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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. 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 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. To ensure safety against seismic forces of multi-storied building hence, there is need to study of 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 static method (Equivalent Static Method) and dynamic method (Response Spectrum Method & Time history Method) using ETABS 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 methods 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.

I. 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 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 structure.

The excitement and prevalence of shaking depends on the orientation of the building. High rise structures have the tendency to magnify the magnitude of long time periodic motions when comparing to the smaller one. Every construction has a resonant prevalence which are the characteristics of structure. Taller buildings have a tendency for long time periods than shorter one which make them relatively more susceptible to damage.

Hence, one has to be careful while performing the analysis of a tall structure. In order to analyse 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 analysing procedure is selected to do the detailed analysis of the interaction between soil and structure. To reduce the seismic effects on tall buildings several equipment is used like dampers or base isolation process. In dampers viscous damper, friction damper, yielding damper, magneto rheological 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 of concrete reinforced building.

Also, analysis of structure by using 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.

II. 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 structural analysis and a part of structural design where earthquake is prevalent. There are different types of earthquake analysis methods.

Some of them used in the project are

- 1) Equivalent Static Analysis
- 2) Response Spectrum Analysis
- 3) Time History Analysis

III. ANALYTICAL WORK

Building consists of 16m in both X direction and Y-direction for Static (Model1:Equivalent Static Analysis) and Dynamics Analysis (Model2: Response Spectrum and Model3: Time History Analysis) on computer program ETABS to studied seismic behaviour 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

Storey height: 3m for all floors.

Grade of steel: Fe-500

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

Intensity of floor finish load =1KN /m²

Intensity of roof treatment load =1KN /m²

Live load (LL):

Intensity of live load =3 KN /m²

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

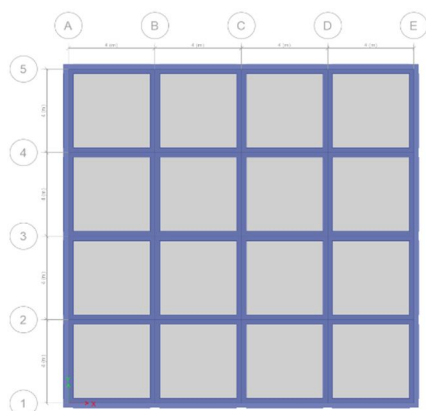


Fig.1: Plan of structure

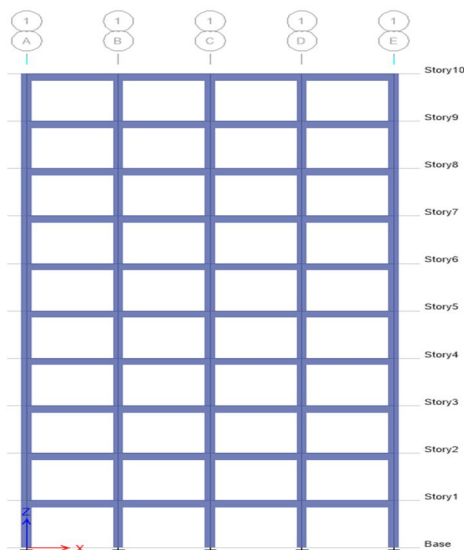


Fig 2: Elevation of Considered Structural Models

IV. RESULTS AND DISCUSSION

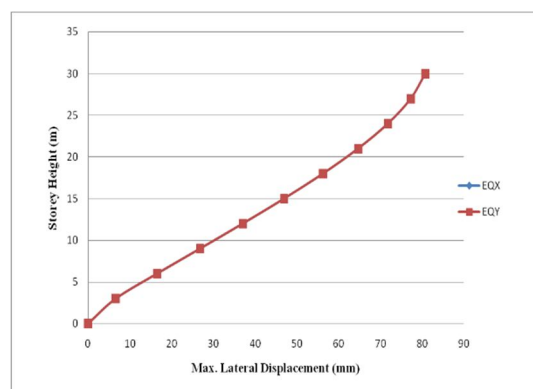
1) Maximum Lateral Displacement

Table1:Maximum displacement of Model 1

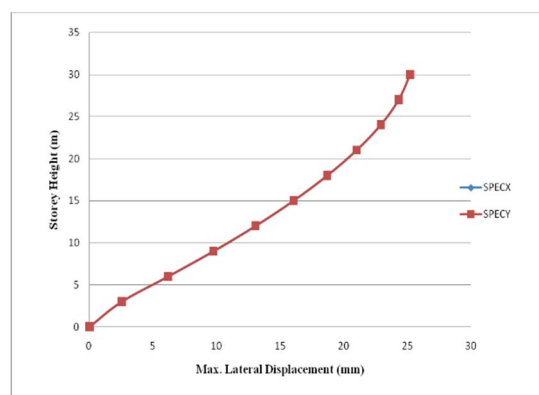
Storey No's	Storey Height (m)	EQX	EQY
Story10	30	80.804	80.804
Story9	27	77.319	77.319
Story8	24	71.85	71.85
Story7	21	64.71	64.71
Story6	18	56.302	56.302
Story5	15	46.986	46.986
Story4	12	37.078	37.078
Story3	9	26.846	26.846
Story2	6	16.541	1.65E+01
Story1	3	6.637	6.637
Base	0	0	0

