SEISMIC NON-LINEAR TIME HISTORY ANALYSIS OF MULTI STORIED RCC RESIDENTIAL BUILDING SUBJECTED TO DIFFERENT EARTHQUAKEGROUND MOTIONS USING ETABS

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Abstract - Seismic analysis of reinforced Concrete (RCC) buildings are one of the research interests nowadays and it is because of, earthquake causes lots of damage and losses with respect to life and damage of structures. The present study is limited to reinforced concrete multi-storied residential building under influence of three different earthquake ground motions. In this study, a nonlinear time history analysis is performed on eight storey RCC building frame considering time history of Landers earthquake 1992, Kobe earthquake 1995 and ChiChi earthquake 1999 using ETABS software. Analysis also performed to study the behavior of building under the seismic and gravity loads as per the IS-1893:2002. All analysis are compared for outcomes such as storey displacements and base shears. From the study it is recommended that analysis of multistoried RCC building using Time History method becomes necessary to ensure safety against earthquake force.

Keywords - Time History Analysis, Multistoried RCC Building, ETABS, IS-1893:2002, Storey Drifts, Storey Displacements, Base Shear.

I. INTRODUCTION

And All over world, there is high demand for construction of tall buildings due to increasing urbanization and spiraling population, and earthquakes have the potential for causing the greatest damages to those tall structures. Since earthquake forces are random in nature and unpredictable, the engineering tools need to be sharpened for analyzing structures under the action of these forces. When earthquakes occur, a building undergoes dynamic motion. This is because the building is subjected to inertia forces that act in opposite direction to the acceleration of earthquake excitations. These inertia forces, called seismic loads, are usually dealt with by assuming forces external to the building. So apart from gravity loads, the structure will experience dominant lateral forces of considerable magnitude during earthquake shaking. It is essential to estimate and specify these lateral forces on the structure in order to design the structure to resist an earthquake. Earthquake loads are required to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Analyzing the structure for various earthquake intensities and checking for multiple criteria at each level has become an essential exercise for the last couple of decades.

For determination of seismic responses it is necessary to carry out seismic analysis of the structure using different available methods (1). Static Analysis, (2) Nonlinear Static Analysis, (3) Linear Dynamic Analysis; and (4) Nonlinear Dynamic Analysis. Linear static analysis or equivalent static method can be used for regular structure with limited height. Linear dynamic analysis can be performed by response spectrum method. The significant difference between linear static and linear dynamic analysis is the level of the forces and their distribution along the height of structure. Nonlinear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of structure. A nonlinear dynamic analysis is the only method to describe the actual behavior of a structure during an earthquake. The method is based on the direct numerical integration of the differential equations of motion by considering the elasto-plastic deformation of the structural element.

Reinforced concrete buildings have been damaged on a very large scale in Landers, Kobe and ChiChi earthquakes, Even though these buildings are analyzed and designed as per IS code. The damages are caused by inconsistence seismic response, irregularity in mass and plan, soft storey and floating columns etc. Hence it becomes necessary to evaluate actual seismic performance of building subjected to earthquake forces. Time History analysis gives more realistic seismic behavior of the building. It gives more accurately seismic responses than response spectrum analysis because of it incorporates material nonlinearity and dynamic nature of earthquake.

II. LITERATURE REVIEW

Patil A. S. (5) studied nonlinear dynamic analysis of 10 storied RCC building considering different seismic intensities and also studied seismic response of such building. The building under consideration is modeled with the help of SAP 2000-15 software and 5 different time histories have been used. The result of the study shows similar variations pattern in seismic response such as base shear and storey displacements and concluded that time history is realistic method used for seismic analysis. It provides a better check to the safety of structure analyzed and designed.

Bhagwat et al. (6) studied dynamic analysis of G+12 multistoried practiced RCC building considering for Koyna and Bhuj earthquake is carried out. The Time History Analysis and Response Spectrum Analysis and seismic responses of the building are comparatively studied. The modeled with the help of ETABS9.7.2 software. Two time histories (i.e. Koyna and Bhuj) have been used to develop different criteria (base shear, storey displacement, storey shear), and concluded that, the value of base shear for Bhuj earthquake is 49.11% more than the Koyna earthquake, and Response Spectrum method gives 50% more result than Time History Analysis.

