Comparitive Study of Static and Seismic Analysis by Response Spectrum Method

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Abstract- *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 wind and earthquake. 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. 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 (P+5) 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.*

Keywords- Equivalent Static Analysis, Response Spectrum Analysis, Displacement. STAAD Pro.

I. INTRODUCTION

Earthquakes, caused by movements on the earth surface, result in different levels of ground shaking leading to damage and collapse of buildings and civil infra-structures, landslides in the case of loose slopes, and liquefaction of sandy soil. Thebehavior of reinforced concrete moment resisting frame structures in recent earthquakes all over the world has highlighted the consequences of poor performance of beam column joints. Beam column joints in a reinforced concrete moment resisting frame are crucial zones for transfer of loads effectively between the connecting elements (i.e., beams and columns) in the structures. Traditionally, seismic design approaches are stated, as the structure should be able to ensure the minor and frequent shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event. The structure should withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. This limit state may correspond to earthquake intensity equal to the strongest either experienced or forecast at the site. The main aim of this paper is to investigate the seismic performance of a reinforced concrete moment resisting frame building under a moderate earthquake ground motion.

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 behaviour 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 epicentre .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.

In tall building the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Sway or drift is the magnitude of the lateral displacement at the top of the building relative to its base. Traditionally, seismic design approaches are stated, as the structure should be able to ensure the minor and frequent shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event. The structure should withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. This limit state may correspond to earthquake intensity equal to the strongest either experienced or forecast at the site. In present study the effect of bare f.rame, brace frame and shear wall frame is studied under the earthquake loading. The results are studied for response spectrum method. The main parameters considered in this study to compare the seismic performance of different models are storey drift, base shear, story deflection and time period.

A. Objectives

Following are the objectives of the present study:

- To design and analysis of RC building frame by using STAAD PRO.
- To compare static and seismic analysis.
- To calculate vertical and horizontal displacement for different heights of studied frame.
- To compare allowable drift and calculated drift of frame.
- Effect of Seismic forces on building for corresponding height.

II. LITERATURE REVIEW

A. General

The literature review gives the idea about the previous research had been done on topic related to seismic and static analysis of RC framed structure. review of those presented as given below.

P.Rajaram1 has studied on a two bay five storey reinforcement cement concrete moment resisting frame for a general building has been analyses and designed in STAAD Pro as per IS 1893:2002 code procedures and detailed as IS 13920:1993 recommendations. A beam column joint has been modeled to a scale of 1/5th from the prototype and the model has been subjected to cyclic loading to find its behavior during earthquake. The test results show that the structural behavior of interior beam column joint model has been similar to that of the analytically predicted one. From test results, important parameter has been worked out such as ductility, energy absorption, stiffness degradation etc., in order to access the seismic behavior of the beam column joint when earthquake comes.

Nilanjan Mitra2has studied on developing a series of analysis and design tools to support the performance-based design of one particular structural component: reinforced-concrete beam-column joints.The particular component is chosen for investigation because, despite the fact that laboratory and post-earthquake reconnaissance suggest that joint stiffness and strength loss can have a significant impact on structural response, the inelastic response of these components is rarely considered in analysis or design. Data from previous experimental investigations of joints, spanning a wide range of geometric, material and design parameters, were assembled. Using these data, a series of models were developed and applied to advance understanding of the seismic behavior, simulation and design of reinforced concrete beam-column joints.

SM Kulkarni and Y D Patil3has studied on increasing the shear capacity of the cyclically loaded exterior beam-column joints. The presence of inclined bars introduces an additional mechanism for shear transfer. External beam-column joints with crossed inclined reinforcement (ARP) modeled in Ansys Workbench showed high strength, and no appreciable deterioration even after reaching the maximum capacity. The load resisting capacity is increased as compared to that of seismic joint (IS: 13920-1993). A parametric study with cross inclined bars at the joint will be studied with different parameters like grade of concrete, tie ratio, joint aspect ratio, energy dissipation, yield ratio etc. External beam-column joints with crossed inclined reinforcement give high strength, and no appreciable deterioration even after reaching the maximum capacity.

