A Study to Observe Effect of Ground Soft Storey on Structural Performance of Multistoried R.C.C Buildings

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DECLARATION

Declared that except where specified by reference to other works, the studies embodied in thesis is the result of investigation carried by the Authors themselves. Neither the thesis nor any part has been submitted to or is being submitted elsewhere for any other purposes.

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DEDICATION

The thesis is dedicated to our Parents and Teachers who have inspired us for making this effort possible

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At first, the Authors would like to convey their profound gratitude to Almighty Allah for giving them the strength and patience to bring about the successful completion of this thesis work.

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ABSTRACT

The rapid growth of urban population and the consequent pressure on limited space have considerably influenced city residential development upward resulting in high rise buildings. Now-a-days majority of the high-rise buildings intend to provide spacious open areas (to provide parking facilities, shops, superstores, other special facilities etc.) at the ground floor for the inhabitants of the residence or other commercial buildings. To facilitate this demand of the building owners, the Structural Engineers design building structures avoiding use of infill walls at the functional area of the ground floor, but maintaining the partition walls in the other floors, which results in an asymmetric structural behavior under service loads. These structures are currently getting special attraction to be analyzed for understanding their structural behavior completely. Keeping this scope in mind, the current study aims to investigate structural behavioral pattern of multistoried RCC buildings to observe ground soft storey effect on these buildings. The study is carried out to analyze ten RCC residential buildings (five with soft storey and the other five without soft storey) by means of numerical finite element analysis software ETABS. A number of structural parameters (base shear, time period, drifts, column reaction forces) have been determined involving load combinations of vertical as well as lateral loads in both directions of building plan. Afterwards, each of these attained outputs have been compared for buildings with soft storey and buildings without soft storey for better understanding. It is observed that, in case of time period and base shear, almost similar values are obtained for buildings with a particular height (for buildings with soft storey and buildings without soft storey). For the cases of support reactions of interior, exterior, or corner columns, the buildings without ground soft storey experiences much higher support reaction compared to those with ground soft stories. Overall, buildings with soft storey have higher storey drift values then those without soft storey. Especially for earthquake loads, the storey drift values of buildings with soft storey vary significantly than those of buildings without soft storey. But for wind loads this, variations is not so prominent. The observations found from the present study addresses several important concerns and it also indicates that more study should be carried out to properly reveal the structural behavior of not only the RCC structures, but also steel and steel-concrete composite buildings, buildings with various slab systems (flat slab, flat-plate slabs, waffle slabs etc.).

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CHAPTER 1
INTRODUCTION

1.1 General

With the demand of the rapid growth of urban population and decreasing of land it has become necessary to construct tall buildings wherever possible. In civil engineering projects sustainability is a very important aspect to consider in designing structures for expected service life. In general low rise buildings are designed according to the required design criteria with a loading system not considering much effect of lateral loads. In case of tall buildings, the wind load and earthquake load are major forms of lateral loads and play vital role as they tend to deflect the whole structure considerably. In this project, the present study aims to investigate a number of RCC buildings with different number of stories (both with and without ground soft story) to determine some structural parameters (for example: base shear, time period, drifts, column reaction forces, beam shear and moment values etc.) The buildings under study have been calculated by means of numerical analysis.

1.2 Objective and Significance of the Study

In recent times, construction of tall buildings has become a prime concern for fulfillment of accommodation facilities. In designing such tall structures, the deflection analysis (drift analysis) of the whole structure is very important. Moreover, adequate lateral stiffness is one of the major considerations in the design of a tall building. The present research work is expected to establish the following objectives:

i. To analyze ten RCC residential buildings with different stories (five with ground soft storey and the rest five without ground soft storey) due to vertical and lateral loads (wind load and earthquake load) by means of Numerical Investigation.

ii. To determine the structural parameters, namely- base shear, time period, maximum storey drifts, column reaction forces for each building.

iii. To make a comparative study for every parameter obtained for different buildings (with and without soft story) and to explain variation in structural behavior.

iv. To make recommendations for future study based on findings of the current study.

1.3 Organization of the Study

The report is organized to best represent and discuss the problem and findings that come out from the studies performed.

Chapter 1, introduces the problem, in which an overall idea is presented before entering into the main studies and discussion.

Chapter 2, is Literature Review, which represents the work performed so far in connection with it collected from different references. It also describes the strategy of advancement for the present problem to a success.

Chapter 3, is all about principle of present study and also shows some figures associated with this study for proper presentation and understanding.

Chapter 4, is the corner stone of this thesis write up, which solely describes the computational investigation made throughout the study in details with presentation by many tables and figures followed by necessary discussions.

Chapter 5, the concluding chapter, summarizes the whole study as well as points out some further directions.

CHAPTER 2

LITERATURE REVIEW

2.1 General

There are some research works to study the overall structural behavior of multistoried RCC buildings with and without ground soft storey. But, these are not enough to properly address the effect of presence or absence of soft storey in a RCC building. Hence, the current research is hoped to investigate a number of RCC buildings with different stories for determination of some structural parameters (namely, base shear, time period, drifts, column reaction forces) involving load combinations of vertical as well as lateral loads in both directions of building plan. After the analysis, comparative study incorporating obtained parameters will be conducted for better understanding. This chapter outlines details of building components, loads coming on buildings, some special terms which are needed to understand very clearly before conducting research.