Dubey et al. (7) presented design of multistoried irregular building with 20 stories and modeled it using software STAAD-PRO for seismic zone IV in India, dynamic response of building under actual earthquake, DELINA (ALASKA)2000 have been considered. This paper highlights the comparison of Time History Method and Response Spectrum Method. The story displacement result has been obtained by using both method of dynamic analysis, and Concluded that Time History Analysis is found to be 2 to 8% higher than that of Response Spectrum Analysis in both type of building i.e. regular and irregular, For high rise building it is necessary to provide dynamic analysis because of nonlinear distribution of force. Storey displacement is found greater in THM as compared to RSM, and observed that the base shear is greater in RSM compared to THM. Thus it can be concluded that time history analysis is economically better for designing.

Rampure et al. (8) studied the dynamic time history analysis and response spectrum analysis of a concrete gravity dam by using STAAD-PRO. Finite element approach is used to analyze the dam and a concrete gravity dam model is prepared in STAAD-PRO to perform the time history analysis and response spectrum analysis and comparison is done between both these methods. They concluded that STAAD-PRO is most convenient and less tedious for dynamic analyses and it provides a computing environment to investigate modelling assumption and computational processes related to the static and seismic structural stability of gravity dam. It is necessary to analyze the structure by dynamic analysis of both these method for below the height of dam 100m and above the height of dam 100m. Hawaldar et al. (9) presented G+12 storey building model with and without infill the time history analysis used for Bhuj and Koynaearthquake function it is carried out in ETABS 2013 software. The seismic responses of story displacements, storey drifts are observed. Time history plots of base force v/s time and roof displacement v/s time for both time history functions are compared and studied. They concluded that the displacement values for bhuj function are higher than the displacement value for koyna function and those for infill building are less than that without in filled building and drift value of bhuj function were more in comparison with drifts for koyna function and infill drift values are comparatively less than for without infill drift values for both time history function. Harshita et al. (10) studied the dynamic behavior of multistoried symmetrical building frame using IS1893- 2002 code recommended response spectrum method and time history method. Study focuses to evaluate the base shear, response spectra at different story levels, bending moment diagram, shear force diagram variation in the building. Analysis has been carried out using the STAAD-PRO software based on the matrix analysis. Based on the result it is found that the base shear obtained from time history analysis is slightly higher compared to response spectrum analysis, this may be due to variation in amplitude and frequency content of the ground motion.

III. OBJECTIVES

The main objective of the present study is to carry out the seismic response of 8 storey RCC frame structure using time history analysis methods. The specific objectives are as given below:

1. Seismic non-linear time history analysis of multi-storied RCC building under influence of different earthquakes using Etabs.
2. To study the behavior of multi-storied RCC building under the action of load combination (seismic loads and gravity loads).
3. The time history analysis is performed for the RCC building firstly and then the seismic analysis is performed for load combination (DL, LL, and EQL).
4. Analysis of base shear and displacement on different storey.
5. To compare seismic behavior of multistoried RCC framed building for different earthquakes in terms of various responses such as, base shear and displacements.
6. The entire process of modeling and analysis of all the primary elements for all the models are carried by using ETABS 2016 nonlinear version software.

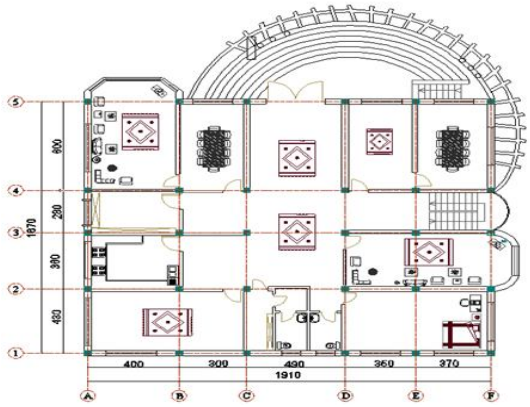
IV. RESEARCH METHODOLOGY

Non-linear time history and load combination analyses performed as per the IS-1893-2002 (11). The finite element analysis software ETABS Ultimate 2016 (12) is utilized to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behaviour of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. The software accepts static loads (either forces or displacements) as well as dynamic (accelerations) actions and has the ability to perform Eigen values, nonlinear static pushover and nonlinear dynamic analyses.

