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## Nonlinearity Effect on Building with Ground Soft Storey

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**ABSTRACT**: Basically, two types of nonlinearities are considered in the analysis of the building viz. geometric nonlinearity and material nonlinearity. Earthquake load mainly induce lateral displacement of the structure, the effect of gravity load acting on the structure's lateral displacement has been called the P-delta effect. P-delta is the secondary effect on moment and shear due to the action of vertical load, interacting with the lateral displacement of building resulting from seismic forces. Due to P-delta effect, geometric nonlinearity induces in the building which creates additional moment and shear. In the urban area buildings are constructed with open ground storey for parking and other purpose. A soft storey is one in which the lateral stiffness of storey is less than 70 percent of that in the storey above/below or less than 80 percent of the average lateral stiffness of the three storey above/below. During the earthquake it has been seen that due to development of excessive moment at the bottom and top of the ground floor, in ground soft storey, failure of the building occurs. Previous studies have shown that the many buildings had collapsed due to additional moment and shear at the base. No work is reported on steel building considering P-delta and soft storey effect. Hence, in this dissertation, an attempt has been made to study the effect of geometric nonlinearity on the seismic behavior of steel building considering P-delta and soft storey effect.

#### I. INTRODUCTION

The performance of a building during an earthquake depends on many factors including: the structure's configuration and proportions, its dynamic characteristics, the hysteretic behavior of the elements and joints, the type of nonstructural components employed, the quality of the materials and workmanship, adequacy of maintenance, the site conditions, the intensity and dynamic characteristics of the earthquake ground motion experienced. In the common linear elastic "first order" analysis P-delta effects are neglected. Whenever secondary effects due to structural deformations, such as delta, are included in the elastic analysis, it is no longer linear and reference is made to a "second order" analysis.

P-Delta is a nonlinear effect that occurs in every structure where elements are subject to axial load with the interaction of lateral displacement.



Figure 1: P-delta effect on column & Soft storey mechanism





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Large open areas with less infill and exterior walls and higher floor heights at the ground level result in soft stories. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below.



#### **II. LITERATURE REVIEW**

Literature survey was conducted on the works carried out by earlier researchers whose efforts have been devoted to study comparative analysis for different height of structures. The summary and gaps found in literature survey are discussed below.

#### Summary of Literature Review

The available literature review shows that performance of the structure is affected by soft storey and P-delta effect. Many of the researchers have worked on RCC building with open ground storey but, no work is reported on steel building considering soft storey effect along with P- delta effect on building.

Hence, in this dissertation, an attempt has been made to study the effect of geometric nonlinearity on the seismic behavior of steel building considering P-delta and soft storey effect.

#### Gaps in Literature Survey

- The present study can be extended by considering the soft storey at different level.
- The study may be further extended by changing the aspect ratio of the building and by considering different types of infill.
- The present work can be done by considering the different height of the soft storey at ground floor.
- Studies particularly targeted for effect of soft storey and height of the structure on overturning moment may be carried out.

#### **OBJECTIVE**

- To study the P-delta effect in steel building.
- To evaluate the performance of steel building considering ground soft storey.
- To study the parameters such as displacement, base shear and overturning moment considering soft storey and P-delta effects.





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#### **III. METHODOLOGY**

In this dissertation three steel building G+14, G+19 and G+24 storey is modeled and designed in SAP 2000 and MATLAB code has been written for analysis of multistory building using Newmark's linear acceleration method of seismic analysis. The parameters such as displacement, base shear, overturning moment and time periods are obtained under all considered earthquakes.

For the validation purpose 3 storey benchmark building is considered, validation has been done in SAP 2000 v16. The nonlinear time history analysis using Newmark's linear acceleration method is carried out for the recorded ground motion of five earthquakes. The cases studied are tabulated in the below table-

Cases	Mode of control	No. of buildings	No. of Earthquake	No. of cases	Total cases
Ι	Without P-delta and without soft storey	3	5	3 x 5 = 15	
Π	Only P-delta	3	5	3 x 5 = 15	
III	Only soft storey	3	5	3 x 5 = 15	60
IV	With P-delta and with soft storey	3	5	3 x 5 = 15	

#### Table 1: Cases studied

#### **Table 2:** Properties of Ground Motions

Sr. No.	Earthquake	Year	Magnitude
1	Bhuj	2001	7.7
2	Chamoli	1999	6.8
3	El-Centro	1940	7.2
4	Koyna	1967	6.5
5	Uttarkashi	2001	6.6

#### IV. MODELLING & ANALYSIS

In SAP 2000, its advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, velocity-dependent dampers, and base isolators. Nonlinear analyses can be static and/or time history, with options for nonlinear time history dynamic analysis and direct integration. From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP 2000 is the easiest, most productive solution for structural analysis and design needs.

SAP 2000 is very much suited for analysis of structures like skyscraper, bridges etc. because of its flexibility in accounting for arbitrary geometry, loading, water pressure and variation in material properties.





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Figure 3: Plan of G+ 14 storied





#### V. RESULTS

#### **G+14 Storey Steel Building Displacement**

It is observed that for G+14 storey building, as the floor level increases, displacement increases in all cases under all earthquakes. Maximum displacement is obtained in Case IV (P-delta + soft. storey) under all earthquakes with a maximum percentage increase of 1614.30% in displacement in Bhuj (2001) earthquake.



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#### G+14 Storey Steel Building Base Shear

It is observed that for G+14 storey building, as the floor level increases base shear decreases in all cases under all earthquakes except in Bhuj (2001) earthquake where the base shear increases with increase in height of building. The base shear in Case III (only soft storey) and Case IV (P-delta + soft storey) are found to overlap under all earthquakes except Bhuj (2001) earthquake. Reduction in base shear has been noted in Case IV (P-delta + soft storey) under Chamoli (1999) and Koyna (1967) earthquake. Maximum reduction of 38.45% in Case IV (P-delta + soft storey) is obtained under Koyna (1967) earthquake. Maximum increment of 29.85% in the base shear is obtained in Case IV (P-delta + soft storey) under El-Centro (1940) earthquake. Under Uttarkashi (2001) earthquake the base shear is found to be same till 7<sup>th</sup> floor for all cases and it is found to be varying after 7<sup>th</sup> floor.

#### **G+14 Storey Steel Building Overturning Moment**

Maximum overturning moment is observed in Case IV (P-delta + soft storey) under Bhuj (2001) and El-Centro (1940) earthquakes. The maximum percentage increase of 9.98% in overturning moment is obtained under Bhuj (2001) earthquake. It should be noted that maximum overturning moment of 38018.77 KN-m (Case II) for G+14 storey structure has occurred under Chamoli (1999) earthquake.

#### **VI. CONCLUSIONS**

- 1. The drift in the first storey columns is very large for buildings with ground soft storey.
- 2. Effect of non-linearity due to P-delta effect is predominant than that of the soft storey effect.
- 3. As far as displacement and base shear is concerned, effect of nonlinearity due to P- delta with soft storey effect is more for low rise building, whereas for high rise building P- delta effect is predominant.
- 4. As the floor level increases base shear decreases, with maximum base shear is observed in P-delta with soft storey case.
- 5. The overturning moment of the steel structure gradually increases up to the mid height of the structure and then decreases.
- 6. It can be concluded that the performance of building under P-delta and soft storey effect should be considered and remedial measures should be taken.

#### VII. FUTURE SCOPE

- 1. The present study can be extended by considering the soft storey at different level.
- 2. The study may be further extended by changing the aspect ratio of the building and by considering different types





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of infill.

3. The present work can be done by considering the different height of the soft storey at ground floor.

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