2.2 Component of a Building

There are a number of components in a building, which are mentioned and discussed below:

1. Roof: The roof forms the topmost component of a building. It covers the top face of the building.

Figure 2.1: Roof

2. Parapet: Parapets are short walls extended above the roof slab. It is generally used for flat slab.

Figure 2.2: Parapet

3. Lintel: Lintels are constructed above the wall opening like as, door or windows.

Figure 2.3: Lintel

4. Beam: A beam is a structural element that is capable of withstanding load primarily by resisting bending.

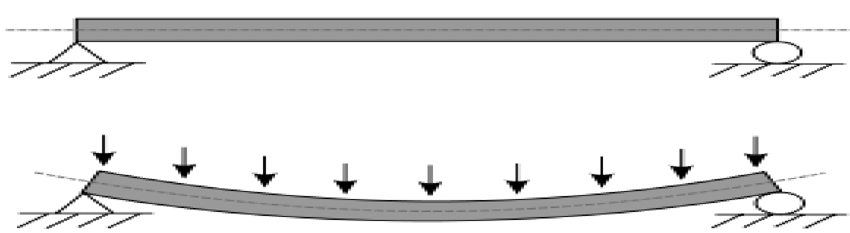


Figure 2.4: A simply supported beam without any load and under the action of compressive load (respectively)

5. Column: It also a vertical member of building. It constructed above the ground level

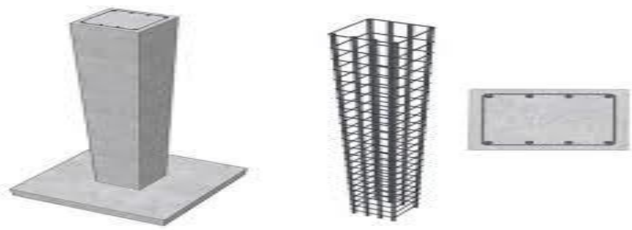


Figure 2.5: Column

6. Damp Proof Course (DPC): Damp proof course is generally usde on ground floor and top floor to resist water.

Figure 2.6: Damp Proof Course

7. Wall: Walls are the vertical members and they carry load and protect against the wind, sunshine, rain etc.

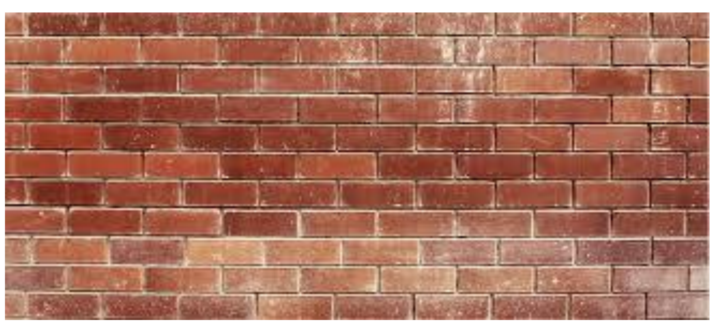


Figure 2.7: Wall

8. Floor: The floor is the surface laid on the plinth level. It directly carries vertical loads and transmit them to beams and columns.

Figure 2.8: Floor

9. Stair: Stair is like as a connector, which connects one floor to other floor. It is like a hanging slab and is designed using the concept of designing slabs.

Figure 2.9: Stair

10. Plinth Beam: Plinth beam is beam structure constructed either at or above the ground level to take up the load of the superstructure.

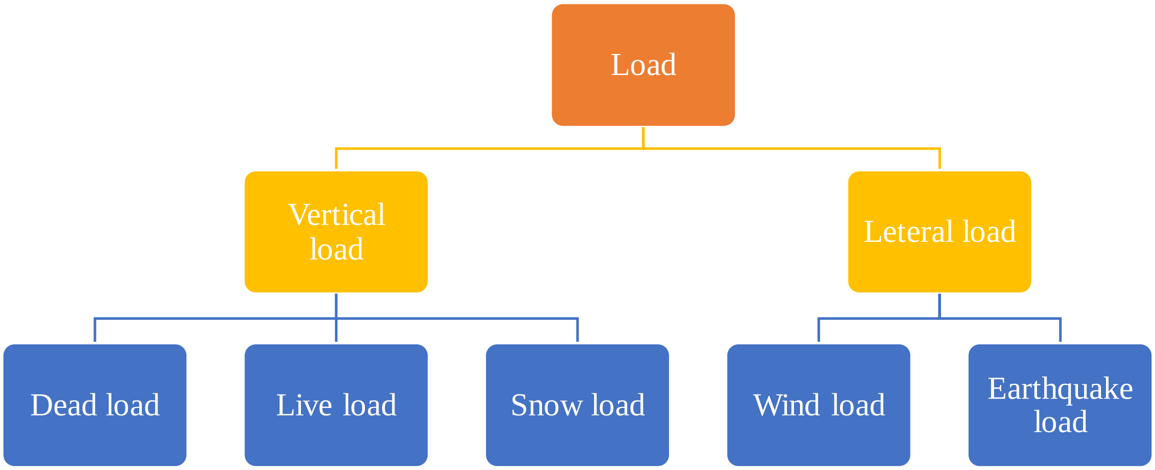
Figure 2.10: Plinth Beam

11. Foundation : Foundation is a structural unit that uniformly distributes loads from superstructure to the underlying soil.

