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Comparative study of various seismic analysis methods for RC structure

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ABSTRACT

A large number of RC frame buildings have been built in India in recent years. A huge number of similarly designed and constructed buildings exist in the various towns and cities situated in moderate to severe seismic zones of the country. Analysis and design of such 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 the mass of the structure, and an understanding of structural dynamics for interpretation of analytical results. Reinforced Concrete (RC) frame buildings are the 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 the earthquake. To ensure safety against seismic forces of multi-storied building hence, there is need to study seismic analysis to design earthquake resistance structures. In the present study, a multi-storied framed structure is selected, And Linear seismic analysis is done for the building by a static method (Equivalent Static Method) and dynamic method (Response Spectrum Method & Time history Method) using ETAB2016 as per the IS-1893-2002-Part-1. As a result, the response of structure has been obtained for considered building models, based on each method of analysis, and then the results are compared with each other.

Keywords— *RC structure, Seismic analysis, Equivalent Static, Response spectrum and time history analysis, Displacement, Acceleration, Base shear*

1. INTRODUCTION

An Earthquake is Earth's Shaking or in other words release of energy due to the movement of tectonic plates. This can be destructive enough to kill thousands of people and bring huge economic loss. This natural disaster has many adverse effects on earth like ground shaking, landslides, rock falls from cliffs, liquefaction, fire, tsunami etc. Buildings are highly affected by an earthquake, and in some cases, they are shattered down to the ground level. When the ground shaking occurs beneath the building's foundations they vibrate in an analogous manner with that of the surrounding ground. The inertia force of a structure can develop a shearing effect on it which in turn causes stress concentration on the connections in structure and on the fragile walls. This results in partial or full failure of the structure. The excitement and prevalence of shaking depend on the orientation of the building. High rise structures have the tendency to magnify the magnitude of a long time periodic motions when comparing to the smaller one. Every construction has a resonant prevalence which are the characteristics of the structure. Taller buildings have a tendency for long time periods than the shorter one which makes them relatively more susceptible to damage. Hence, one has to be careful while performing the analysis of a tall structure. In order to analyze a tall structure mainly three analysis procedures are valid like a) Equivalent static analysis, b) Response spectrum analysis, c) Time history analysis. Soil structure interaction analysis is also essential to be considered. After identifying the soil type analyzing procedure is selected to do the detailed analysis of the interaction between soil and structure. To reduce the seismic effects on tall buildings several types of equipment is used like dampers or base isolation process. In dampers, viscous damper, friction damper, yielding damper, magnetorheological fluid dampers tuned mass damper or harmonic absorber can be used.

The main objective of this project is to study the seismic behavior and damage to the concrete reinforced building. Also, analysis of structure by using the equivalent static method, response spectrum method and time history method has been surveyed based on IS codes; The maximum storey displacements result have been obtained by using all methods of analysis and compared to displacement capacity of building to assess the damage of building.

1.1 Seismic analysis methods

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. In the past, the buildings were designed just for gravity loads and seismic analysis is a recent development. It is a part of the structural analysis and a part of structural design where an earthquake is prevalent.

There are different types of earthquake analysis methods. Some of them used in the project are:

- Equivalent Static Analysis
- Response Spectrum Analysis
- Time History Analysis

1.1.1 Equivalent static analysis

The equivalent static analysis procedure is essentially an elastic design technique. It is, however, simple to apply than the multi-modal response method, with the absolute simplifying assumptions being arguably more consistent with other assumptions absolute elsewhere in the design procedure.

1.1.2 Response spectrum analysis

This approach permits the multiple modes of response of a building to be taken into account. This is required in many building codes for all except for very simple or very complex structures. The structural response can be defined as a combination of many modes. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure. In this, the magnitude of forces in all directions is calculated and the effects on the building are observed

1.1.3 Time history analysis

Time history analysis techniques involve the stepwise solution in the time domain of the multi-degree-of-freedom equations of motion which represent the actual response of a building. It is the most sophisticated analysis method available to a structural engineer. Its solution is a direct function of the earthquake ground motion selected as an input parameter for a specific building. This analysis technique is usually limited to checking the suitability of assumptions made during the design of important structures rather than a method of assigning lateral forces themselves.

