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Seismic Response of Soft Storey on High Rise Building Frame

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Abstract

The modern trend is toward taller and slender high rise structure is also requiring first storey for parking for vehicle or large space. Due to this functional requirement, the first storey has lesser strength and stiffness as compared to upper storey. As per IS: 1893-2002, the soft storey is the one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffeners of the three stories above. So we have analyzed a 20 soft-story high-rise building frame as per Indian standard codes. The building is situated in seismic zone III. For this we have studied displacements, storey drift, inter-storey drift, storey shear etc. Hence from above study, it can be concluded that there is a need of accurate linear modeling and analysis of existing RC building for seismic response.

INTRODUCTION

The modern trend is toward taller and slender high rise structure is also requiring first storey for parking for vehicle or large space. Due to this functional requirement, the first storey has lesser strength and stiffness as compared to upper storey. As per IS: 1893-2002, the soft storey is the one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffeners of the three stories above. The above irregularity is one of the main reasons of high rise building damages of earthquake. The seismic response of soft storey on high-rise buildings and the effect of the seismic loads on the member forces of the basement are investigated in this study. Buildings between approximately 23m to 150m high can be considered high-rises structure. Severe structural damage suffered by several modern buildings during recent earthquakes illustrates the importance of avoiding sudden changes in lateral stiffness and strength. Recent earthquakes that occurred have shown that a large number of existing reinforced concrete buildings are vulnerable to damage or even collapsed during a strong earthquake. While damage and collapse due to soft storey are most often observed in buildings, they can also be developed in other types of structures. The lower level containing the concrete columns behaved as a soft storey in that the columns were unable to provide adequate shear resistance during the earthquake. Due to the severe shortage of land and for effective use of the sites for new constructions in areas in the city, multi-purpose buildings have been built frequently to date. Many high-rise buildings with setback damage were observed during recent earthquakes. The purpose of this study is to investigate the effect of structure on the dynamic behavior of high rise buildings.

The reinforced concrete and steel are common materials used for the structural system of high-rise buildings. The structures are high and lead to higher lateral loads, mainly due to wind and earthquake loads in comparison with lower buildings. If structural irregularities are not properly taken into consideration, construction cannot be said to be a resistant one no matter the highest quality concrete is used. Just like an illness in one part of the body affects the whole body, so does an irregularity in a constructions. Nearly 85-90 % of the collapsed and damaged buildings had soft storey in high rise building. . High rise buildings having open ground story for parking facilities is a common construction practice in the whole of India.

High rise building with soft storey, the seismic force distribution is dependent on the distribution of stiffness and mass along the height. In buildings with soft first storey, the upper storey being stiff, undergo smaller inter-storey drifts. However, the inter-storey drift in the soft first storey is large. The strength demands on the columns in the first storey for the buildings is also large, as the shear in the first storey is maximum.The concept of the soft storey is an attempt and find the actual response in a building by allowing the first-storey and also different soft storey column to yield during an earthquake and produce energy-dissipation action.

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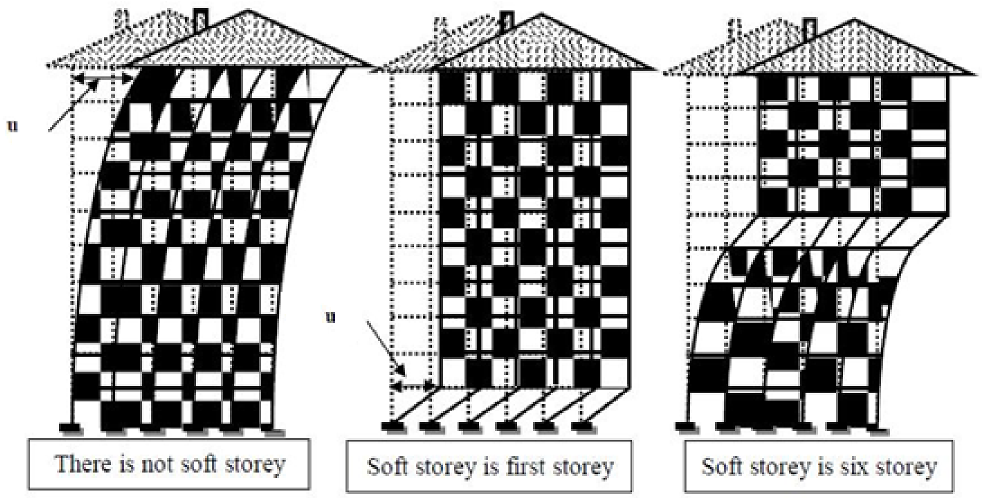

Figure 1: Behaviour of Soft-Storey in Earthquake

1. High Rise Building

The high rise building is generally conceder as one is the taller than the maximum height which people are willing to walk up it thus requires mechanical vertical transportation. This includes a rather limited range of building uses, primarily residential apartments, hotels, and office buildings, through occasionally including retail and educational facilities. High-rise building is defined as a building 23 meters or greater in height.

