Non-Linear Dynamic Analysis of Earthquake Resistant Reinforced Concrete Building

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Abstract - *Ground motion due to earthquake can cause severe damage to the structures thus a threatening to the mankind. In order to take protection against the damage of structures due to strong ground motion, it is important to know its characteristics. The most important and useful dynamic characteristics of an earthquake are peak ground acceleration, frequency and duration. These characteristics play an important role in studying the behavior of buildings under the earthquake ground motion. There are different methods of seismic analysis of building. Among the different methods of seismic analysis of structure time history analysis method is one of the most important method for structural seismic analysis generally when the estimated structural response is nonlinear in nature. In this project I am doing non-linear dynamic analysis on RC buildings with and without shear wall with different codes. As the IS 1893-2016 is latest revision so to know new provisions this code is taken into consideration. Also, to know the other countries codal provision Eurocode 8 -1998 is also taken into consideration. It is commonly recognized that nonlinear time-history analysis method is the most correct way for simulating response and behavior of structures exposed to strong levels of seismic excitation. There are two methods of analysis one is linear method and second is nonlinear method. In linear and nonlinear analysis there are sub types one is static and another is dynamic. "Nonlinear time history analysis is known for simulating a building behavior under severe earthquake more proper than other methods" [10].*

Key Words: Non-linear Dynamic analysis, Storey-displacement, Storey – drift, Pushover analysis, Time history analysis

1. INTRODUCTION

"Nonlinear dynamic analysis uses the combination of ground motion records with a detailed structural model, therefore is capable of producing results with moderately low uncertainty" [11]. "In nonlinear dynamic analyses, the detailed structural model subjected to a ground motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using methods such as the complete quadratic combination and square-root-sum-of-squares" [11]. As noted, the goal of structural analysis is to get useful information for design. If there is significant nonlinear behavior in a structure, it is moderate to expect that a nonlinear analysis will give better information and results than a linear analysis, because it is basically more rational. Nonlinear analysis is currently used mostly for retrofit, where the behavior can be complex, and the cost savings realized by allowing nonlinear behavior can justify the added analysis costs. For new design, methods based on linear analysis may be sufficient. Nonlinear analysis has the potential to provide much improved data and results for expecting the amount of damage, and hence for determining earthquake risk.

2. METHODOLOGY

Nonlinear time history analysis is conducted on ETAB for G+10 Storey building with shear wall and also building without shear wall. Seismic performance factors are described in details. After performing response spectrum analysis, the basic model is used for nonlinear analysis. Here time history nonlinear analysis is performed. Their time histories are considered. They are Imperial valley, Northridge, Elcentro. Both material and geometric non linearity is defined. In case of material non linearity auto hinges are applied according to ASCE 41-13 at 0.05L and 0.95L. For beams degree of freedom is defined as M3 and for column degree of freedom is three i.e. P-M2-M3. Column are check for both cases i.e. flexure and shear. In geometric non linearity P-Δ effect is considered. Geometric non linearity gives idea about strain and displacement behavior under nonlinear zone and material non linearity gives idea about stress and strain behavior under nonlinear zone. For time history analysis all ground motion is scaled with respective to time.

3. MODEL DEFINITION

For the research building with symmetrical plan has taken into consideration. Two types of building model are used. One is with shear wall and another is without shear wall. Key assumptions have to be made in order to validate the comparison procedure and their corresponding results. Identifying the proper variables in the comparison study is also of great importance. Detailed model definitions considering various prospects are presented in the following.

3.1 Material

Concrete material is used in this research. For the building which modelled using Indian code has HYSD 415 rebar. Also, Eurocode model has same properties as Indian code had according to their code.

3.2 Configuration of Building

For seismic evaluation, building location governs the intensity of the earthquake loading on structure and also its configuration. The loading data along with section properties and seismic parameters are given in following tables. Building models are symmetrical in plan.