Figure 2.11: Foundation

2.3 Type of Loads

Loads are the prime concern for a structure, for which a structure is designed to convey its users safety, comfort, functionality, reliability, sustainibility and so on. The loads coming on a building may be divided in following way:



Vertical Load: Gravity loads include all the vetical loads coming on a structure.

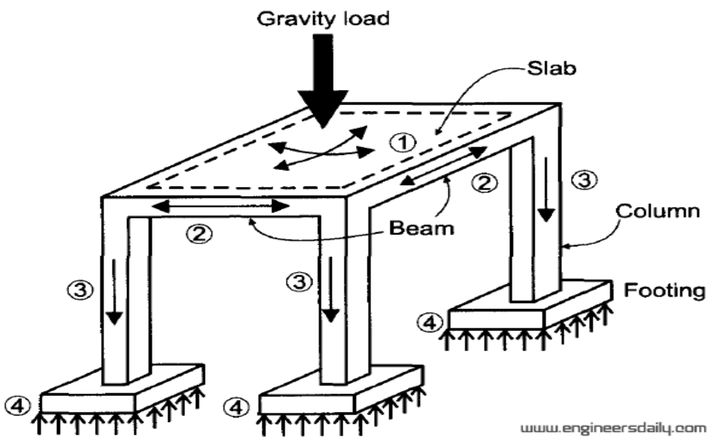


Figure 2.12: Vertical loads on a structure

Dead Load: All the permanent loads, which will sustain from the beginning of the structure built till the end of its service life are termed as dead loads.

Live Loads: The loads which come temporarily on a sturcture and may vary in magnitute time to time are termed as live loads.

Snow load: Design snow load for a sturcture is based on the ground snow load for its geopraphic location exposure to wind and its thermal, geometric and functional charactiristies.

Wind Load: Wind load is the natural load governed by the wind speed and its air density onto a building.

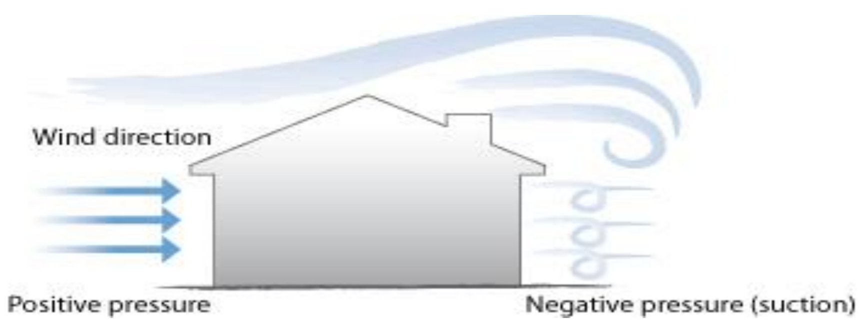


Figure 2.13: Wind Load

Earthquake Load: Seismic loading is one of the basic concept of earthquake engineering, which means application of an earthquake generated agitation tp a structure.

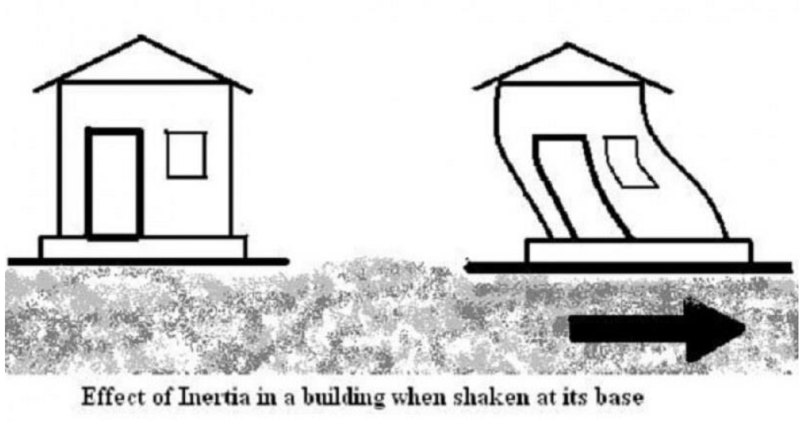


Figure 2.14: Earthquake Load

2.4 Some Important Terms for Building Analysis

Drift: Drift (horizontal deflection) of a structure refers to its horizontal movement between its supports under lateral load (earthquake or wind load). Drift is caused by the accumulated deformation of each member, such as a column, beam, brace and shere wall.

At base of a tall structure, drift is usually zero. Drift is one of the most serious issues in tall building design, relating to the dynamic characteristies of the building during earthquake and strong winds.