2. ANALYTICAL WORK

Building consists of 16m in both X-direction and Y-direction for Static (**Model 1**:Equivalent Static Analysis) and Dynamics Analysis (**Model 2**: Response Spectrum and **Model 3**: Time History Analysis) on computer program ETABS2016 to studied seismic behavior of structure for globally considered models, so from preliminary design the sizes of various structural members were estimated as follows:

Brick masonry wall Thickness: 230mm
Story height: 3m for all floors.
A grade of steel: Fe-500
A grade of concrete: M-25
Column Size: 450X450mm
Beam Size: 450X 450mm
Slab thickness: 150 mm
Dead Load (DL):
Intensity of wall (Ext. & Int. wall) = 13.11 KN /m
The intensity of floor finish load =1KN /m^2
The intensity of roof treatment load =1KN /m^2
Live load (LL):
The intensity of live load =3 KN /m^2
Lateral loading (IS 1893 (Part I):2002):
Building under consideration is in Zone –V
Period Calculation: Program Calculated
Top Storey: Storey- 10
Bottom Storey: Ground Floor or Base
Response reduction factor, R = 5
Importance factor, I = 1
Building Height H = 30m
Soil Type = II (Medium Soil)
Seismic zone factor, Z = 0.36
Ground Motion Database: Matched To Response Spectrum
Time history motion type: Transient Case: EQX and EQY
Spec X and Spec Y
THX and THY

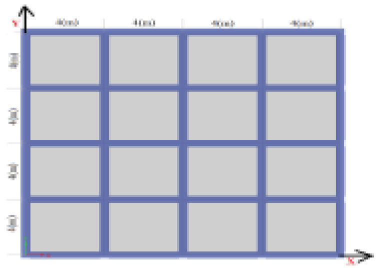

Fig. 1: Plan of structure

3. RESULTS AND DISCUSSION

3.1 Storey drifts

3.1.1 Storey drift in X-direction

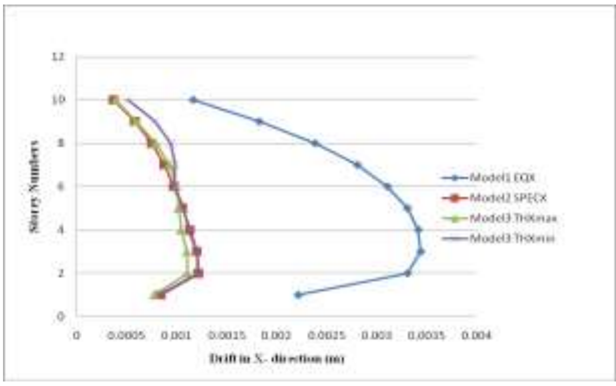

Fig. 2: Comparison of storey drift in X-dir. of building Model 1, Model 2 & Model 3 with respect to story numbers

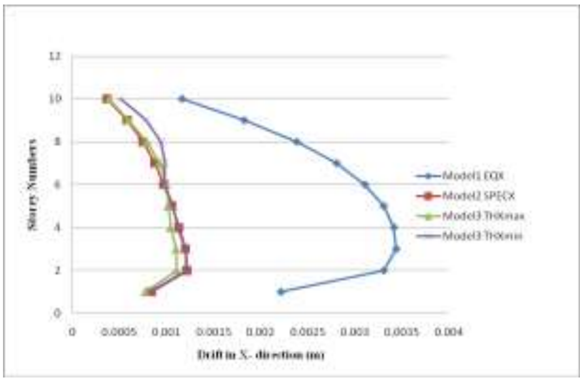

Fig. 3: Comparison of storey drift in Y-dir. of building Model 1, Model 2 & Model 3 with respect to storey numbers

Lateral Displacement & Storey Drift

Storey displacement is the lateral movement of the structure caused by lateral force. And Drift is also defined as the lateral displacement. Storey drift is the drift of one level of a multistorey building relative to the level below. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. No other parameter of comparison can give a better idea of the behavior of the structure than a comparison of storey deformation. As per code IS 1893: 2002 clause 7.11 page 27, The storey drift in any storey due to the minimum specified design lateral force, with a partial load factor of 1.0, shall not exceed 0.004 times the storey height. All the above-considered models are satisfied with the clause.

