COMPARATIVE PARAMETRIC STUDY OF LINEAR AND NONLINEAR BEHAVIOR OF MULTISTORY STRUCTURES

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Abstract

The earthquake analysis of multistorey structure is done by linear and nonlinear methods. Response spectrum method of analysis is linear dynamic analysis. For nonlinear dynamic analysis time history method is used. In this paper, response spectrum method is used for linear analysis. For nonlinear analysis, time history method is used. For time history method, time history function of Bhuj earthquake is used. Both the analyses are done using ETABs software. To study seismic behaviour, base shear, time period, storey displacement parameters are studied

Keywords: *linear analysis, nonlinear analysis, response spectrum method, time history method, ETABs.*

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1. INTRODUCTION

1.1 General

The earthquakes occurred in recent past have indicated that if structures are constructed without considering seismic forces, not properly designed, they will undergo huge destruction and also loss of life. So it is necessary to analyze structure for seismic responses. The analysis is performed on basis of external action, behaviour of structural material, type of structural model selected. Linear static analysis can be used for small structures. Linear dynamic analysis can be done by response spectrum method. In this method peak response of a structure is obtained directly from earthquake response.

Nonlinear method gives actual behaviour of structure. In nonlinear static analysis method, to study behaviour of structure, capacity curve is used. Capacity curve is relation between base shear and displacement of roof. It is also called Push over analysis. Nonlinear dynamic analysis is known as time history analysis. For this type of analysis, time history of a particular earthquake for a given structure is required. This method is used to determine seismic behaviour of structure under dynamic load.

The seismic responses and seismic performance of structure can be evaluated by dynamic response of equivalent single degree of freedom system obtained from multi degree of freedom system. The second method is obtaining responses by analysis of multi degree of freedom system.

1.2 Linear Dynamic Analysis

For linear dynamic analysis, response spectrum method is used. In this method, peak responses of a structure during the earthquake are obtained directly from earthquake responses. The response spectrum is an envelope of upper bound responses based on several different ground motions. The design spectrum given in IS 1893: 2002 Part 1 is used. This spectrum is based on strong motion records of eight Indian earthquakes. In response spectrum method, maximum values of displacements and member forces are calculated for each mode, using design spectra. Response spectra help to calculate peak structural responses under linear range, which can be used to calculate lateral forces developed in structure due to earthquake. This helps for earthquake resistant design.

1.3 Nonlinear Dynamic Analysis

Nonlinear method is most accurate method for calculation of seismic responses of structure. For this type of analysis earthquake time history of representative earthquake is required. The base of the structure is subjected to actual ground motion which is representation of ground acceleration verses time. The ground acceleration is determined at small time steps to give ground motion record. In this dynamic analysis of structure is done at each increment of time. Three main parameters for time history are magnitude, distance and soil condition category. For time history analysis, recorded ground motion database from past natural events are used.

2. MODELLING

2.1 General

For parametric study of multistorey structure, ETABS software is used. Models for G+14, G+17, and G+20 are generated. These models are analysed by response spectrum and time history method. ETABS is completely integrated software for analysis and design of reinforced structure. Creation of model, modification of model, analysis, all are accomplished using single interface. A single structural model can be used for wide variety of different type analysis and design.

2.2 Problem Statement

Models for G+14, G+17 and G+20 are taken for purpose of study. These models are analysed by both response spectrum and time history method. For time history analysis method, time history record of Bhuj earthquake is used. The typical floor height is taken as 3m.

2.2.1 Dimensions of Proposed Model

Table 2.1 Dimensions of Model

Sr. No.	Property	Dimension
1	Plan Dimension in X Direction	16m
2	Plan Dimension in Y Direction	12m

2.2.2 Loads Considered as per IS 1893 – 2002 (Part I)

1. Dead Load
2. Live Load = 2 kN/m^2
3. Floor Finish = 1 kN/m^2
4. Earthquake force in X direction
5. Earthquake force in Y direction
6. Wind force in X direction
7. Wind force in Y direction

2.2.3 Earthquake Parameters Based on Structure Location IS 1893 – 2002 (Part I)

Table 2.2 Earthquake Parameters Based on Structure Location IS 1893 – 2002 (Part I)

Sr. No.	Parameters	Code Provisions
1	Type of Structure	RCC
2	Nature of Building	Residential
3	Damping of Concrete	5%
4	Importance Factor	1
5	Response Reduction Factor	5