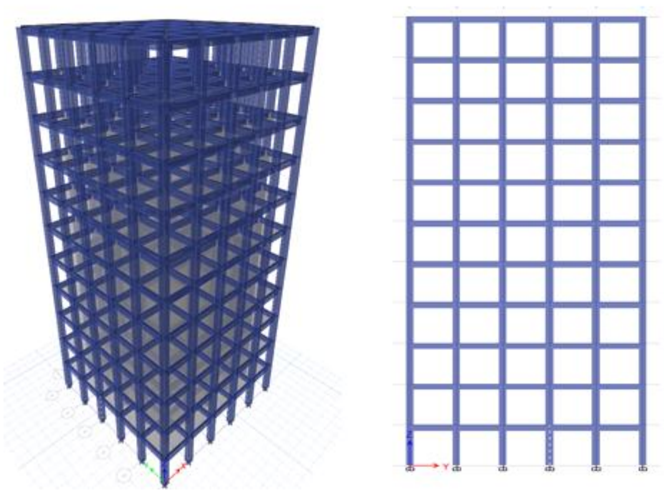

Figure 1. FEM Modelling of Building without Shear Wall

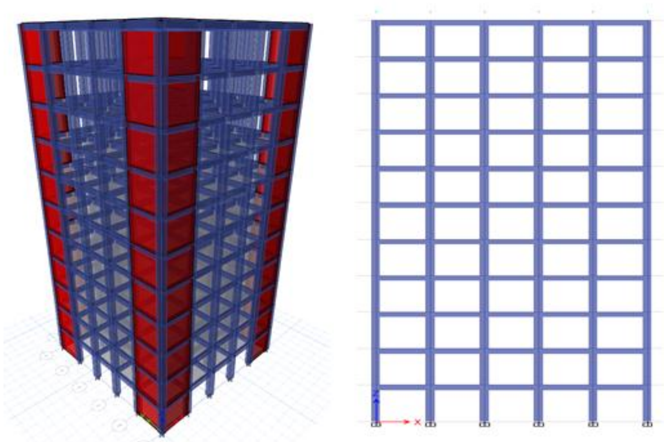

Figure 2. FEM modelling of building with shear wall

3.3 Loading and Other Data

General plan dimensions along with loading and material data are listed below. Building is considered as commercial building. According to commercial building loading data are considered. All beams, columns, slabs and shear walls are designed using M25 grade. For the building model with Eurocode design has C20 grade concrete for all beams, columns, slabs and shear wall.

- Plan area – 15m x 15m
- No. of Storey – G+10
- Storey height – 3m
- DL – self weight
- LL- 4KN/m2
- Grade of concrete - M25 and C25

Each bay is of 3 meters and beam size is of 450x250mm. Similarly, selections of building sections are done with the help of software analysis under ETAS and each load combination. These sections are listed below in the table 1.

Beam size	450x250
Column size	500x500
Slab depth	150
Shear wall thickness	300

Table 1. Section properties

3.4 Seismic Parameters

The behavior of all models is studied according to seismic zone of India (IS-1893:2016 part 1) and zone III is considered. Soil type is considered as medium soil. Importance factors and response reduction factors are 1.5 and 5 respectively. They are also shown in table 2.

Zone factor	0.16
Importance factor	1.5
Response reduction factor	5
Soil type	II

Table 2. Seismic parameters

4. RESULT AND DISCUSSION

4.1 Storey Displacement by Time History Analysis

Following table x and graph x shows the result of storey displacement obtained by doing time history analysis on building without shear wall. The storey displacement for Eurocode design building has more than IS code design.