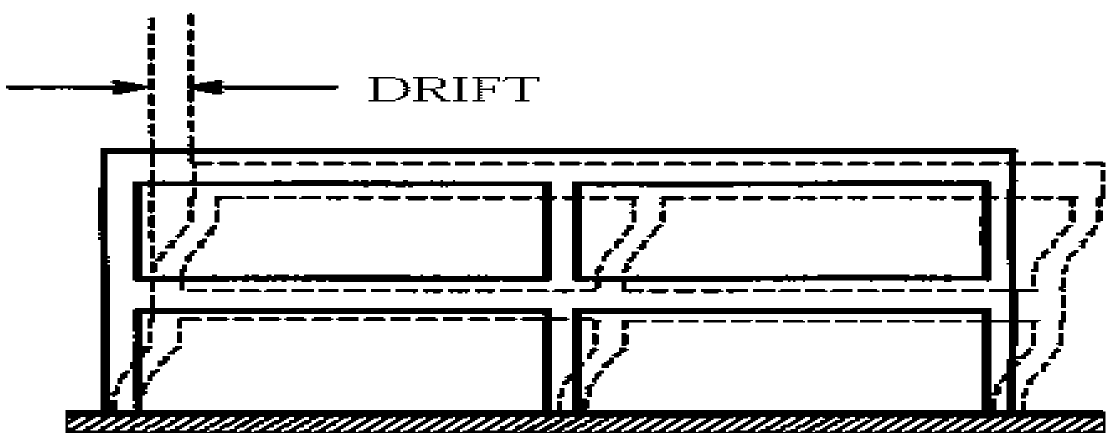


Figure 2.15: Drift on a building

Story Drift: Story drift is the difference of displacements between two consecutive stories divided by the height of that story. Story displacement is the absolute value of displacement of the storey under action of the lateral forces. The importance of story drift is in design of partitions/ curtain walls.

Soft Storey Building: A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average stiffness of the three storeys above.Recently, many high-rise buildings are designed to have an open first-floor area that is easily accessible to the public. These soft stories are good for functional purpose, but have inadequate shear resistanceor inadequate ductility (energy absorption capacity) to resist the earthquake-induced building stresses; therefore, may present a very serious risk in the event of an earthquake, both in human safetyand financial liability.

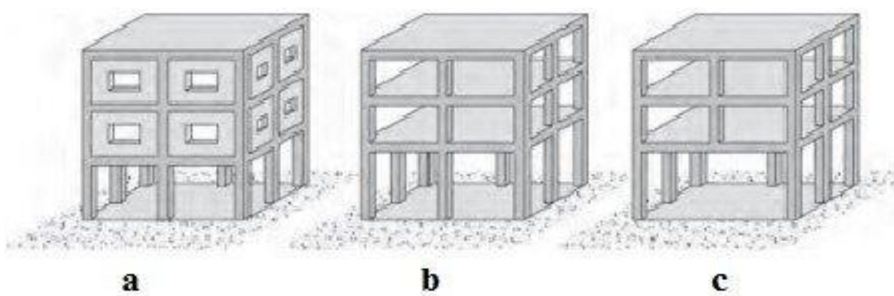


Figure 2.16: Different types of soft storey buildings

Base Shear: Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity.

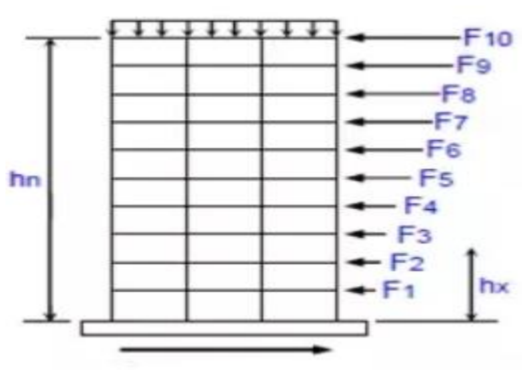


Figure 2.17: Base Shear

Structure Period:The determination of the fundamental period of a building is an integral part of the lateral load calculation. The structure period is the inverse of building frequency, when set to motion by lateral loads (wind or earthquake).Buildings with shorter fundamental periods attract higher seismic force, as the code based design spectrum exhibits higher accelerations at shorter periods.

Structure period, $T = C_t(h_n)^{3/4}$

2.5 Remarks

The present chapter discusses about the theories of buildings and the next chapter (chapter 3) will discuss about the overall methodology of entire study.

CHAPTER 3

METHODOLOGY OF PRESENT STUDY

3.1 General

Base shear, time period, drift, column reaction forces etc. are the cardinal parameters in building design. In this study, all these parameters have been determined by Numerical Analysis and also by following equations prescribed by BNBC-2006. This chapter will represent summary of methodology of the study in detail.

3.2 Available Options for Numerical Analysis

A large number of Computer Packages are available now for designing and analyzing structures, such as-

- ETABS
- STAAD.Pro
- ANSYS
- RISA
- RFEM5
- RSTAB8
- Dlubal
- LUSAS
- Tekla
- IES
- Strusoft&
- SAP
- ABACUS

They vary in degree of complexity and versatility. The above mentioned software's are used for various types of structural analysis such as design of foundation, Frame, Slab, Bridge etc. of these software's, ETABS-9.6 is efficient and relatively user friendly for static and dynamic analysis of building structures. The present study involves analysis of the building using ETABS -9.6.