2.3 Structural Modelling and Analysis

2.2.4 Sizes of Structural Members

Table 2.3 Sizes of Structural Elements

Sr. No.	Structural Member	Size
1	Columns	800mmX800mm
2	Beams	350mmX600mm
3	Thickness of typical slab	125mm
4	Thickness of wall	230mm
5	Grade of Concrete and Steel	M20 & Fe415

2.2.5 Seismic and Wind Parameters

Table 2.4 Seismic and Wind Parameters

Sr. No.	Location	Seismic Zone	Zone Factor (Z)	Wind Speed m/s)
1	Bhuj	V	0.36	50

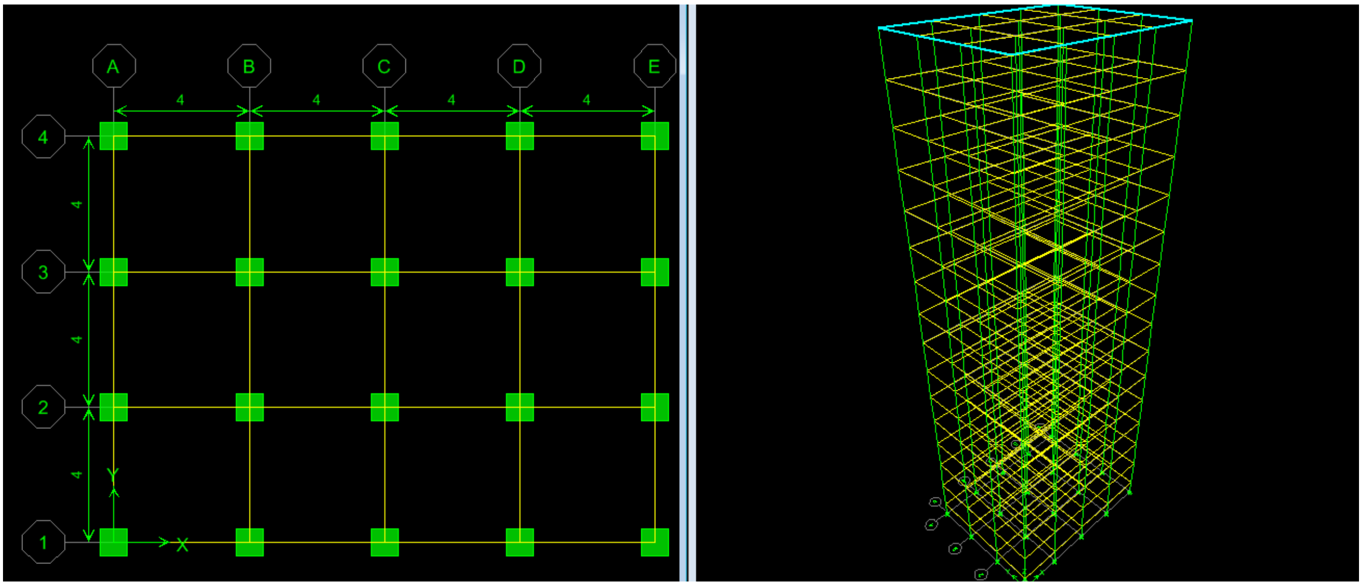

Fig.1 Model of G+ 14 Structures

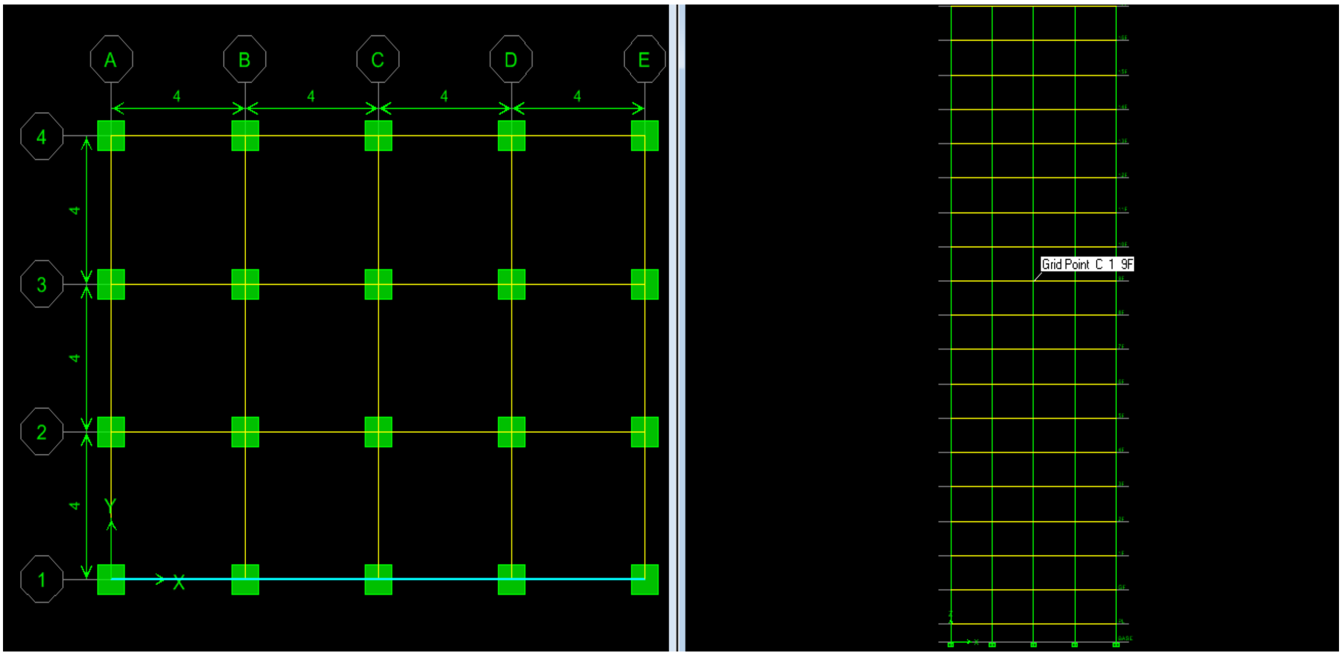

Fig.2 Model of G+ 17 Structures

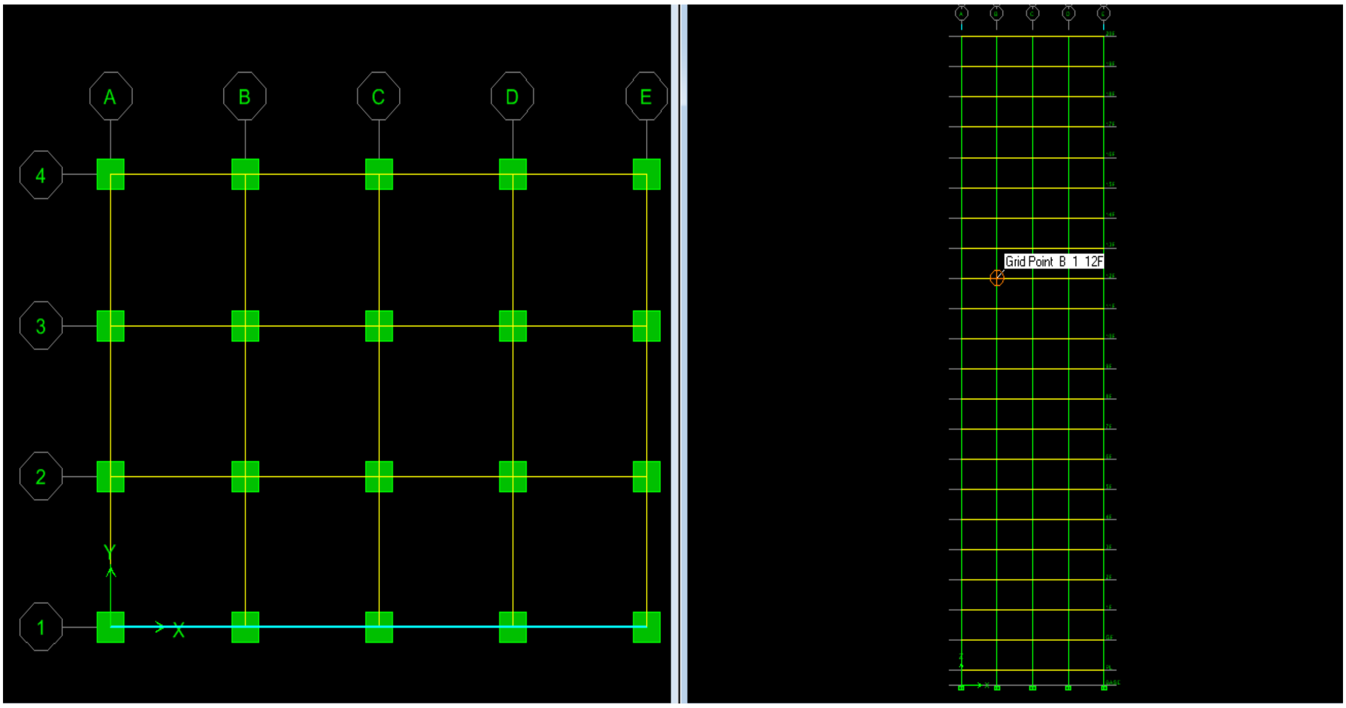

Fig.3 Model of G+ 20 Structures

3. RESULTS AND DISCUSSION

The results of analysis of multistorey structure by both linear and nonlinear methods are tabulated below.

3.1 Linear Analysis (Response Spectrum Method)

3.1.1 Following Table shows values of Storey Shear for G+14, G+17, G+20 Structures.

Table 3.1 Storey Shear of G+14, G+17, G+20 Structures

Floor	Storey Shear (KN) for G+20 Structure	Storey Shear (KN) for G+17 Structure	Storey Shear (KN) for G+14 Structure