Table2:Maximum displacement of Model 2

Storey No's	Storey Height (m)	SPECX	SPECY
Story10	30	25.231	25.231
Story9	27	24.327	24.327
Story8	24	22.905	22.905
Story7	21	21.011	21.011
Story6	18	18.711	18.711
Story5	15	16.052	16.052
Story4	12	13.058	13.058
Story3	9	9.753	9.753
Story2	6	6.181	6.181
Story1	3	2.533	2.533
Base	0	0	0



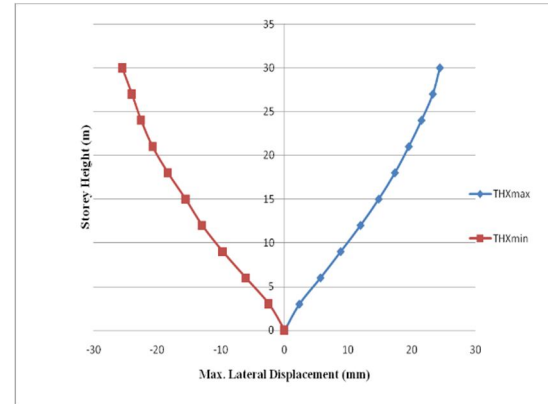
Graph 1: Maximum displacement of Model 1 with respect to height



Graph 2: Maximum displacement of Model 2 with respect to height

Table3:Maximum displacement of Model 3 (For X / Y Direction)

Storey No's	Storey Height (m)	THXmax	THXmin
Story10	30	24.373	-25.462
Story9	27	23.268	-23.931
Story8	24	21.483	-22.492
Story7	21	19.495	-20.698
Story6	18	17.313	-18.289
Story5	15	14.776	-15.516
Story4	12	11.918	-12.921
Story3	9	8.8	-9.686
Story2	6	5.632	-6.079
Story1	3	2.318	-2.457
Base	0	0	0

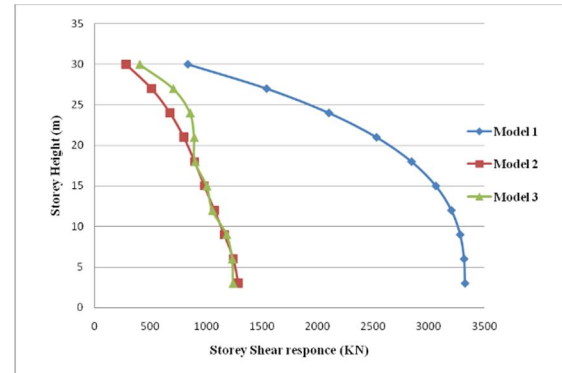


Graph 3: Maximum displacement of Model 3 with respect to height

2) Store Shear Response

Table4:Storey shear force(KN) distribution along X-direction

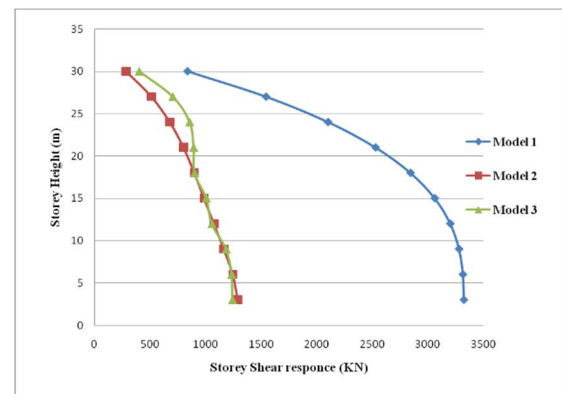
Storey No's	Storey Height (m)	Model I	Model 2	Model 3
Story10	30	837.0815	281.076	402.2952
Story9	27	1544.2724	509.517	704.5752
Story8	24	2103.0405	674.577	855.6859
Story7	21	2530.8473	798.744	891.8088
Story6	18	2845.1543	895.874	900.1325
Story5	15	3063.4231	983.548	1005.546
Story4	12	3203.1152	1072.94	1056.222
Story3	9	3281.6919	1161.83	1184.224
Story2	6	3316.6149	1242.79	1234.16
Story1	3	3325.3457	1287.69	1241.807