3.3 Method Involved in Present Study

This project has been taken from a real project of Gulshan area. But for purpose of present study, ten RCC residential buildings (five with soft storey and other five without soft storey) have been recreated using the same plan. All these buildings have been investigated by means of numerical analysis (by ETABS). After that, the following parameters are determined and then compared by means of tables and graphs along with necessary explanations for better understanding.

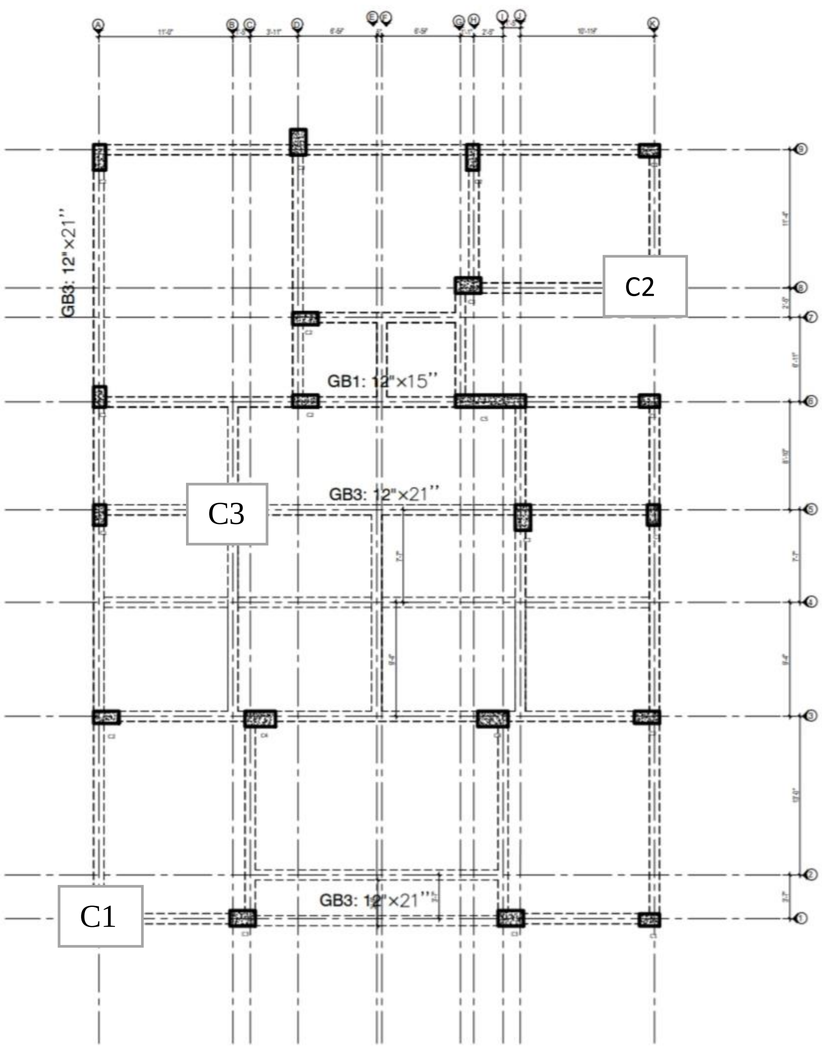


Figure 3.1: Plan of building under study

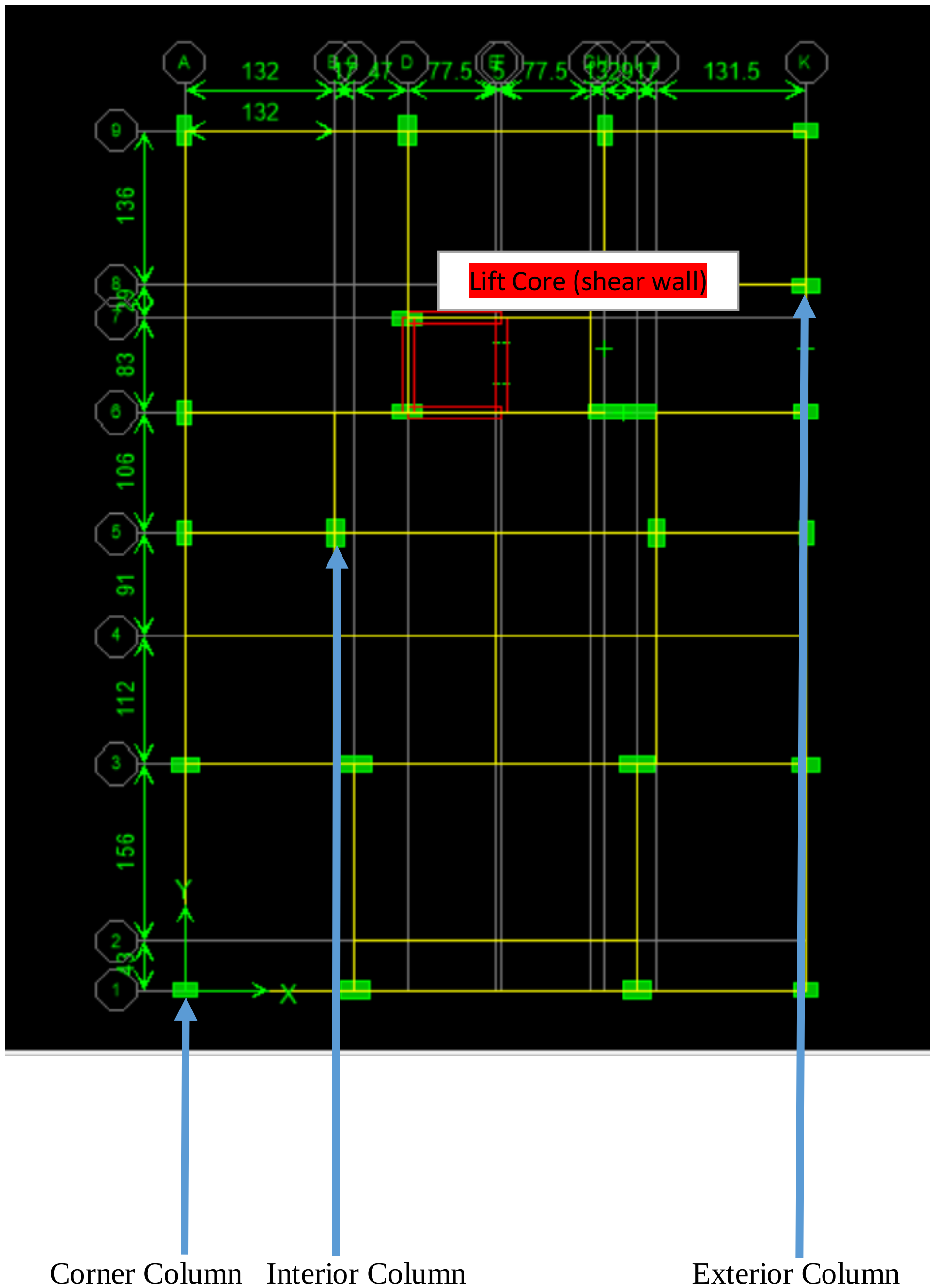


Figure 3.2: Lay-out plan of the building in ETABS

