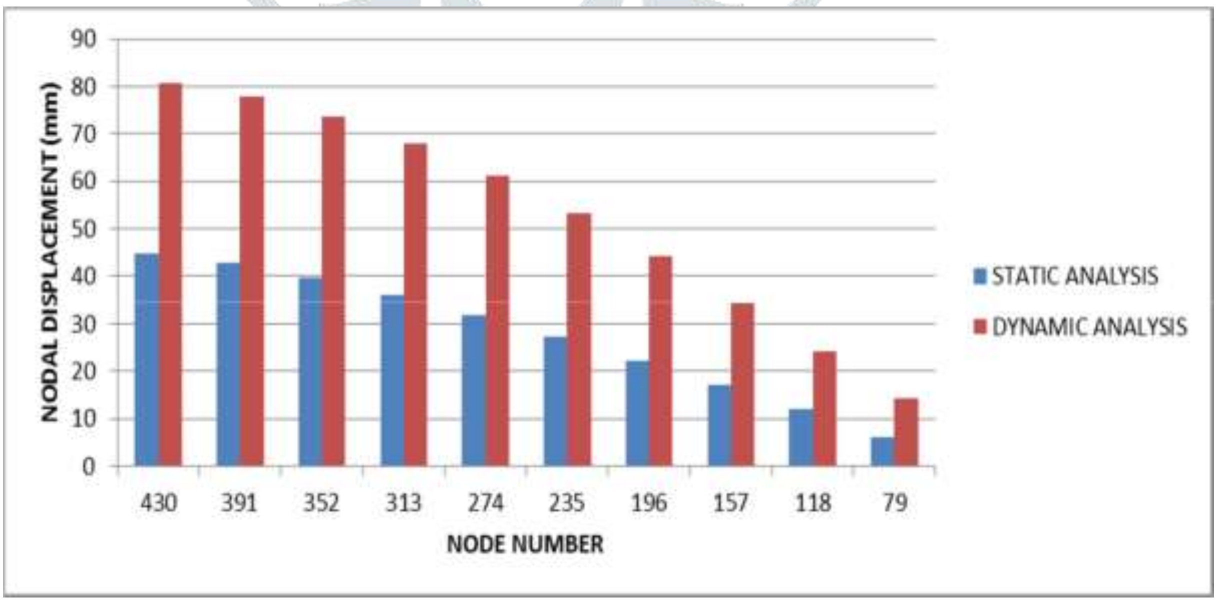

Fig. 4.5: Nodal-Displacements in Z-Direction

4.6. Comparison of Beam Stresses in Static Analysis

Table 4.6. Comparison of Beam Stresses in Static Analysis

		STATIC ANALYSIS	
BEAM	L/C	MAX COMPRESSIVE STRESS (N/mm^2)	MAX TENSILE STRESS (N/mm^2)
604	9	6.49	-5.82
548	9	9.1	-9.09
492	9	10.82	-10.84
436	9	12.24	-12.25
380	9	13.27	-13.29
324	9	13.93	-13.95

4.7. *Comparison of Beam Stresses in Dynamic AnalysisTable*

Table 4.7. Comparison of Beam Stresses In Dynamic Analysis

		DYNAMIC ANALYSIS	
BEAM	L/C	MAX COMPRESSIVE STRESS (N/mm^2)	MAX TENSILE STRESS (N/mm^2)
604	10	10.95	-10.44
548	10	13.67	-13.6
492	10	16.01	-15.98
436	10	18.27	-18.24
380	10	20.23	-20.2
324	10	21.78	-21.76

4.8. *Nodal Displacements in 5-A-C Frame*

Table 4.8. Nodal Displacements In 5-A-C Frame

Node	L/C	X-Trans (mm)	Y-Trans (mm)	Z-Trans (mm)	RESULTANT (mm)
36	SEISMIC LOADS	-1.558	0.176	0.107	1.571
	DEAD LOAD	-0.002	-0.192	0.039	0.196
	STATIC+SEISMIC	-2.34	-0.025	0.219	2.35
107	SEISMIC LOADS	-4.576	0.335	0.322	4.599
	DEAD LOAD	-0.024	-0.367	0.111	0.384
	STATIC+SEISMIC	-6.899	-0.047	0.65	6.93
146	SEISMIC LOADS	-8.056	0.474	0.587	8.091
	DEAD LOAD	-0.048	-0.523	0.204	0.564
	STATIC+SEISMIC	-12.156	-0.074	1.185	12.214
185	SEISMIC LOADS	-11.664	0.591	0.879	11.712
	DEAD LOAD	-0.077	-0.662	0.307	0.734
	STATIC+SEISMIC	-17.612	-0.108	1.779	17.702
224	SEISMIC LOADS	-15.249	0.686	1.188	15.31
	DEAD LOAD	-0.11	-0.783	0.417	0.894
	STATIC+SEISMIC	-23.038	-0.147	2.407	23.164
263	SEISMIC LOADS	-18.7	0.759	1.502	18.776
	DEAD LOAD	-0.146	-0.886	0.533	1.044
	STATIC+SEISMIC	-28.269	-0.19	3.052	28.434
302	SEISMIC LOADS	-21.914	0.814	1.812	22.003
	DEAD LOAD	-0.183	-0.971	0.652	1.184
	STATIC+SEISMIC	-33.146	-0.235	3.696	33.352