20F	147.03	-	-
19F	328.98	-	-

18F	487.04	-	-
17F	619.06	156.11	-
16F	726.99	346.99	-
15F	815.36	510.5	-
14F	888.73	646.49	169.47
13F	950.35	759.71	373.84
12F	1002.49	855.94	547.42
11F	1047.79	939.07	693.89
10F	1089.96	1011.47	820.38
9F	1132.94	1076.11	931.51
8F	1179.32	1137.1	1029.58
7F	1229.63	1197.8	1117.81
6F	1282.98	1259.2	1200.17
5F	1338.2	1320.36	1278.26
4F	1393.96	1380.04	1351.01
3F	1447.68	1436.72	1416.94
2F	1494.68	1486.89	1474.04
1F	1529.04	1524.49	1517.31
GF	1546.53	1544.08	1540.36
PL	1548.08	1545.83	1542.45

3.1.2 Storey Displacement

Table 3.4 Storey Displacement of G+14, G+17, G+20 Structures

Floor	Storey Displacement (m) G+20 Structure	Storey Displacement (m) G+17 Structure	Storey Displacement (m) G+14 Structure
20F	0.0386	-	-
19F	0.0378	-	-
18F	0.0369	-	-
17F	0.0359	0.0321	-
16F	0.0346	0.0315	-
15F	0.0333	0.0306	-
14F	0.0318	0.0296	0.0259
13F	0.0301	0.0284	0.0253
12F	0.0284	0.027	0.0245
11F	0.0266	0.0255	0.0234
10F	0.0247	0.0238	0.0222
9F	0.0227	0.022	0.0208
8F	0.0206	0.0201	0.0191
7F	0.0184	0.018	0.0174