Table 3.1: Details of Buildings (Studied)

Building type	Building Storey				
With Soft Storey	6	9	12	15	20
Without Soft Storey	6	9	12	15	20

All the buildings have been analyzed numerically by means of ETABS 9.6 software.

List of Structural parameters: In the present study, the following parameters are determined:

- Base shear
- Time period
- Storey drifts and
- Column reaction forces

Table 3.2: List of Building Elements with Dimensions

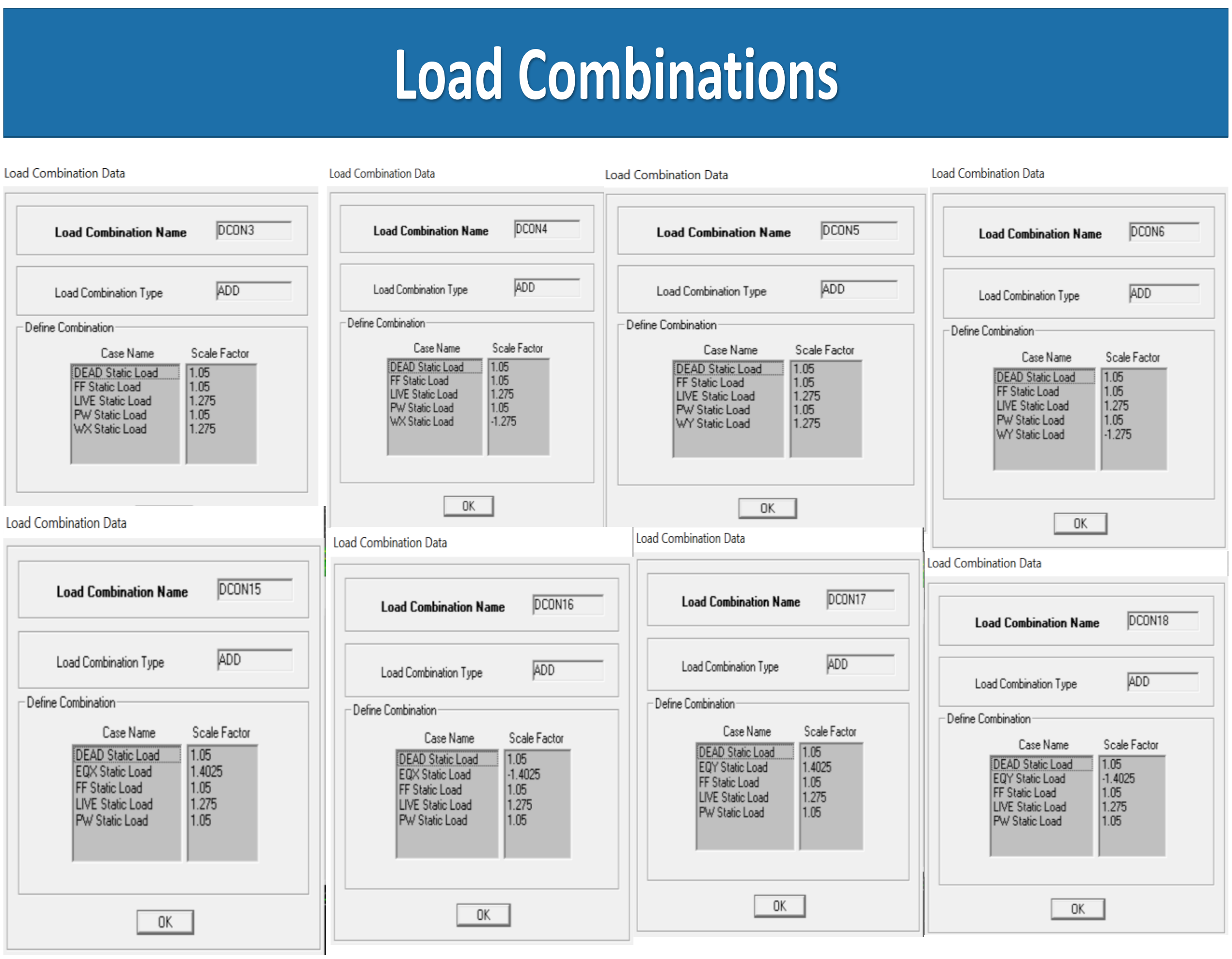
Columns:	Beams:	
C1: 12” x 20”	GB1: 12” x 15”	Shear Wall Thickness: 10 inch
C2: 12” x 25”	GB2: 12” x 18”	Slab Thickness: 5 inch
C3: 15” x 25”	GB3: 12” x 21”	Slab Area (per floor): 2817.12 ft^2 = 261.719 m^2
C4: 15” x 30”	B1: 10” x 15”	