341	SEISMIC LOADS	-24.782	0.851	2.108	24.886
	DEAD LOAD	-0.221	-1.037	0.775	1.313
	STATIC+SEISMIC	-37.504	-0.279	4.325	37.753
380	SEISMIC LOADS	-27.195	0.873	2.382	27.313
	DEAD LOAD	-0.256	-1.084	0.898	1.431
	STATIC+SEISMIC	-41.176	-0.317	4.92	41.47
419	SEISMIC LOADS	-29.058	0.884	2.627	29.19
	DEAD LOAD	-0.292	-1.114	1.016	1.535
	STATIC+SEISMIC	-44.024	-0.344	5.464	44.364
458	SEISMIC LOADS	-30.373	0.888	2.843	30.519
	DEAD LOAD	-0.352	-1.124	1.114	1.621
	STATIC+SEISMIC	-46.088	-0.353	5.936	46.47

4.9. ***Column End Forces of 5-A-C frames***

COLUMN	L/C	Node	Shear-Y (KN)	Shear-Z (KN)	Moment-Y (KN-m)	Moment-Z (K-Nm)
C907	SEISMIC LOADS	374	-72.563	-0.272	3.154	-170.257
		335	72.563	0.272	-2.337	-47.431
	DEAD LAOD	374	-21.665	24.186	-36.129	-32.838
		335	21.665	-24.186	-36.429	-32.158
	STATIC+SEISMIC	374	-141.342	35.871	-49.463	-304.643
		335	141.342	-35.871	-58.149	-119.383
C911	SEISMIC LOADS	382	-154.739	0.03	1.804	-288.402
		343	154.739	-0.03	-1.893	-175.814
	DEAD LAOD	382	-4.579	0.546	-3.282	-7.242
		343	4.579	-0.546	1.645	-6.495
	STATIC+SEISMIC	382	-238.977	0.863	-2.218	-443.466
		343	238.977	-0.863	-0.372	-273.464
C939	SEISMIC LOADS	413	-51.635	1.662	-0.785	-148.44
		374	51.635	-1.662	-4.2	-6.467
	DEAD LAOD	413	-22.525	25.759	-40.699	-36.058
		374	22.525	-25.759	-36.577	-31.516

	STATIC+SEISMIC	413	-111.24	41.131	-62.227	-276.746
		374	111.24	-41.131	-61.165	-56.974
C943	SEISMIC LOADS	421	-114.611	0.121	1.165	-234.016
		382	114.611	-0.121	-1.529	-109.816
	DEAD LAOD	421	-4.781	0.371	-3.573	-8.662
		382	4.781	-0.371	2.461	-5.682
	STATIC+SEISMIC	421	-179.088	0.738	-3.611	-364.017
		382	179.088	-0.738	1.397	-173.247

C971	SEISMIC LOADS	452	-13.411	1.956	-3.014	-70.852
		413	13.411	-1.956	-2.853	30.618
	DEAD LAOD	452	-21.983	26.049	-46.996	-39.129
		413	21.983	-26.049	-31.151	-26.819
	STATIC+SEISMIC	452	-53.091	42.007	-75.015	-164.971
		413	53.091	-42.007	-51.005	5.699
C975	SEISMIC LOADS	460	-79.254	0.171	0.341	-184.53
		421	79.254	-0.171	-0.855	-53.233
	DEAD LAOD	460	-2.985	-0.088	-2.374	-6.911
		421	2.985	0.088	2.639	-2.045
	STATIC+SEISMIC	460	-123.359	0.125	-3.051	-287.16
		421	123.359	-0.125	2.676	-82.918

4.10. *Beam End Forces of 5-A-C Frame*

4.10 Beam End Forces of 5-A C Frame

Beam	L/C	Node	Shear-Y (KN)	Shear-Z (KN)	Moment-Y (K-Nm)	Moment-Z (K-Nm)
B540	SEISMIC LOADS	374	66.297	-2.684	13.944	178.009
		382	-66.297	2.684	0.185	171.046
	DEAD LAOD	374	58.909	-0.009	0.091	64.584
		382	64.356	0.009	-0.046	-46.395
	STATIC+SEISMIC	374	187.81	-4.038	21.053	363.889
		382	-2.911	4.038	0.208	186.975
B596	SEISMIC LOADS	413	44.635	-3.524	17.675	119.659
		421	-44.635	3.524	0.877	115.344
	DEAD LAOD	413	58.438	0.266	-0.661	63.227
		421	64.827	-0.266	-0.737	-47.52
	STATIC+SEISMIC	413	154.61	-4.887	25.521	274.33

		421	30.289	4.887	0.209	101.736
B652	SEISMIC LOADS	452	25.778	-4.599	21.65	72.241
		460	-25.778	4.599	2.562	63.483
	DEAD LAOD	452	33.511	0.478	-1.334	38.493
		460	42.528	-0.478	-1.181	-29.704
	STATIC+SEISMIC	452	88.933	-6.182	30.475	166.1
		460	25.124	6.182	2.071	50.668

CONCLUSION

The results as obtained using STAAD PRO 2008 for the Static and Dynamic Analysis are compared for different categories

- As per the results in Table No 3,We can see that the values for Moments are 35 to 45 % higher for Dynamic analysis than the values obtained for Static analysis .
- As per the results in Table No 4, We can see that there is not much difference in the values of Axial Forces as obtained by Static and Dynamic Analysis of the RCC Structure.
- As per the results in Table No 5,We can see that the values of Torsion of columns are negative for Static analysis and for Dynamic analysis the values of torsion are positive.
- As per the results in Table No 6, We can see that the values for Displacements of columns are 40 to 45% higher for Dynamic analysis than the values obtained for Static analysis.
- As per the results in Table No 7, We can see that the values of Nodal Displacements in Z direction are 50% higher for Dynamic analysis than the values obtained for Static analysis .
- As per the results in Table No 8 and 9, Compressive and tensile stresses in the studied beams were approximately equal.
- Nodal Displacements and Bending moments in beams and columns due to seismic excitation showed much larger values compared to that due to static loads.

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