6F	0.0162	0.0159	0.0154
5F	0.0139	0.0137	0.0133
4F	0.0115	0.0114	0.0111
3F	0.0091	0.009	0.0088
2F	0.0066	0.0065	0.0064
1F	0.0042	0.0041	0.0041
GF	0.0019	0.0019	0.0019

3.1.3 Time Period

Table 3.5 Time Period of G+14, G+17, G+20 Structures

Sr. No.	Model	Time Period (sec)
1.	G+14	1.22
2.	G+17	1.5
3.	G+20	1.81

3.2 Nonlinear Analysis (Time History Method)

3.2.1 Storey Shear

Table 3.6 Storey Shear of G+14, G+17, G+20 Structures

Floor	Storey Shear (KN) for G+20 Structure	Storey Shear (KN) for G+17 Structure	Storey Shear (KN) for G+14 Structure
20F	61.90	-	-
19F	140.24	-	-
18F	214.25	-	-
17F	272.51	68.72	-
16F	340.96	162.74	-
15F	448.45	280.78	-
14F	538.04	391.39	71.35
13F	661.35	528.68	159.37
12F	710.77	606.86	240.81
11F	749.27	671.53	305.45
10F	785.86	729.27	384.76
9F	837.13	795.14	512.33
8F	880.01	848.50	623.31
7F	934.40	910.21	777.88
6F	978.14	960.01	915.01
5F	1067.75	1053.52	1019.92
4F	1088.46	1086.87	1082.43
3F	1093.24	1091.51	1084.50
2F	1109.78	1105.69	1088.88
1F	1116.84	1106.47	1101.26
GF	1126.84	1120.97	1108.05
PL	1132.09	1123.52	1111.28