Comparisons of storey drift are shown in Table 1 and table 2 These storey drift values from results are within (0.004X3) 0.012m range which is a permissible limit as per IS specification.

Table 1: Comparison of Model 1, Model 2 & Model 3

Story	Storey Height(m)	Model 1 EQX(m)	Model 2 SPECX(m)	Model 3 THXmax(m)	Model 3 THXmin(m)
10	30	0.00116	0.00037	0.00039	0.00051
9	27	0.00182	0.00058	0.0006	0.00078
8	24	0.00238	0.00075	0.00079	0.00094
7	21	0.0028	0.00088	0.00093	0.00098
6	18	0.00311	0.00097	0.001	0.00098
5	15	0.0033	0.00105	0.00102	0.00107
4	12	0.00341	0.00113	0.00104	0.00112
3	9	0.00344	0.0012	0.0011	0.0012
2	6	0.0033	0.00122	0.00111	0.00121
1	3	0.00221	0.00084	0.00077	0.00082

Table 2: Comparison of Model 1, Model 2 & Model 3

Story	Storey Height(m)	Model 1 EQY(m)	Model 2 SPECY(m)	Model 3 THYmax(m)	Model 3 THYmin(m)
10	30	0.00116	0.00037	0.00039	0.00051
9	27	0.00182	0.00058	0.0006	0.00078
8	24	0.00238	0.00075	0.00079	0.00094
7	21	0.0028	0.00088	0.00093	0.00098
6	18	0.00311	0.00097	0.001	0.00098
5	15	0.0033	0.00105	0.00102	0.00107
4	12	0.00341	0.00113	0.00104	0.00112
3	9	0.00344	0.0012	0.0011	0.0012
2	6	0.0033	0.00122	0.00111	0.00121
1	3	0.00221	0.00084	0.00077	0.00082

In back and forth direction at different floors of structures causes to decrease the stiffness and mass of the structure.

The displacement results are computed for time history analysis in the same way as in the response spectrum analysis. This is due to the fact that both analyses rest on the mode superposition method based on the assumption that the system behaves linearly. Superposition of waves is simply finding the net effect that more than one waveform has on a medium. A wave's displacement is either positive or negative at a point in time and space. If more than one wave is at that point in time and space then a 'net effect' will be observed.

The reason for high storey displacements in buildings is that the overall stiffness of the building decreases due to attract maximum lateral forces. Due to decreasing stiffness, the flexibility increases and strength decrease resulting in high displacements.

3.2 Natural Period and Acceleration

3.2.1 Natural period and acceleration values for response spectrum analysis

Table 3: Acceleration values for particular natural period of Model 2

Mode	SPECX		SPECY	
	Period (sec)	Acc. mm/sq sec	Period (sec)	Acc. mm/sq sec
1	1.56	314.67	1.56	314.67
2	1.56	314.67	1.56	314.67
3	1.373	357.51	1.373	357.51
4	0.511	900	0.511	900
5	0.511	900	0.511	900
6	0.452	900	0.452	900
7	0.294	900	0.294	900
8	0.294	900	0.294	900
9	0.265	900	0.265	900
10	0.204	900	0.204	900
11	0.204	900	0.204	900
12	0.184	900	0.184	900

Table 3 shows, acceleration values are obtained in the first mode and it gives values with the considered seismic intensity of zones. After the first mode acceleration value will increase to the constant value before stop vibrating the structure. The reason for this to happen is that long duration earthquake with high peak ground acceleration (PGA) have more energy flux and it takes a long time for the structure to dissipate energy. The energy gets dissipated after getting transferred up to full length of structure hence the top portion has maximum acceleration.