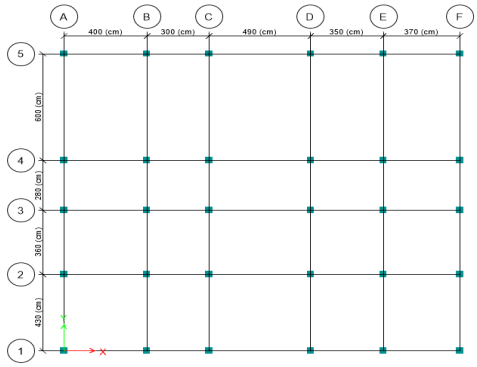
V. PROBLEM FORMULATION

Various time histories are considered as a real time seismic data to perform ETABS analysis. The time histories are: Landers, Kobe and Chichi. Several data's are to be decided to use as an input parameters for software analysis. The parameters are tabulated in tabular format.

Preliminary Data	
Project type	8 storey Residential Building
Dimension of building	19.10m x 16.70m
Beam size	35cm x 40cm
Column size	35cm x 35cm
Slab thickness	15cm
Support Condition	Fixed
G+Typical storey height	3m
Underground storey height	4m
Live load, LL	2kN/m²
Partition and floor finishing load, FL	1kN/m2
External Wall load	13kN/m
Grade of concrete	M30
Seismic zone	III
Zone factor	0.16
Response reduction factor R	3
Importance factor	1
Damping	5%

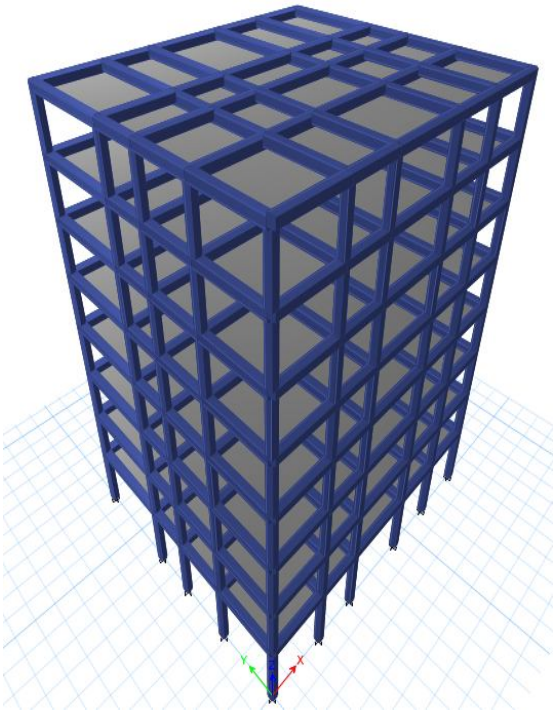


a) Architectural plan





b) 3D view of residential building (Revit Architecture)



d) 3D view of residential building (ETABS)