2. Analysis Procedures

Seismic action can be represented in various forms, such as ground acceleration or velocity, time-history (recorded or artificial), power spectrum, and response spectrum. The form of seismic action to be used in seismic resistance verification depends on the importance and complexity of the structure under consideration. Ground acceleration or velocity, time-history represent the direct form of representation of` seismic action, which is used to calculate the structural response, and hence, action effects. Response spectra, however, already imply the calculation of structural response. In the case where the design seismic loads are determined on the basis of response spectra, only the calculation of action effects is needed.

Four standard procedures are commonly used for seismic analysis of buildings, two linear procedures, and two nonlinear procedures. The linear procedures are termed the Linear Static Procedure (LSP) and the Linear Dynamic Procedure (LDP). The nonlinear procedures are termed the Nonlinear Static Procedure (NSP) and Nonlinear Dynamic Procedure (NDP).

1. Linear Static Procedure (LSP)
2. Linear Dynamic Procedure (LDP)
3. Nonlinear Static Procedure (NSP)
4. Nonlinear Dynamic Procedure (NDP)

3. Analysis Procedures Selection

Seismic analysis is a subset of structural analysis and is the calculation of the response of the building structure to earthquake and is a relevant part of structural design where earthquakes are prevalent. The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behavior of the overall structure. The analysis may be static or dynamic in approach as per the code provisions.

Thus broadly we can say that linear analysis of structures to compute the earthquake forces is commonly based on one of the following three approaches:

1. An equivalent lateral procedure in which dynamic effects are approximated by horizontal static forces applied to the structure. This method is quasi-dynamic in nature and is termed as the Seismic Coefficient method in the IS code.
2. The Response Spectrum Approach in which the effects on the structure are related to the response of simple, single degree of freedom oscillators of varying natural periods to earthquake shaking.
3. Response History Method or Time History Method in which direct input of the time history of a designed earthquake into a mathematical model of the structure using computer analyses.

Two of the above three methods of analysis, *i.e.* Seismic Coefficient Method and Response Spectrum Method, are considered for the analysis of buildings studied here. Details of these methods are described in the following section. The seismic method of analysis based on Indian standard 1893:2002 (Part – 1) is described as follows:

1. Equivalent Static Analysis
2. Response Spectrum Analysis

4. Lateral displacements

As the number of stories in the basement increases, the rotation at the bottom of columns in the first story increases because of the flexibility introduced by the basement structure. Due to this phenomenon, the lateral stiffness decreases resulting in the increase of the lateral displacements.

5. Ductility

Ductility of a structure or its member is the capacity to undergo large inelastic deformation without significant loss of strength or stiffeners. The earthquake resistant design, the term ductility is used for evaluating the performance of structure, by indicating the quantity of seismic energy, which may be dissipated through plastic deformation. The use of the ductility concept gives the possibility to reduce the seismic design force and allows producing some controlled damage in the structure also in case of strong earthquakes.

In the practice of plastic design of structure, ductility defines the ability of a structure to undergo deformation after its yield, without any significant reduction in ultimate strength. The ductility of structure allows us to predict the ultimate capacity of a structure, which is the most important criteria for designing structure under conventional load.

6. Storey Drift and Deflection

Story drift is the displacement of one level relative to the other level above or below Lateral deflection is the predicted movement of a structure under lateral loads; and story drift is defined as the difference in lateral deflection between two adjacent stories. During an earthquake, large lateral forces can be imposed on structures; the 1997 UBC Code requires that the designer assess the effects of this deformation on both structural and non-structural elements. Lateral deflection and drift have three primary effects on a structure; the movement can affect the structural elements (such as beams and columns); the movements can affect non-structural elements (such as the windows and cladding); and the movements can affect adjacent structures. Without proper consideration during the design process, large deflections and drifts can have adverse effects on structural elements, non-structural elements, and adjacent structures.