3.2.2 Natural period and acceleration values for time history analysis

Table 4: Acceleration values for time history analysis

Period sec	Damping 0.03 SA m/sec²	Damping 0.05 SA m/sec²	Damping 0.07 SA m/sec²
0.2	0.12	0.12	0.12
0.3	0.28	0.26	0.25
0.4	0.49	0.44	0.4
0.5	0.91	0.84	0.79
0.6	2.78	2.12	1.71
0.641	3.13	2.41	1.98
0.7	2.61	2.15	1.83
0.728	2.31	1.95	1.68
0.8	1.55	1.42	1.31
0.9	1.16	1.08	1.01
1	1.14	1.04	0.96
1.1	1.16	1.05	0.96
1.2	1.05	0.96	0.88
1.3	1.04	0.92	0.85
1.4	1.1	1.02	0.96
1.5	1.38	1.25	1.14
1.6	1.48	1.3	1.15
1.8	1.95	1.57	1.3
1.957	2.49	2.04	1.72
2	2.59	2.1	1.76
2.2	2.08	1.86	1.69
2.212	2.05	1.84	1.67
2.4	1.41	1.25	1.21
2.6	1.08	1.06	1.04
2.8	1.1	1.09	1.08
3	1.27	1.18	1.12
3.3	1.64	1.32	1.13
3.398	1.67	1.34	1.14
3.6	1.54	1.4	1.29
3.778	1.48	1.34	1.24
4	1.13	1.07	1.04
4.4	1.01	0.96	0.93
4.7	1.05	0.87	0.83
4.906	0.89	0.87	0.87
5	0.89	0.89	0.88
5.438	1.09	1.02	0.98
5.5	1.13	1.04	0.98
6	0.76	0.81	0.83
6.5	0.65	0.74	0.79

Period sec	Damping 0.03	Damping 0.05	Damping 0.07
	SA m/sec²	SA m/sec²	SA m/sec²
7	1.03	0.96	0.92
7.5	0.86	0.9	0.92
8	1.03	0.99	0.97
8.5	1.01	0.99	0.97
9	0.92	0.93	0.93
10	0.89	0.89	0.89
11	0.86	0.85	0.86
12	0.81	0.83	0.85
13	0.85	0.88	0.88
14	0.91	0.9	0.89
15	0.89	0.89	0.89
16.5	0.85	0.87	0.88
18	0.92	0.91	0.9
20	0.89	0.89	0.89
22	0.86	0.87	0.88
25	0.89	0.89	0.89
28	0.9	0.9	0.89
33	0.88	0.88	0.88

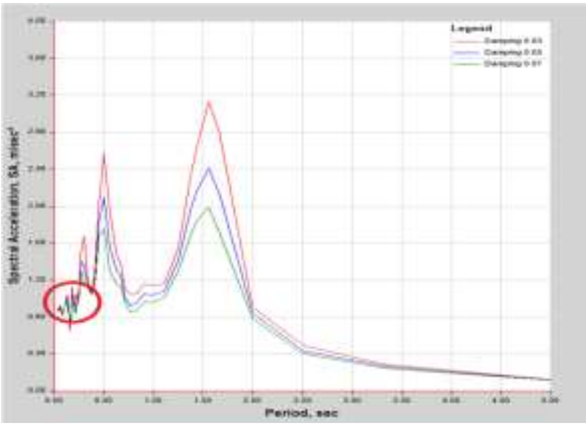

Fig. 4: Spectral acceleration varies with period for the different damping ratio

Figure 4 shows the region of the red circle marked a slight change in nature period can lead to large variation in maximum acceleration. The effect of damping on the resonant response is seen clearly, the lower is the damping value, the bigger the response