S. S. Patil and S. S. Manekari4has studied on corner and exterior beam column joints and their behavior, support conditions of beam-column joints i. e .both ends hinged and fixed, stiffness variation of the joint. In this study various parameters are studied for monotonically loaded exterior and corner reinforced concrete beam column joint. The corner as well as exterior beam-column joint is analyzed with varying stiffness of beam-column joint. The behavior of exterior and corner beam-column joint subjected to monotonic loading is different. Various graphs like load vs. displacement (deformations), Maximum stress, Stiffness variations i.e. joint ratios of beam-column joints are plotted. For fixed support condition for corner and exterior joint the displacement, minimum stress and maximum stress values are minimum as compare to hinge support condition. As stiffness of the structure changes the displacement, minimum stress and maximum stress changes Non-linearly.

Jawed Qureshi and J. Toby Mottram5has studied on the test results to characterize the moment-rotation response of nominally pinned joints in frames of pultruded shapes. Mimicking conventional steel construction the major-axis beam to-column joints are formed using pultruded FRP web cleats having steel bolting. There are two joint configurations with either a single row of three or two bolts per cleat leg. Testing is conducted on nominally identical specimens to statistically quantify the key joint properties. The average stiffness of all joints at damage onset is found to be 50% more variable than the average moment resistance. The presence of 70% difference between the minimum and maximum initial stiffness measured makes a single specimen measurement for stiffness unsuitable for frame analysis. Joint moments at loss of linear response, onset of material failure, and ultimate failure do not vary much for the three- and two-bolted configurations.

B. Concluding Remark

From the above literature review it is concluded that the behavior of a building during earthquakes critically depends on its overall shape, size and geometry, in addition to how the earthquake forces are carried. So there is need to analyse the structure for mitigating such a vulnerable failures.

III. PROBLEM STATEMENT

A. Design Parameters

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

B. Design Characteristics

The following design characteristic are considered for Multistory rigid jointed plane frames.

TABLE 1: Parameters of Problem statement in detail

Sr No	Particular	Dimension/Size/Value
1	Model	P+5
2	Seismic zone	III
3	Floor height	3m
4	Plan size	8.92X11.03m
5	Beam size	0.45X0.23
6	Column size	0.375X0.23
7	Wall thickness	0.23m
8	Thickness of slab	0.15m
9	Type of soil	Type II, Medium soil as per IS-1893
10	Material used	Concrete M 20, Reinforcement Fe-415
11	Static analysis	Equivalent Lateral force method
12	Seismic analysis	Response spectrum method
13	Earthquake load	As per IS 1893-2000
14	Special weight of RCC	25KN / m^2
15	Special weight of infill	20KN/ m^2
16	Software used	STAAD PRO

IV. METHODOLOGY

A. 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
- Seismic co-efficient method of earthquake analysis.
- Response spectrum method

B. By IS code method for dynamic analysis

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

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 practise 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 lateraltorsional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances.

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 that response spectrum case of analysis have been performed according to IS 1893.

V. RESULTS AND DISCUSSSION

The 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.

TABLE 2: Column end forces of frame

Column	L/C	Node	Fx kN	Fy Kn	Mz kN.m
C185	Dead load + Live load	54	978.040	-3.598	-2.431
		100	-968.896	3.598	-8.362
	Seismic load	54	701.698	0.809	3.741
		100	-694.382	-0.809	-1.315
	Static + seismic	54	1679.74	-2.789	1.31
		100	-1663.28	2.789	-9.677
C295	Dead load + Live load	100	806.229	-6.189	-8.441
		146	-797.084	6.189	-10.125
	Seismic load	100	577.575	-1.689	-1.989
		146	-570.259	1.689	-3.078
	Static + seismic	100	1383.804	-7.878	-10.43
		146	-1367.34	7.878	-13.203
C405	Dead load + Live load	146	632.283	-6.854	-9.040
		192	-623.138	6.854	-11.524
	Seismic load	146	452.888	-2.929	-3.695
		192	-445.572	2.929	-5.093
	Static + seismic	146	1076.171	-9.783	-12.735
		192	-1068.71	9.783	-16.62
C877	Dead load + Live load	192	448.621	-20.224	-31.372
		510	-439.477	20.224	-29.299
	Seismic load	192	322.701	-7.067	-11.931
		520	-315.385	7.067	-9.269
	Static + seismic	192	771.322	-27.291	-43.303
		510	-754.862	27.291	-38.568
C999	Dead load + Live load	510	255.570	-19.080	-28.320
		552	-246.425	19.080	-28.921
	Seismic load	510	185.809	-8.313	-13.269
		552	-178.491	8.313	-11.669
	Static + seismic	510	441.379	-27.393	-41.589
		552	-424.916	27.393	40.59
C1121	Dead load + Live load	552	61.984	-20.315	-29.872
		604	-52.839	20.315	-31.073
	Seismic load	552	44.421	-13.620	-20.881
		604	-37.105	13.620	-19.980
	Static + seismic	552	106.405	-33.935	-50.753
		604	-89.944	33.935	-51.053