Graph 4: Storey shear force(KN) distribution along X-direction

Table5:Storey shear force(KN) distribution along Y-direction

Storey No's	Storey Height (m)	Model I	Model 2	Model 3
Story10	30	837.0815	281.076	402.2952
Story9	27	1544.2724	509.517	704.5752
Story8	24	2103.0405	674.577	855.6859
Story7	21	2530.8473	798.744	891.8088
Story6	18	2845.1543	895.874	900.1325
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Story4	12	3203.1152	1072.94	1056.222
Story3	9	3281.6919	1161.83	1184.224
Story2	6	3316.6149	1242.79	1234.16
Story1	3	3325.3457	1287.69	1241.807

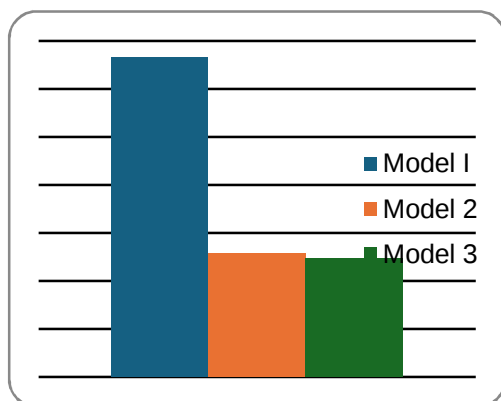


Graph 5: Storey shear force(KN) distribution along Y-direction

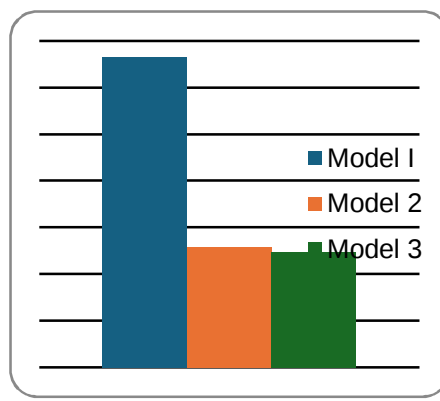
3) Base Shear

Table5.15: Comparison of Base Shear for Model1, Model2 & Model3

Model	Analysis	X-direction	Y-direction
Model 1	ESA	3325.3457	3325.3457
Model 2	RSA	1287.693	1287.693
Model 3	THA	1235.1789	1235.1789



Graph 6: Maximum Base Shear along X direction for all considered Models



Graph 7: Maximum Base Shear along X direction for all considered Models

V. COMPARISON OF SEISMIC ANALYSIS METHODS

Comparison of Seismic Analysis Methods			
Sr. No.	Equivalent Static Method	Response Spectrum Method	Time History Method
1	This is the simplest method.	This provides a balance and practicality.	This is most detailed and computationally intensive.
2	This method simplifies dynamic earthquake load into static force.	It represents the peak response of a single degree of freedom system.	This method simulates structural response over time.
3	Generally used for regular, low-rise buildings in less seismically active regions.	Suitable for a wide range of structure including regular and moderately complex buildings especially in moderate to high seismic zone.	Used for complex structure, critical structures or when high level of accuracy is required.
4	It is least accurate; it doesn't account for dynamic characteristics.	More accurate than ESM.	Most accurate method, as it directly simulates structural response to specific earthquake.
5	Simple to understand and apply require minimal computational resources.	Offer a good balance between accuracy and computational efforts.	Provides detailed information about structures behaviour including displacement, velocity, acceleration and internal forces over time.
6	Potentially leading to inaccurate results specially for complex or tall buildings.	Still a linear analysis, so it may not accurately capture the behaviour of structure with significant non-linearities.	Most computationally intensive require significant computational resources and expertise.

VI. CONCLUSION

In this study, the seismic vulnerability of building is shown through an example building. The main object of this investigation is to study the effect of horizontal loading on reinforced concrete frames for three different analysis models i.e. (I) Model 1- Structure Analyzed by Equivalent Static Analysis, (II) Model 2- Structure Analyzed by Response Spectrum Analysis and (III) Model 3- Structure Analyzed by Time History Analysis. In this section only the conclusion obtained from the analysis result and their discussions are presented. This study leads to following conclusion.

- 1) 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
- 2) The spectral acceleration versus period is used to define the acceleration values in the 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 other two methods.
- 3) 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. Linear dynamic analysis are 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.
- 4) Static analysis is not sufficient for high rise building and its necessary to provide dynamic analysis. The results of equivalent static analysis are approximately uneconomical because values of displacement are higher than dynamic analysis.
- 5) A quantitative comparison of the base shear for three models is presented. Their seismic performance during the seismic time period interval has been vary. Although the three analysis have different attributes, they all have acceptable performance and are expected to behave desirably in seismic events.
- 6) 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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