3.2.2 Storey Displacement

Table 3.7 Storey Displacement of G+14, G+17, G+20 Structures

Floor	Storey Displacement (m) for G+20 Structure	Storey Displacement (m) for G+17 Structure	Storey Displacement (m) for G+14 Structure
20F	0.0304	-	-
19F	0.0295	-	-
18F	0.0288	-	-
17F	0.0280	0.0250	-
16F	0.0264	0.0240	-
15F	0.0253	0.0233	-
14F	0.0241	0.0224	0.0196
13F	0.0223	0.0210	0.0187
12F	0.0202	0.0192	0.0174
11F	0.0179	0.0172	0.0158
10F	0.0155	0.0150	0.0140
9F	0.0131	0.0127	0.0120
8F	0.0108	0.0105	0.0100
7F	0.0091	0.0089	0.0086
6F	0.0079	0.0078	0.0075
5F	0.0067	0.0066	0.0064
4F	0.0055	0.0054	0.0053
3F	0.0041	0.0040	0.0039
2F	0.0029	0.0029	0.0028
1F	0.0018	0.0018	0.0018
GF	0.0008	0.0008	0.0008

Following figures show the comparative storey shear graph by both response spectrum and time history method for G+ 14, G+17, G+20 structures.

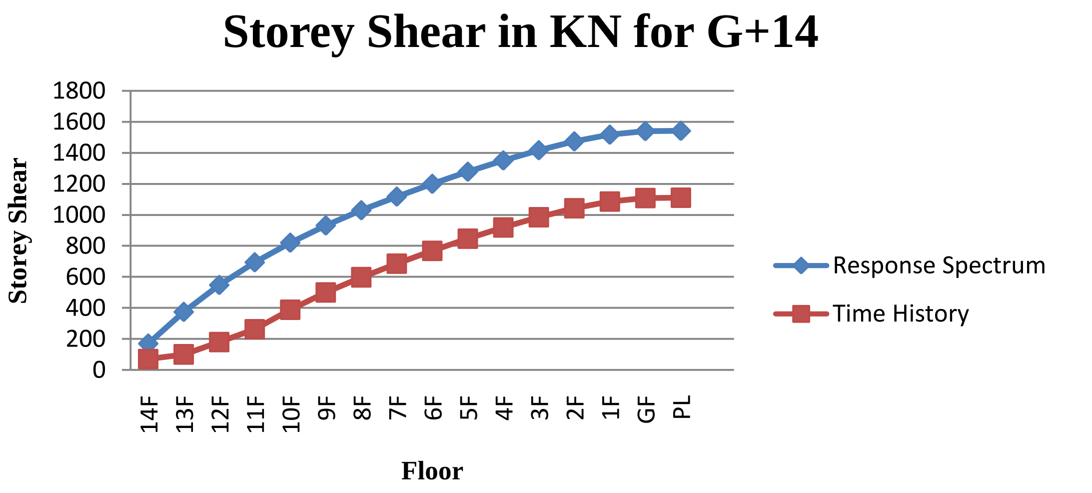

Fig. 4 Storey Shear in KN for G+14 Structure

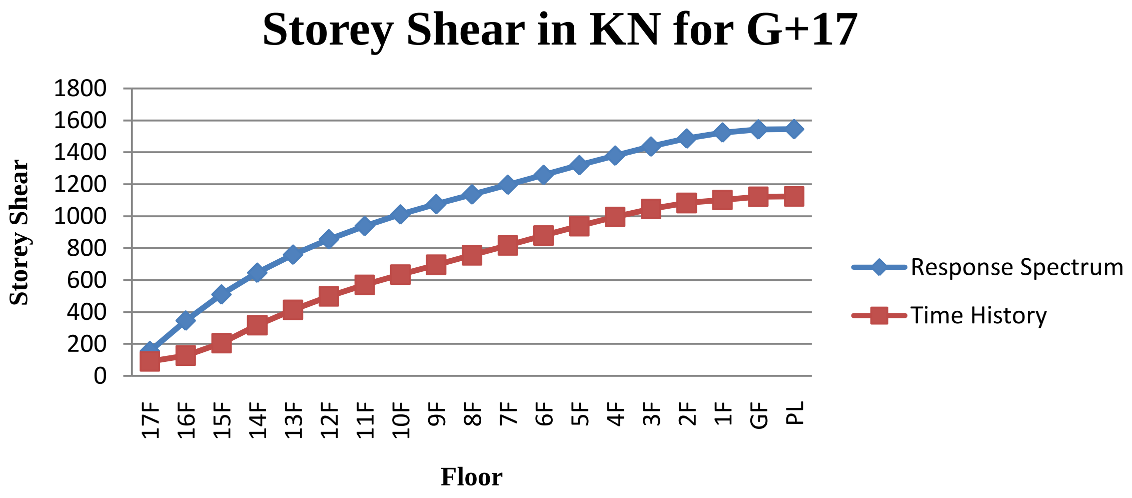

Fig. 5 Storey Shear in KN for G+17 Structure

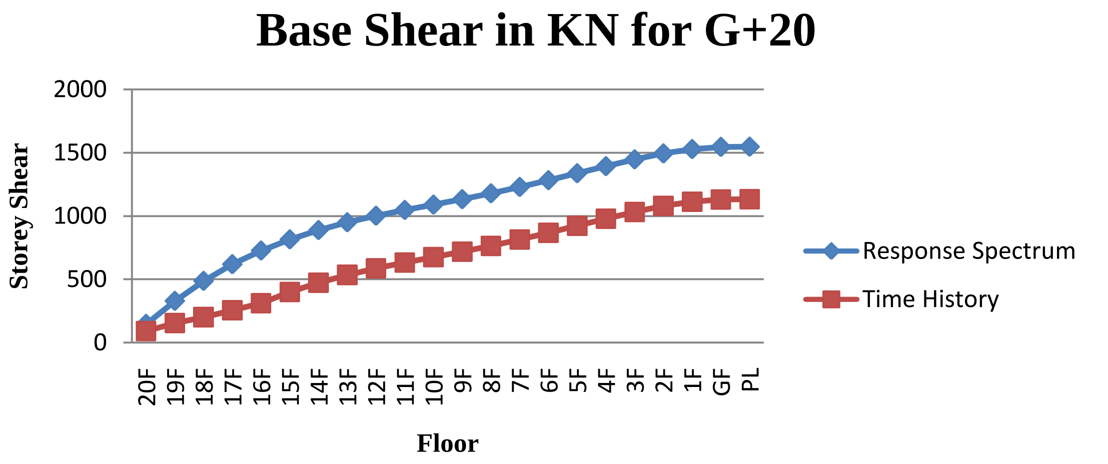

Fig. 6 Storey Shear in KN for G+20 Structure

Following figures show the comparative storey shear graph by both response spectrum and time history method for G+ 14, G+17, G+20 structures.