7. Storey Drift Limitation

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height, For the purposes of displacement requirements only (see IS 1893 (PART-I) 2002 Clouse 7.11.1, 7.11.2 and 7.11.3 only), it is permissible to use seismic force obtained from the computed fundamental period (T) of the building without the lower bound limit on design seismic force specified in 7.8.2. There shall be no drift limit for single storey building which has been designed to accommodate storey drift.

8. Inter-Storey Drift Ratio

Lateral drift and inter-storey drift are commonly used damage parameter in structural analysis. In this study lateral drift of the building frame was analyzed for earthquake load coming from long direction. Inter storey drift was also evaluated and tabulated which is defined by

$\Delta=(\delta\mathbf{i} - \delta\mathbf{i\text{-}1})/hi$

Where,

$\delta i - \delta_{i-1}$ = displacement between successive storey,

h_i = storey height

OBJECTIVE OF STUDY:

As the previous sections mentioned, there is a need to evaluate the seismic response of structures, and there are technical limitations which are preventing this need from being met. The seismic performance of high-rise building which essentially comprises of analysis and design of the structure when subjected to earthquake loading is to be studied the project and also perform the seismic response after high-rise building apply p-delta, displacement , story drift

The objective of the project can be mentioned as:

- Analysis & design of 20 soft-story high-rise building frame as per Indian standard codes. The building is situated in seismic zone III.
- Response analysis of building to study various parameters including displacement and drift. soft story
- To study the IS Codes in regard to seismic design of building.

METHODOLOGY:

To meet the above mentioned objectives of the present study, following steps are adopted:

- An extensive survey of the literature on the behavior and performance of high-rise R/C structures is to be performed for updating regarding the soft-storey which has been done in part.
- There RC buildings twenty storied are designed with different level soft-storey, for as per Indian Standard for Zone-III as per IS1983-2002.

- Analytical study of twenty storied RC building with different level soft-storey is performance considering up gradation to using STAAD-Pro-2006, including deficiency & weakness observation.
- Seismic evaluation by static analysis and dynamic analysis method.
- Comparison result for different level soft storey.

RESULTS & GRAPHS:

STAAD.Pro2006 is used to compute the response of a twenty storey buildings frame for various floors taken soft storey for flexible floor diaphragm Linear Dynamic (response spectrum).

Results from Response Spectrum analysis are observed for the natural frequencies and modal mass participation, Displacements of structure and storey drift.

This chapter presents the results of Analysis of RCC frame. Analysis of RCC frame under the dynamic load has been performed using STAAD.Pro2006 software

Table 1 Displacement of Various Floor Soft Storeys by Response Spectrum Analysis

DISPLACEMENT IN (mm)						
FLOOR LEVEL	**1st Floor Soft Storey**	**4th Floor Soft Storey**	**8th Floor Soft Storey**	**12th Floor Soft Storey**	**16th Floor Soft Storey**	**20th Floor Soft Storey**
20	223.3	236.0	239.3	230.4	235.5	224.3
16	192.1	204.6	207.5	199.2	200.1	184.3
12	146.7	158.1	160.6	151.7	137.8	137.7
8	99.2	109.1	108.3	87.3	88.9	88.8
4	47.4	53.1	37.2	36.3	36.7	36.6
1	10.4	4.1	3.8	3.0	3.8	3.8
0	0.0	0.0	0.0	0.0	0.0	0.0