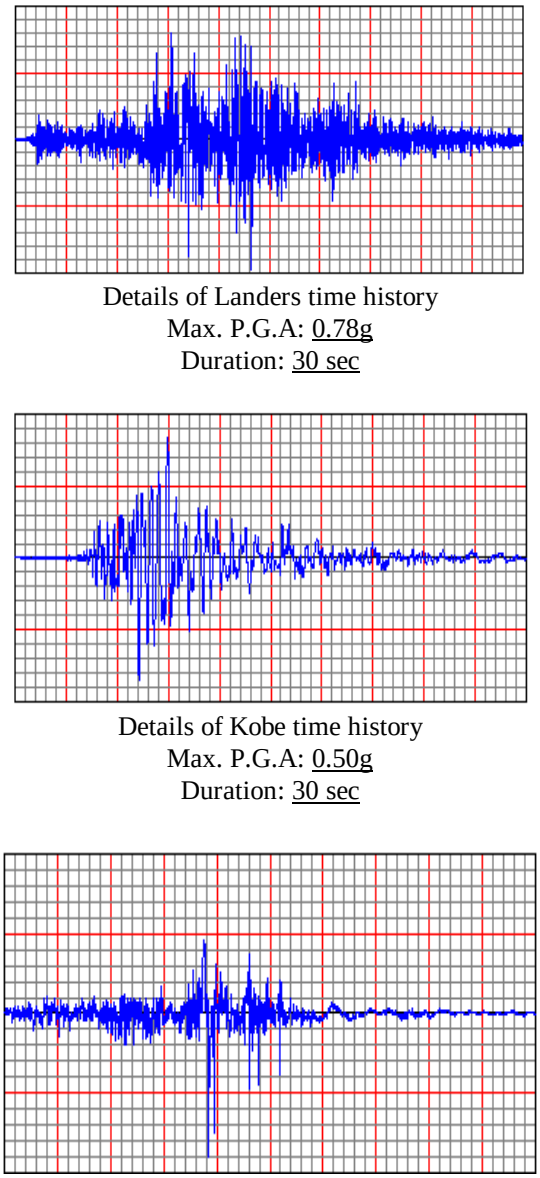
Fig.1: Layout of multi-storied RCC residential building

VI. ANALYSIS OF STRUCTURE

6.1. TIME HISTORY ANALYSIS

Various time histories are considered as a real time seismic data to perform ETABS analysis. Several data's are to be decided to use as an input parameters for software analysis. In this study, a nonlinear time history analysis will be performed on a multi storey RCC building frame considering time history of Landers Earthquake 1992, Kobe Earthquake 1995 and ChiChi Earthquakes 1999.

The refined and convenient special purpose analysis and design program Etabs is used to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. Figure 2. shows the details of acceleration time history of Landers, Kobe and Kocaeli Earthquakes. Results obtained from the analysis are tabulated in Tables 1 to 7. Graphical representations of variations in results are shown in Figures 3 to 9.



Details of Landers time history
Max. P.G.A: 0.78g
Duration: 30 sec

Details of Kobe time history
Max. P.G.A: 0.50g
Duration: 30 sec

Details of ChiChi time history
Max. P.G.A: 0.36g
Duration: 30 sec

Fig. 2: Details of acceleration time history for different earthquakes

Maximum Base Shear

The base shear of a RCC building is calculated by time history analysis method. In the time history analysis of a building Landers earthquake 1992, Kobe earthquake 1995 and ChiChi earthquake 1999 earthquake records are used. The numerical value of the building are given in Table 1 and shown as graphic form (Fig.3).

Table 1: Maximum base reaction of building for different earthquakes

Maximum Base Shear (abs)					
Time History	P.G.A (g)	Fx (kN)	Fy (kN)	Mx (kN.m)	My (kN.m)
Landers	0.78	4065.02	4136.37	64906.53	65716.67
Kobe	0.50	3938.64	3507.05	63849.95	65460.58
ChiChi	0.36	3474.74	3437.30	54048.43	55000.06