TABLE 3: Nodal vertical displacement of frame

Node	L/C	Horizontal X (mm)	Vertical Y (mm)	Horizontal Z (mm)	Resultant (mm)
54	Dead load + Live load	-0.006	-0.802	-0.043	0.803
	Seismic load	0.573	-0.573	-0.140	0.823
	Static + seismic	0.567	-1.375	-0.183	1.626
100	Dead load + Live load	-0.009	-2.361	-0.554	2.425
	Seismic load	4.428	-1.691	-1.173	4.883
	Static + seismic	4.419	-4.052	-1.727	7.308
146	Dead load + Live load	0.001	-3.645	-1.568	3.968
	Seismic load	8.464	-2.610	-2.568	9.222
	Static + seismic	8.465	-6.255	-4.136	13.19
192	Dead load + Live load	-0.020	-4.650	-2.938	5.501
	Seismic load	12.378	-3.329	-4.086	13.453
	Static + seismic	12.358	-7.979	-7.024	18.931
510	Dead load + Live load	0.002	-5.361	-4.830	7.216
	Seismic load	14.500	-3.840	-5.837	16.096
	Static + seismic	14.502	-9.201	-10.667	23.312
552	Dead load + Live load	-0.004	-5.763	-6.894	8.986
	Seismic load	16.053	-4.132	-7.478	18.185
	Static + seismic	16.049	-9.895	-14.372	27.171
604	Dead load + Live load	0.043	-5.855	-8.580	10.388
	Seismic load	16.782	-4.197	-8.733	19.379
	Static + seismic	16.825	-10.052	-17.313	29.767

TABLE 4: Vertical drift in frame

Node	L/C	Displacement Resultant (mm)	Drift (mm)
54	Static + seismic	1.626	-
100	Static + seismic	7.308	5.682
146	Static + seismic	13.19	5.882
192	Static + seismic	18.931	5.741
510	Static + seismic	23.312	4.381
552	Static + seismic	27.171	3.853
604	Static + seismic	29.767	2.596

TABEL 5: Column stresses of frame

Column	L/C	Length	Max Compression		Max Tension	
			Stress (N/mm²)	Dist. (m)	Stress (N/mm²)	Dist. (m)
C185	Dead load + Live load	3	15.717	3	0.00	3
	Seismic load	3	10.314	3	0.00	3
	Static + seismic	3	26.031	3	0.00	3
C295	Dead load + Live load	3	15.623	3	0.00	3
	Seismic load	3	8.0352	3	0.00	3
	Static + seismic	3	23.658	3	0.00	3
C405	Dead load + Live load	3	13.581	3	0.00	3
	Seismic load	3	7.112	3	0.00	3
	Static + seismic	3	20.693	3	0.00	3
C877	Dead load + Live load	3	11.812	3	-1.622	3
	Seismic load	3	6.021	3	0.00	3
	Static + seismic	3	17.833	3	-1.622	3
C999	Dead load + Live load	3	9.610	3	-3.896	3
	Seismic load	3	5.275	3	-1.136	3
	Static + seismic	3	14.885	3	-5.032	3
C1121	Dead load + Live load	3	6.443	3	-5.218	3
	Seismic load	3	4.343	3	-3.483	3
	Static + seismic	3	10.786	3	-8.701	3

VI. CONCLUSION

Based on the obtained results from the analysis of the reinforced concrete frame building, it can be concluded that:

1. The interior columns in all floor levels were the most affected by the compression forces resulting from all case of load combinations.
2. Bending moments in beams and columns due to seismic excitation showed much larger values compared to that due to static loads.
3. The compressive stresses generated from all cases of loads in ground floor columns were greater than tensile stresses in these columns whereas in other levels the difference was slight.
4. The frame was inadequate to resist the applied seismic load.

VII. ACKNOWLEDGMENT

This paper has been undertaken as a part of improving the awareness level project for maintaining the life span of structure and for preventive inspection and maintenance plan of civil structures.

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