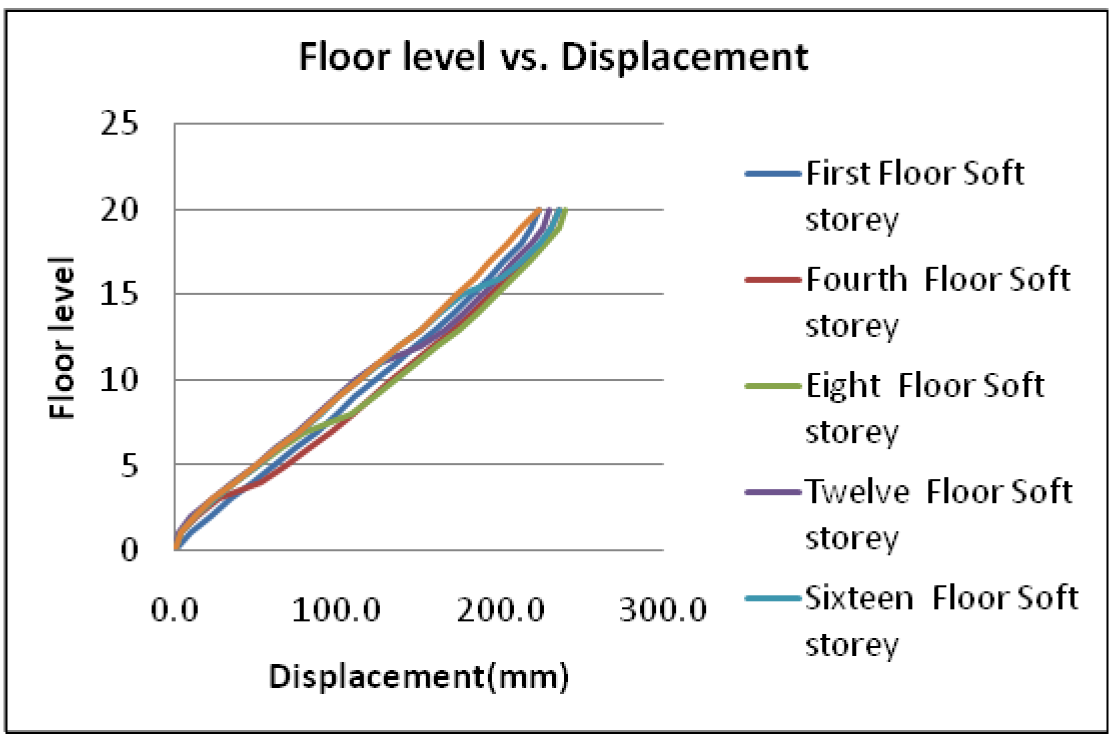

Figure 2: Displacement of Response Spectrum Analysis (Graphical representation)

Table 2: Storey Drift of Various Floor Soft Storey's by Response Spectrum Analysis

STOREY DRIFT IN %						
FLOOR LEVEL	1St Floor Soft Storey	4th Floor Soft Storey	8th Floor Soft Storey	12th Floor Soft Storey	16th Floor Soft Storey	20th Floor Soft Storey
20	0.1436	0.3806	0.3860	0.3717	0.3798	0.3618
16	0.3251	0.4091	0.4150	0.3983	0.4169	0.3840
12	0.4107	0.4162	0.4227	0.4214	0.3827	0.3825
8	0.4153	0.4196	0.4512	0.3639	0.3705	0.3699
4	0.4383	0.4422	0.3100	0.3023	0.3055	0.3049
1	0.2084	0.1351	0.1282	0.1014	0.1272	0.1270
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