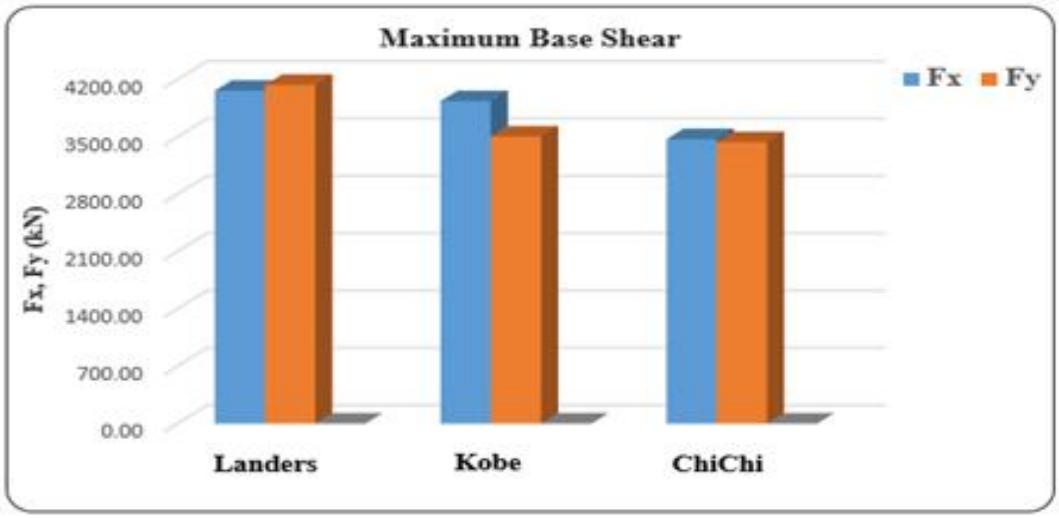


Fig. 3: Storey base shear

The Fig.3 shows the comparison of absolute base shear for RCC building under influence of different earthquake ground motions. From the analysis it observed that, the base share for Landers earthquake is bigger than Kobe earthquake and ChiChi earthquake respectively.

Absolute Storey Displacements

The displacement of RCC building is calculated by time history analysis method. The maximum values of absolute storey displacements of 8 floor RCC building for different earthquakes in x and y directions are given in Table 2 and Table 3. The numerical value which is got from analysis is also shown as graphic form (Fig. 4, Fig. 5).

Table 2: Storey max displacements for x direction

Storey	Storey Max Displacements for X Direction		
	Landers (0.78g)	Kobe (0.50g)	ChiChi (0.36g)
Storey 8	120.40	119.44	99.70
Storey 7	115.00	113.33	96.60
Storey 6	105.73	102.91	91.12
Storey 5	95.82	89.32	83.09
Storey 4	84.73	74.06	72.46
Storey 3	69.44	58.28	59.47
Storey 2	51.64	42.81	44.50
Storey 1	32.19	26.30	27.68

Table 3: Storey max displacements for y direction

Storey	Storey Max Displacements for Y Direction		
	Landers (0.78g)	Kobe (0.50g)	ChiChi (0.36g)
Storey 8	130.12	118.52	104.71
Storey 7	123.95	112.82	101.24
Storey 6	113.53	103.83	95.35
Storey 5	100.28	91.74	86.88
Storey 4	86.84	77.48	75.76
Storey 3	70.84	61.77	62.15
Storey 2	54.63	45.11	46.49
Storey 1	34.89	27.38	28.67

The Fig.4 and Fig. 5 shows the comparison of displacement for RCC building under influence of different earthquake ground motions in x and y directions. From the analysis it observed that, the floor maximum displacement for Landers earthquake is bigger than Kobe earthquake and ChiChi earthquake respectively.