Table 3.3: Input Loads for Analysis in ETABS

Load	Value (psf)
Dead Load (DL)	Calculated automatically in ETABS
Partition wall (PW)	25
Floor finish (FF)	25
Live load (LL) on slab	40
Live load (LL) on stair	100

All loads have been given input according to BNBC 2006 Code for residential buildings.

Table 3.4: List of Load Combinations (in ETABS)



Some qualitative figures (Figure 3.4, 3.5, 3.6 and 3.7) are extracted from ETABS after analysis of the structures:

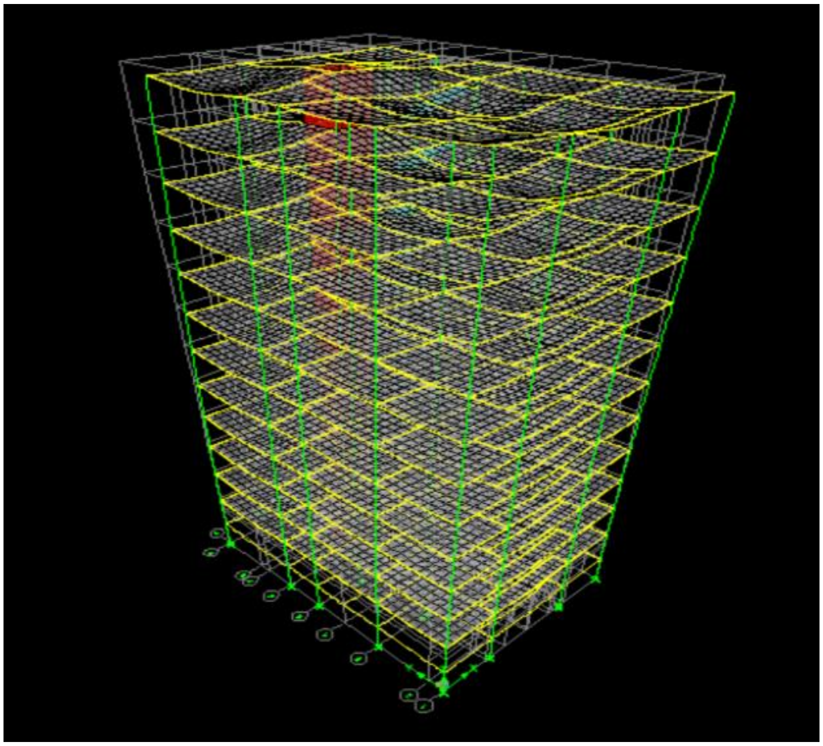


Figure 3.4: Deformed shape of the building (3D view)