3.3 Base Shear

Table 5: Comparison of base shear for Models 1, 2 & 3

Model	Analysis	X-dir. (KN)	Y-dir. (KN)
Model 1	ESA	3325.3457	3325.3457
Model 2	RSA	1287.693	1287.693
Model 3	THA	1235.1789	1235.1789

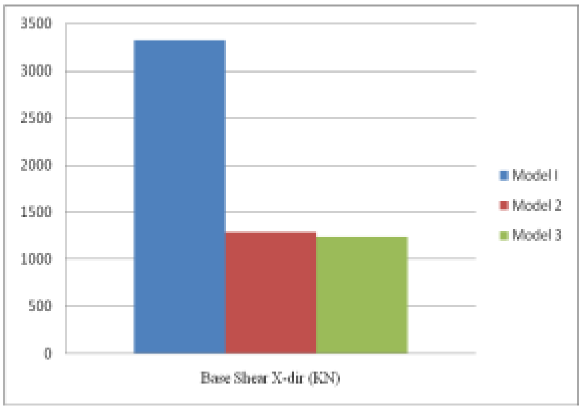

Fig. 5: Maximum base shear along X dir. or Y dir. for all considered models

Table 6: Base Shear from time history response output for a specified load case

Model	X-direction		Y-direction	
Model 3	Base Shear (KN)	Time (Sec)	Base Shear (KN)	Time (Sec)
	1235.17	2.9	-1184.50	3.7

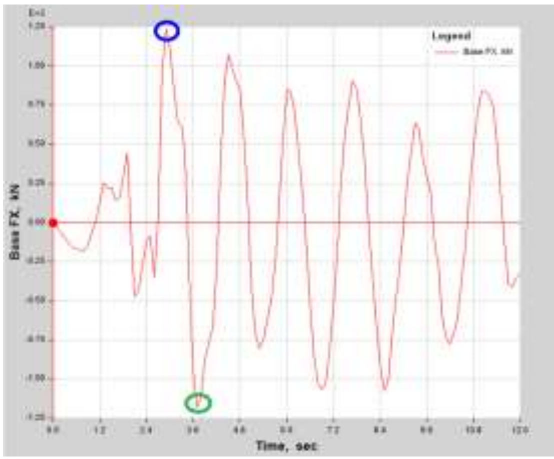

Fig. 6: Base shear from time history response output for a specified load case

The Indian code distributes the base shear force to the floor levels by the proportions of the weighted average of the square of the height of the floor; in considered models here height and assigning weight are same for all cases only seismic analysis of structure has been changing. Figure 6 shows base shear values of structure in particular time interval for back and forth direction during acceleration flux vibrates the structure globally.

A quantitative comparison of the base shear for the three models is presented. However, their seismic performance during the seismic time period interval will vary. Although the three analysis has different attributes, they all have acceptable performance and are expected to behave desirably in seismic events.

3.4 Nodal Load Participation ratio for all Models

Table 7: Static and dynamic percentage

Case	Item Type	Item	Static %	Dynamic %
Modal	Acceleration	UX	99.98	97.03
Modal	Acceleration	UY	99.98	97.03

As per code IS 1893: 2002 clause 7.8.4.2 page 25, The number of modes to be used should be such that the sum of the total of modal masses of all modes considered is at least 90% of the total seismic mass in IS code of practices. In the present study, the initial modes are found to be in translation for all structural system based on various codes of practices and excite more than 90% of the total mass. All the above-considered models are satisfied with the clause.

4. CONCLUSION

This study leads to the following the conclusions:

i. As a result of comparison between three mentioned analysis, it is observed that the displacement obtained by static analysis are higher than dynamic analysis including response spectrum and time history analysis.

ii. The spectral acceleration verces period is used to define the acceleration values in both directions, i.e. THX and

THY, to account for the directional uncertainty of the earthquake motions and the low probability of simultaneous occurrence of the maximum response for each direction, the time-history method allows a much more complete analysis because it provides the time evolution of any kind of result. For important structures, time history analysis should be performed as it predicts the structural response more accurately in comparison with the other two methods.