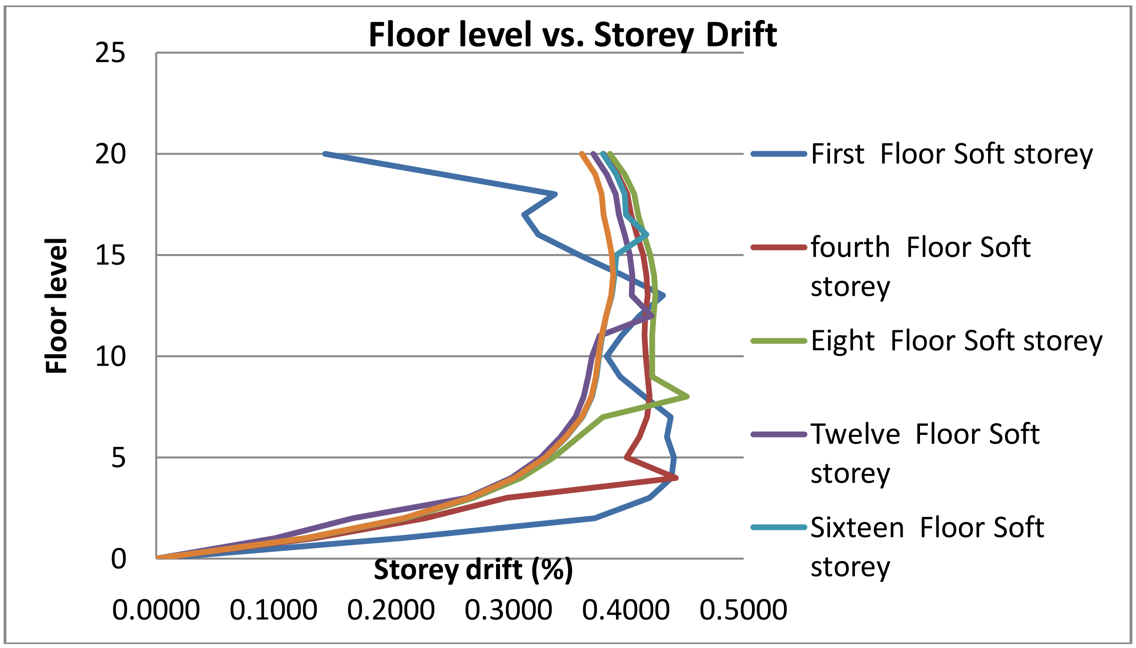

Figure 3: Storey Drift of Response Spectrum Analysis (Graphical representation)

Table 3: Inter Storey Drift of Various Floor Soft Storey's by Response Spectrum Analysis

INTER STOREY DRIFT %						
FLOOR LEVEL	1St Floor Soft Storey	4th Floor Soft Storey	8th Floor Soft Storey	12th Floor Soft Storey	16th Floor Soft Storey	20th Floor Soft Storey
20	0.3602	0.1438	0.1423	0.1400	0.1490	0.2277
16	0.3843	0.3304	0.3335	0.3287	0.4805	0.3343
12	0.3861	0.4227	0.4317	0.5456	0.4214	0.4228
8	0.3815	0.4326	0.5699	0.4135	0.4256	0.4252
4	0.3382	0.5245	0.4295	0.4150	0.4207	0.4198
1	0.2084	0.1351	0.1282	0.1014	0.1272	0.1270
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

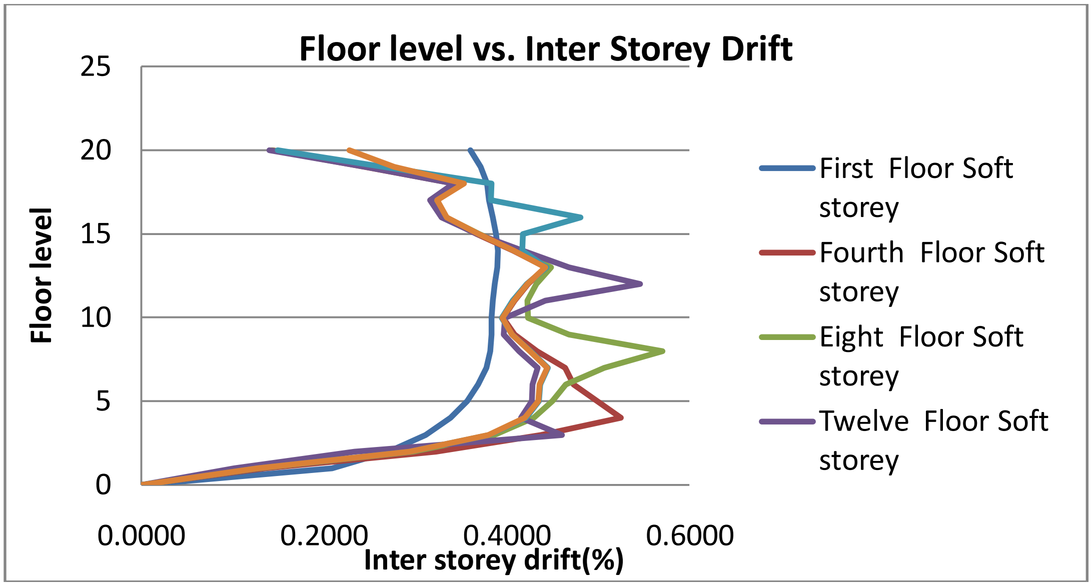

Figure 4: Inter Storey Drift of Response Spectrum Analysis

STOREY SHEAR (kN)						
FLOOR LEVEL	1St Floor Soft Storey	4th Floor Soft Storey	8th Floor Soft Storey	12th Floor Soft Storey	16th Floor Soft Storey	20th Floor Soft Storey
20	486.3	507.0	542.8	530.2	533.6	608.6
16	2311.6	2442.3	2536.5	2494.3	2596.9	2508.2
12	3138.2	3380.9	3409.6	3349.8	3333.7	3363.8
8	3843.7	4168.9	4262.1	4062.1	4189.0	4189.6
4	4636.8	5024.5	5016.0	4965.1	4998.8	4991.0
1	4906.0	5194.8	5188.8	5184.4	5182.0	5176.7
0	4906.0	5194.8	5188.8	5184.4	5182.0	5176.7