Storey	Displacement	
	IS-Code	Eurocode
11	16.859	29.433
10	16.388	28.539
9	15.636	27.126
8	14.57	25.175

7	13.198	22.735
6	11.556	19.871
5	9.687	16.661
4	7.652	13.169
3	5.508	9.472
2	3.315	5.69
1	1.24	2.124
0	0	0

Table 3. Storey Displacement of Building without Shear Wall (NTHA)

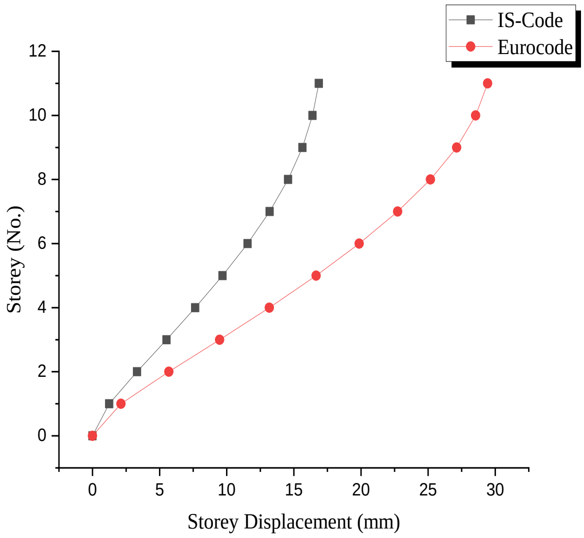

Fig 3. Storey Displacement of Building without Shear Wall (NTHA)

Following table x and graph x shows the result of storey displacement obtained by doing time history analysis on building with shear wall. The storey displacement for Eurocode design building has more than IS code design

Storey	Displacement	
	IS-Code	Eurocode
11	8.082	24.75
10	7.3	22.323
9	6.472	19.763
8	5.603	17.088
7	4.703	14.346
6	3.794	11.577
5	2.903	8.852
4	2.057	6.277
3	1.295	3.954
2	0.663	2.017
1	0.208	0.629
0	0	0

Table 4. Storey Displacement of Building with Shear Wall (NTHA)

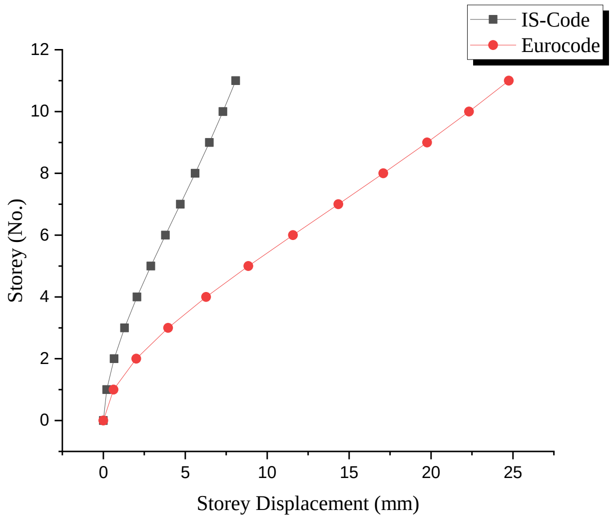

Fig 4. Storey Displacement of Building with Shear Wall (NTHA)

4.2 Storey Drift by Time History Analysis

From the fig x and table x, the results of the storey drift of building without shear wall is obtained by doing time history analysis. It is observed that Indian code has less storey drift while Eurocode has more storey drift. The max limiting value of storey drift is 0.004 x H as per IS 1893-2016, where H is storey height. According to that max permissible storey is 12mm in this design. So, as per that drift values are within limit

Storey	Drift	
	IS-Code	Eurocode
11	0.00016	0.000299
10	0.000254	0.000472
9	0.000356	0.000652
8	0.000458	0.000815
7	0.00055	0.000955
6	0.000625	0.001073
5	0.000681	0.001166
4	0.000716	0.001232
3	0.000731	0.00126
2	0.000691	0.001189
1	0.000413	0.000708
0	0	0

Table 5. Storey Drift of Building without Shear Wall (NTHA)