iii. An increase in the time duration of strong motion causes the response spectra to be flatter and have a smaller slope, so for most periods an increase in time duration causes greater spectral values.

iv. From results and discussion chapter, Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated as per code based fundamental time period of the structure. The linear dynamic analysis is an improvement over linear static analysis, as this analysis produces the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way.

v. Static analysis is not sufficient for high rise building and it's necessary to provide dynamic analysis. The results of the equivalent static analysis are approximately uneconomical because values of displacement are higher than dynamic analysis.

vi. A quantitative comparison of the base shear for the three models is presented. Their seismic performance during the seismic time period interval has been varying. Although the three analysis has different attributes, they all have acceptable performance and are expected to behave desirably in seismic events.

vii. Suitable methods of analysis are provided in codes of practice; in general, the more complex and tall the building, the more stringent the analysis that is required. The linear time history method has huge potential to improve seismic performance in that dynamic amplification effects due to yielding are explicitly included in the evaluation.

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6. REFERENCES

[1] Mrunmayi Gursale and P.S. Patil, the Comparative parametric study of the linear and nonlinear behavior of multistory structures, International Journal of Research in Engineering and Technology, Volume: 04 Issue: 04 | Apr-2015.

[2] Saurabh Lonkar and Prof. Riyaz Sameer Shah, Comparative study of static and dynamic analysis of multistorey regular & irregular building, International Journal of Research in Engineering science and Technology, Volume: 01 Issue: 08 | Dec – 2015.

[3] Aniruddha Gottala, Kintali Sai Nanda Kishor, and Dr.Shaik Yajdhani, comparative study of static and dynamic seismic analysis of a multistorey building, International Journal of Research in Engineering science and Technology, Volume: 02 Issue: 01 | July-2015.

[4] Bahador Bagheri, Ehsan Salimi Firoozabad, and Mohammadreza Yahyaei, Comparative study of the static and dynamic analysis of the multistorey irregular building, International Journal of Civil, Environment, Structural, Construction and Architectural Engineering, Volume: 06 Issue: 11 | 2012.

[5] Mr. S. Mahesh, Mr. Dr. B. Pandurangarao, Comparison of analysis and design of regular and irregular configuration of the multistrorey building in various seismic zones and various types of soils using ETABS and STAAD, IOSR Journal of Mechanical and Civil Engineering, Volume: 11 Issue: 06 | Dec -2014.

[6] E. Pavan Kumar, A. Naresh, M. Nagajyothi, M. Rajasekhar, Earthquake analysis of multistoried residential building – A case study, International Journal of Engineering, Research and Applications, Volume: 04 Issue: 11 | Nov-2014

[7] Nilanjan Tarafdar, Kamlesh Bhowmik and K. V. Naveen Kumar, Earthquake resistant techniques and analysis of tall buildings, International Journal of Research in Engineering & Technology, Volume: 04 Issue: 13 | Dec-2015.

[8] Bahador Bagheri, Krishna Nivedita, and Ehsan Salimi Firoozabad, Comparative damage assessment of irregular building based on static and dynamic analysis, International Journal of Civil and Structural Engineering, Volume: 03 Issue: 03 | 2013

[9] Santosh Kumar Adhikari and Dr. K. Rajasekhar, Comparative static and dynamic study on seismic analysis of uniform and non-uniform column sections in a building, International Journal of Innovative Research in Science, Engineering & Technology, Volume: 04 Issue: 08 | Aug-2015.

[10] Pankaj Agrawal, Manish shrikhande, Earthquake resistant design of the structure.

[11] S.K. Duggal, Earthquake resistant design of the structure.

[12] Chopra A. K, Dynamic of structure

[13] IS 1893(part 1) (2002), Indian Standard Code of Practice for Criteria for Design of Earthquake Resistant Structures, Bureau of Indian Standards, New Delhi.

[14] IS 456:2000, Indian Standard Code of Practice for Criteria for Plain and Reinforcement concrete, Bureau of Indian Standards, New Delhi.