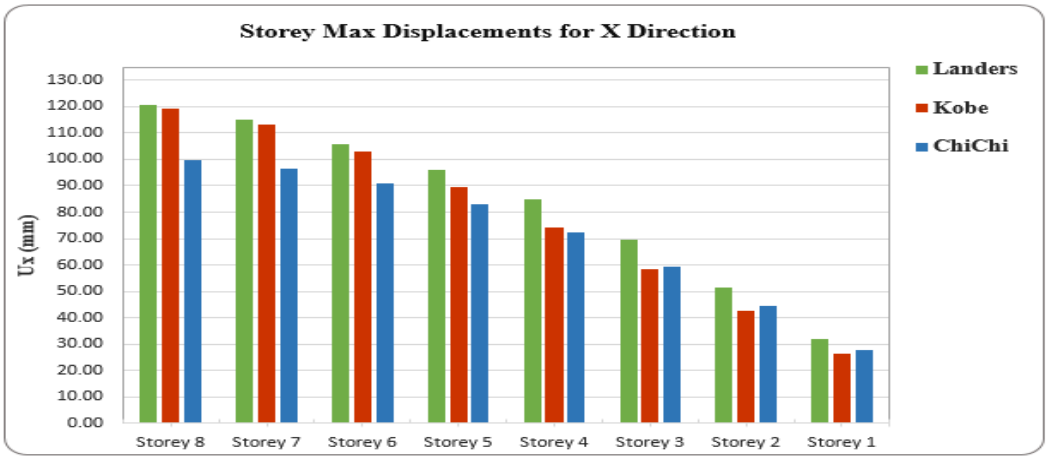


Fig. 4: Storey max displacement

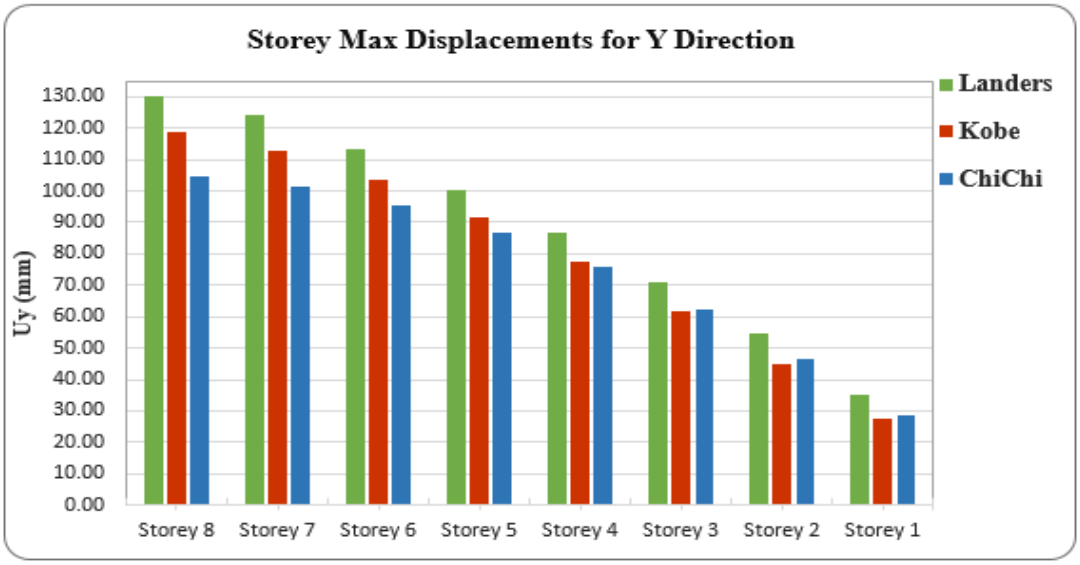


Fig. 5: Storey max displacement

6.2. LOAD COMBINATION ANALAYSIS

There are two types of load considered in this structural analysis. They are gravity loads that include dead load and live load, and earthquake loads. Results obtained from the analysis are tabulated in Tables 8 to 11. Graphical representations of variations in results are shown in Figures 10 to 12.

A) Gravity Loads

Dead loads and live loads are defined as gravity loads that will be accelerated laterally with the structural frame under earthquake motion. Live loads are defined as gravity loads that do not accelerate laterally at the same rate as the structural frame when the structure under goes earthquake motion.

B) Earthquake Load

Earthquake load consists of the inertial forces of the building mass that result from the shaking of its foundation by a seismic disturbance. Other severe earthquake forces may exist, such as those due to land sliding, subsidence, active faulting below the foundation, or liquefaction of the local subgrade as a result of vibration.

C) Load Combinations

The various loads should, therefore, be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations are made. The most unfavorable effect in the building, and structural member concerned may be adopted. It should also be recognized in load combinations that the simultaneously occurrence of maximum values of earthquake and imposed loads. Load combination analysis performed to study the behavior of building under the seismic and gravity loads as per the IS-1893-2002.

Base Reactions

The maximum values of base reaction of 8 floor RCC frame from base for earthquake load and gravity loads (live load and dead load) are given in Table 8.