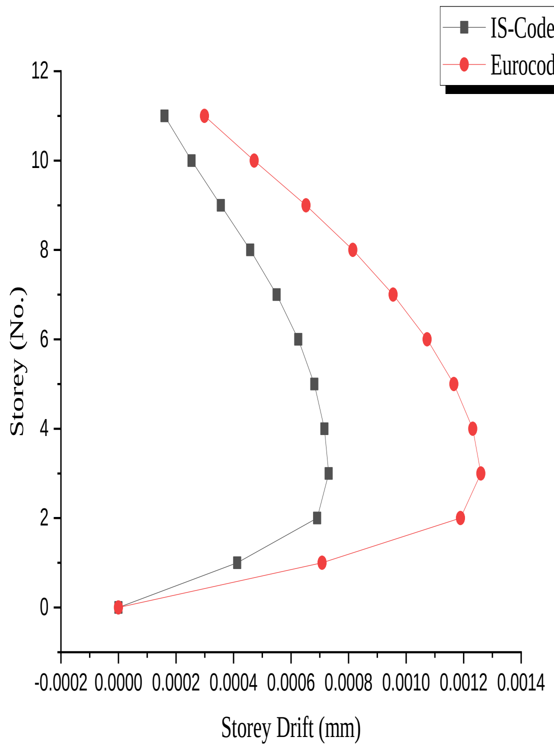

Fig 5. Storey Drift of Building without Shear Wall (NTHA)

Following tables x and fig x shows the result of storey drift in building with shear wall. From the result it clearly seen that shear wall provision in building greatly reduces the storey drift. Also, the values are within limit according to respective codes.

Storey	Displacement	
	IS-Code	Eurocode
11	0.000261	0.000812
10	0.000276	0.000856
9	0.00029	0.000894
8	0.0003	0.000921
7	0.000304	0.000929
6	0.000298	0.000911
5	0.000282	0.000862
4	0.000254	0.000776
3	0.000211	0.000646
2	0.000152	0.000463
1	0.000069	0.00021
0	0	0

Table 6. Storey Drift of Building with Shear Wall (NTHA)

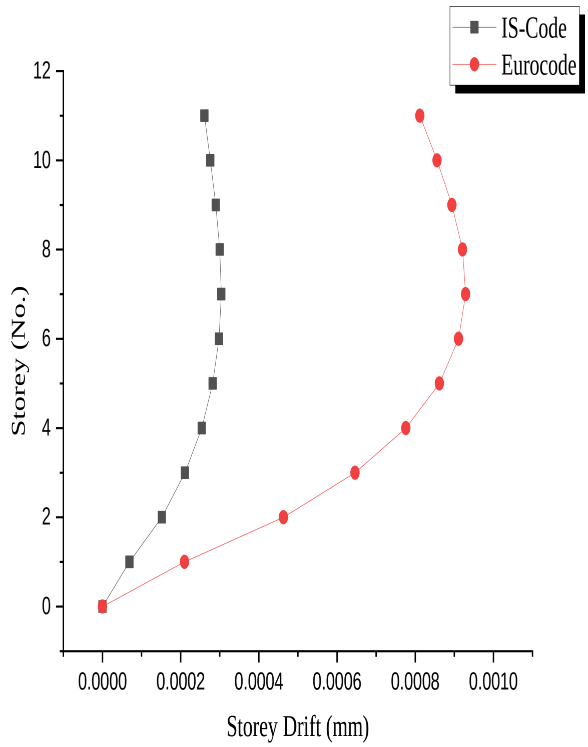

Fig 6. Storey Drift of Building with Shear Wall (NTHA)

5. CONCLUSIONS

Based on above results and discussion following conclusion are made,

1. According to results the storey displacement and storey drift is less for IS code design parameters than Eurocode design parameters.
2. Use of shear wall significantly reduces base shear, storey displacement and story drift in building in analyses.
3. The results show that storey displacement is 1.74% more in case of Eurocode design parameters than IS code in building without shear wall and 3.06 %more in building with shear wall.
4. Also, storey drift is 1.86% more in case of Eurocode design parameters than IS code in building without shear wall and 3.1%more in building with shear wall.
5. By comparing seismic parameters under time history and response spectrum analysis time history analysis shows 1.31% and 1.2% more base shear, 1.01% and 1.61% more roof displacement, 9.04% and 12.72% more overturning moment for building with shear wall and without shear wall respectively than response spectrum analysis.

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