Table 4: Storey Shear of Various Floor Soft Storey's by Response Spectrum Analysis

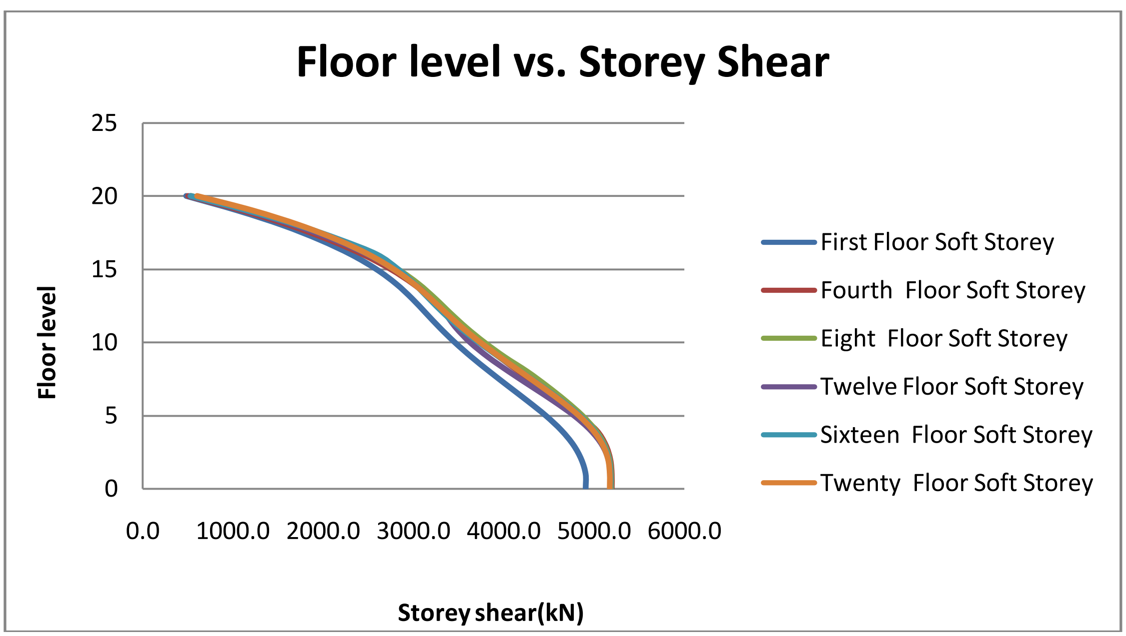

Figure 5: Storey Shear Drift of Response Spectrum Analysis (Graphical Representation)

Table 5: Overall Displacement Various Floor Soft Storey's by Response Spectrum Analysis

FLOOR LEVEL	STOREY DRIFT IN %				
	1	5	10	15	20
20	223.3	244.7	233.0	234.9	224.3
16	192.1	213.7	201.4	201.3	184.3
12	146.7	167.6	155.0	136.4	137.7
8	99.2	118.6	89.1	88.2	88.8
4	47.4	45.7	36.5	36.5	36.6
1	10.4	5.0	3.8	3.8	3.8
0	0.0	0.0	0.0	0.0	0.0