Table 8. Max base shear results for diff. load combinations

Maximum Base Shear Results for Different Load Combinations (abs)			
Load Case	Fx (kN)	Fy (kN)	Fz (kN)
1.5DL+1.5LL	0	0	64961.78
1.2DL+1.2LL+1.2EQL	9765.85	958.48	51969.43
Maximum Base Shear Results for Different Load Combinations (abs)			
Load Case	Mx (kN.m)	My (kN.m)	Mz (kN.m)
1.5DL+1.5LL	533658.96	620739.83	0
1.2DL+1.2LL+1.2EQL	445883.21	689733.97	78253.23

Storey Displacements for 1.5DL+1.5LL

The maximum values of absolute storey displacements of 8 floor RCC building for live load and dead load combination are given in Table 9.

Table 9. Max displacements for 1.5DL+1.5LL

Storey Max Displacements for 1.5DL+1.5LL		
Story	Load Case	Uz (mm)
Storey 8	1.5DL+1.5LL	13.21
Storey 7	1.5DL+1.5LL	12.00
Storey 6	1.5DL+1.5LL	11.70
Storey 5	1.5DL+1.5LL	10.97
Storey 4	1.5DL+1.5LL	10.04
Storey 3	1.5DL+1.5LL	8.87
Storey 2	1.5DL+1.5LL	7.42
Storey 1	1.5DL+1.5LL	6.06

Storey Displacement 1.2DL+1.2LL+1.2EQL

The maximum values of absolute storey displacements of 8 floor frame for seismic load and gravity loads (live load and dead load) combination in both x and y directions are given in Table 10 .

Table 10: Max displacements for 1.2DL+1.2LL+1.2EQL

Storey Max Displacements for 1.2DL+1.2LL+1.2EQL		
Story	Ux (mm)	Uy (mm)
Storey 8	361.84	76.70
Storey 7	344.00	72.92
Storey 6	314.65	66.58
Storey 5	276.50	58.39
Storey 4	232.22	48.91
Storey 3	184.03	38.62
Storey 2	133.71	27.91
Storey 1	81.38	16.82

CONCLUSIONS

Seismic non-linear time history analysis of a multistoried RC building for three different earthquakes; Landers, Kobe and ChiChi is carried out. From the present study the following conclusions can be drawn out.

1. The seismic responses namely base shear, and storey displacements in both the directions (x, y) are found for the Landers time histories (0.78g), Kobe time histories (0.50g) and ChiChi time histories (0.36g).
2. From results it is observed that the storey shear is decreased as height of the building increased and

reduced at top floor in all the building models subjected to seismic loads considered. The storey shear is maximum at the base.

3. The base shear of structure increases as we go to time histories with higher PGA. For the proposed RC building the base shear (x and y directions) value of Lander time history is 4065.02 KN, 4136.37 KN for Kobe time history is 3938.64 KN, 3507.05KN and for ChiChi time history is 3474.74 KN, 3437.30KN . This means base shear increases if PGA is changes from 0.78g to 0.50g and 0.36g.
4. The displacement of building models increases with the increasing of time history PGA. The displacement is very high at roof and very low at the base. The displacements in both directions (x, y) occurs at top floor for Landers earthquake is 120.40mm, 130.12mm; Kobe earthquake is 119.44mm, 118.52mm and ChiChi earthquake is 99.70mm, 104.71mm. This means top floor displacement increases if PGA is changes from 0.78g to 0.50g and 0.36g.
5. The values of base shear, storey displacements and storey drifts (X direction) for Landers time history are found to be more by 1.03, 1.16; 1.01, 1.20; 1.05, 1.16 times, respectively as compared to Kobe time histories and ChiChi time histories.
6. The values of base shear and storey displacements (y direction) for Landers time history are found to be more by 1.18, 1.20; 1.24; 1.20 times, respectively as compared to Kobe time histories and ChiChi time histories.
7. It is concluded from results and discussion that the outcomes varies from time history to time history. The designers worked for seismic zones must consider time history data while designing RC buildings.
8. As time history is realistic method, used for seismic analysis, it provides a better check to the safety of structures analyzed and designed by method specified by IS code.
9. Results from various time histories can be efficiently presented and utilized for future building design problems. Standards can be established for same.
10. For important structures time history analysis should be performed as it predicts the structural response more accurately in comparison with other methods.

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