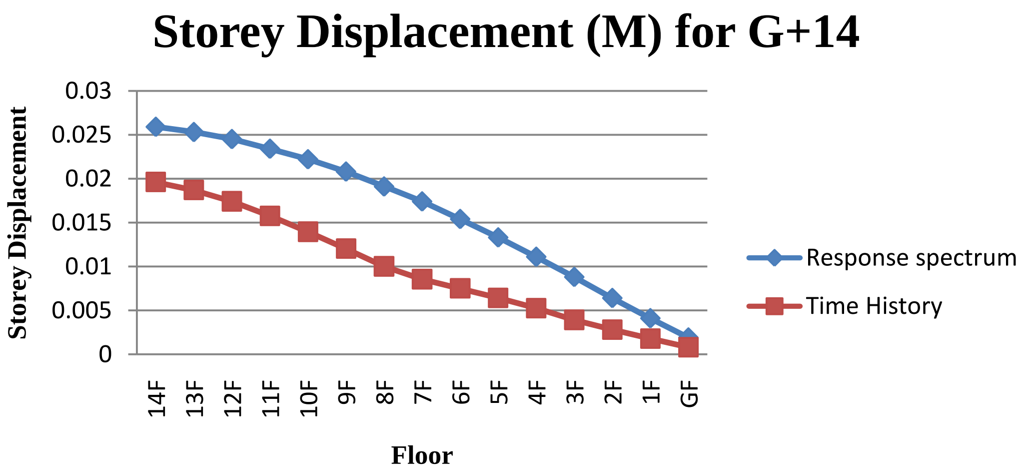

Fig. 7 Storey Displacement in M for G+14 structure

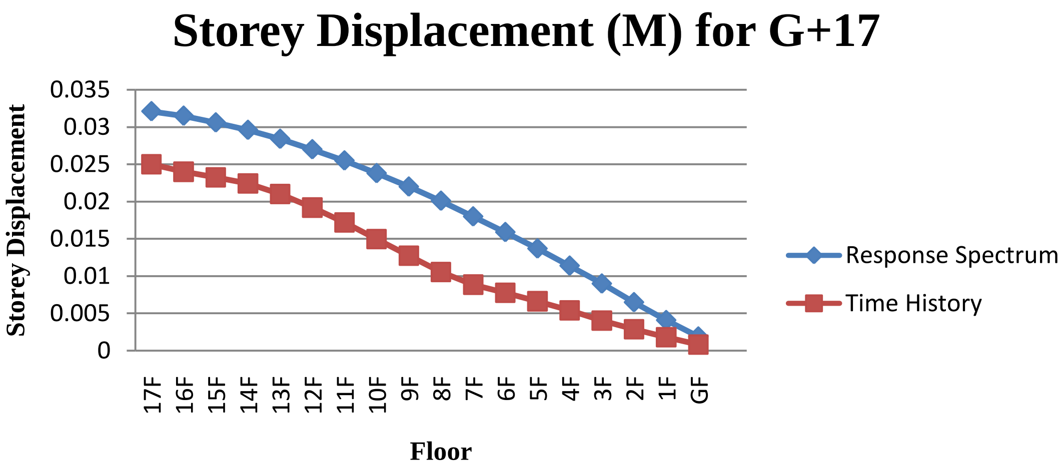

Fig. 8 Storey Displacement in M for G+17 Structure

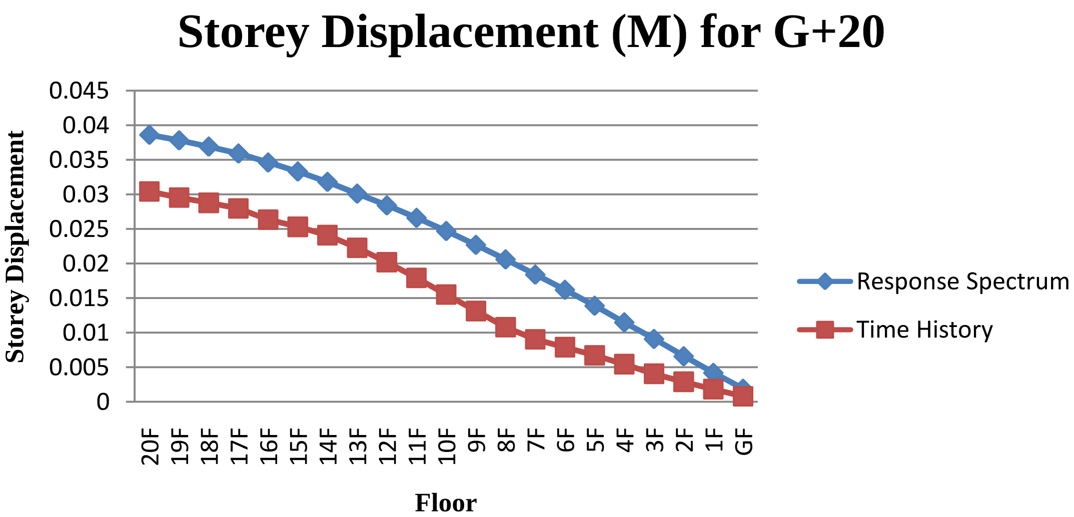

Fig. 9 Storey Displacement in M for G+20 Structure

4. CONCLUSION

The study is based on linear and nonlinear analysis of multistorey structure for finding base shear, storey displacement and time period.

1. The storey shear results obtained for G+14, G+17, and G+ 20 by response spectrum method are respectively 37%, 30.63%, and 34.24% more than those obtained by time history method.
2. The storey displacement results obtained for G+14, G+17, and G+ 20 by response spectrum method are respectively 44.59%, 30.63%, and 34.24% more than those obtained by time history method.
3. From results it is observed that time period of structure increases with increase in height.
4. As base shear depends on weight of structure, it is observed that it increases with increase in height both by response spectrum and time history method.
4. From results it is recommended that time history analysis should be performed as it predicts the structural response more accurately than response spectrum analysis.

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