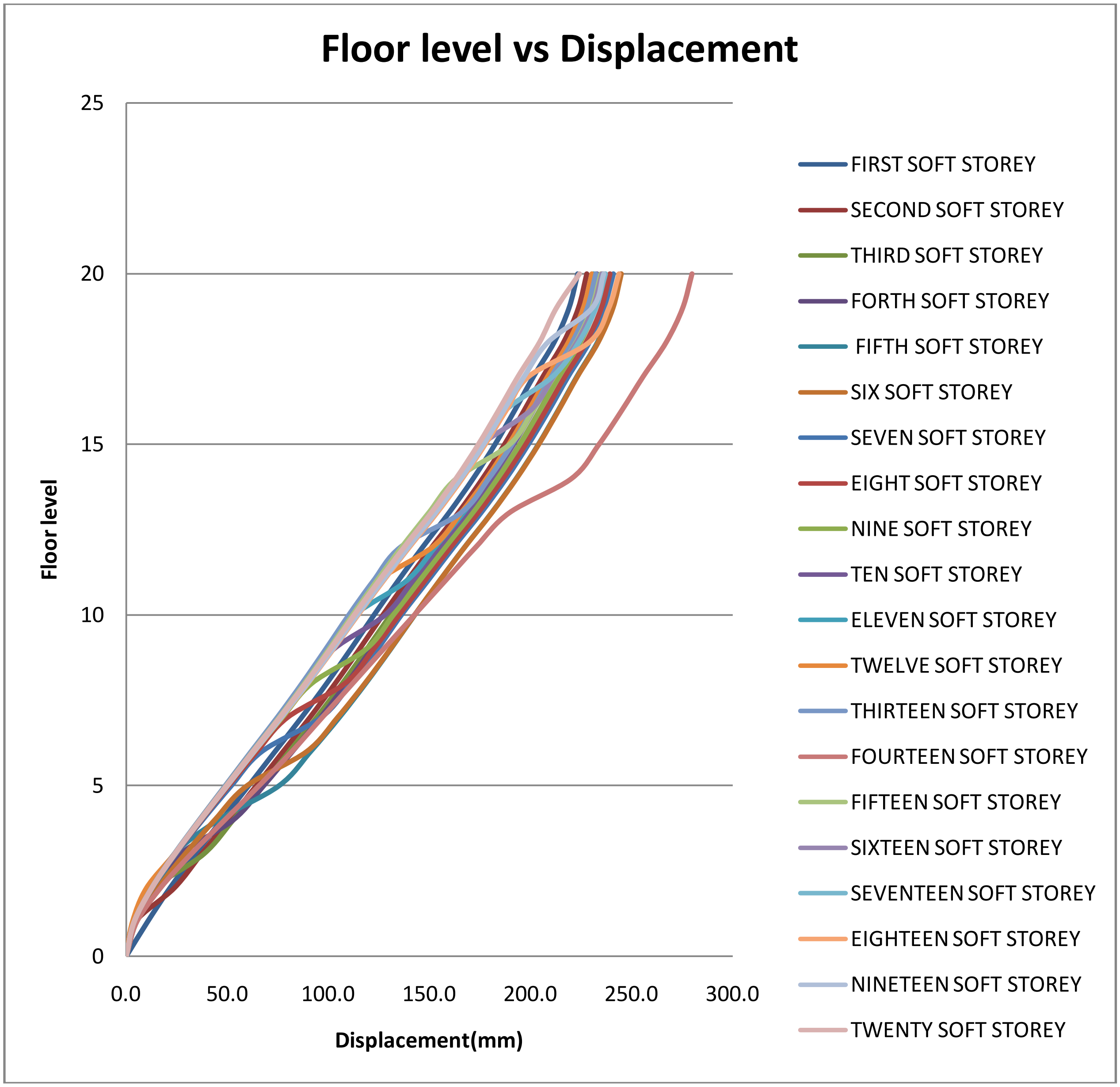

Figure 6: Overall Displacement of Response Spectrum Analysis (Graphical Representation)

CONCLUSION:

1. From above study, it can be concluded that there is a need of accurate linear modeling and analysis of existing RC building for seismic response.
2. Linear seismic performance based analysis and design procedures are necessary to be incorporated in Indian codes.
3. The maximum displacement observed in soft storey fourteen floor and minimum displacement in soft storey first floor.
4. As comparison to soft storey first floor to soft storey fourteenth floor is 25% more displacement and average all other soft storey 6% displacement.
5. The maximum storey drift observed in soft storey fourteen floor in 0.005 and it is more than 0.004 As per IS 1893-2002.
6. The maximum inter storey drift observed in soft storey fourteen floor in 0.006 and it is more than 0.004 As per IS 1893-2002.
7. It observed that this study in fourteenth floor is more effectively than other stories.

FUTURE SCOPE:

Recommendations for further research the following topics are recommended for future studies:-

- In this article, analysis is done in building with same dimension. The possibilities of application of proposed method to different plan dimension with different analysis methods like push over analysis, time history analysis (linear and non-linear).
- In this article, RCC structure considers. The possibilities of application of proposed method with steel structure.

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