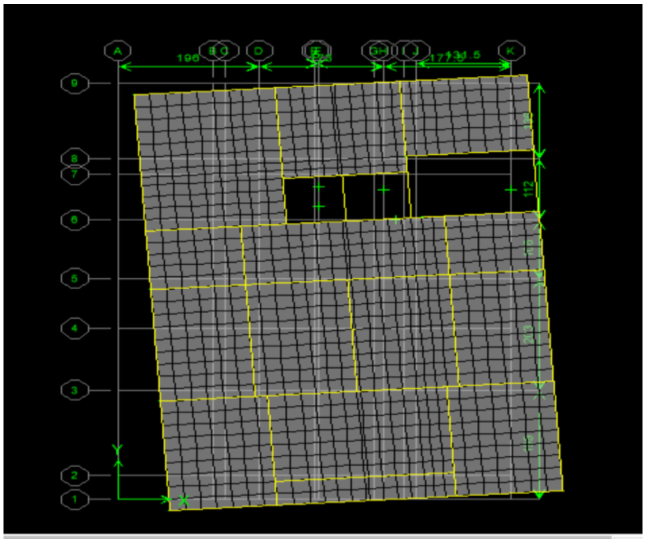


Figure 3.5: Deflection in X direction

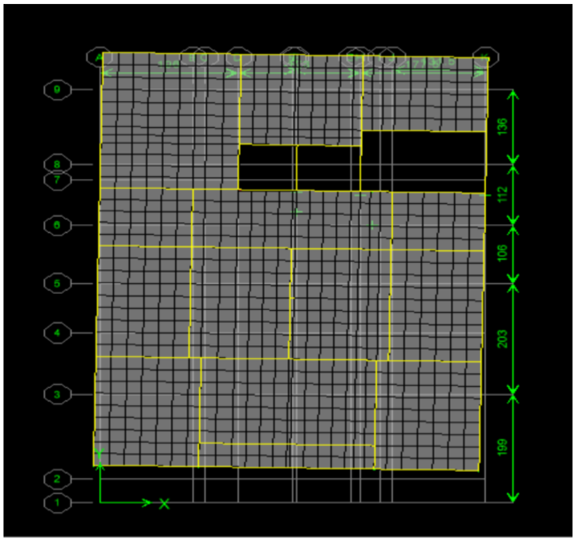


Figure 3.6: Deflection in Y direction

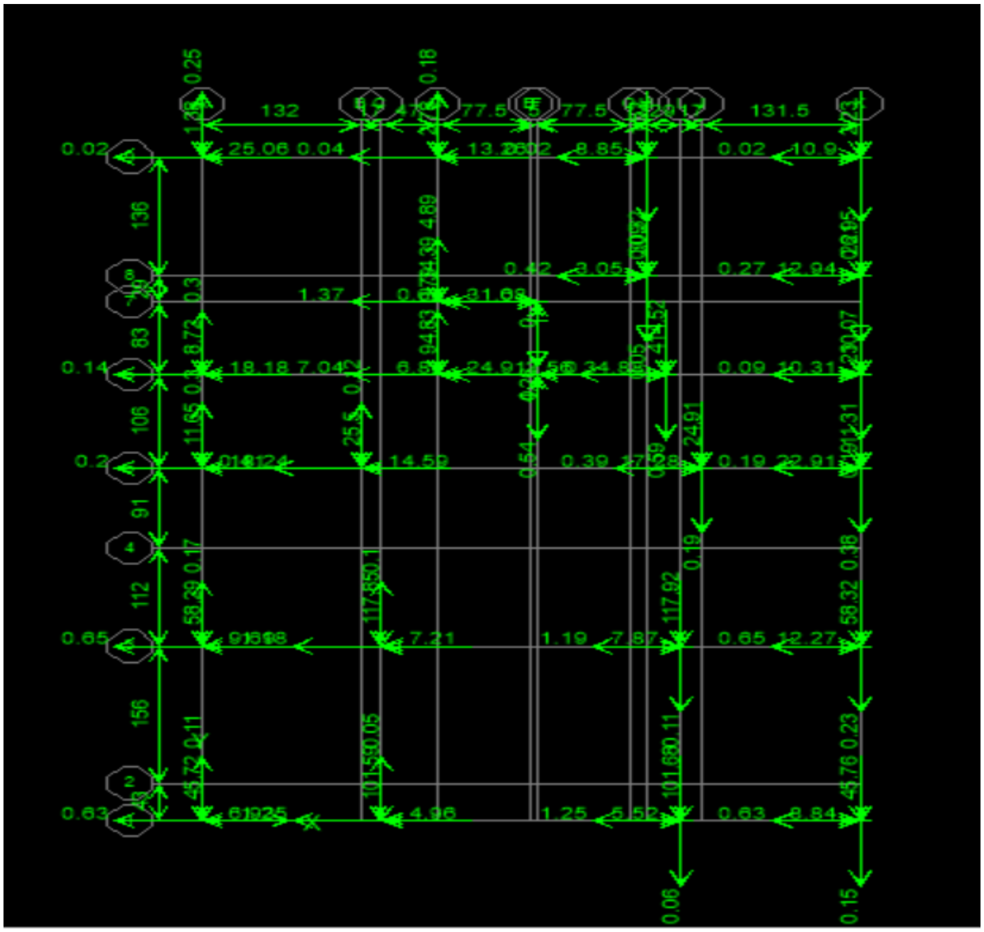


Figure 3.7: Column reaction forces at the basement

3.4 Remarks

The present chapter summarizes the information about the building under study with the location of Shear walls and core walls etc and also discusses step by step methodology of the whole study. The following chapter (Chapter 4) will present the results obtained from the study with detailed explanation.

CHAPTER 4

RESULT AND DISCUSSION

4.1 General

The present study involves determination of several parameters of a number of buildings with soft storey and without soft storey. The entire analysis has been carried out by means of ETABS and also by use of formulas recommended in BNBC 2006. After numerical analysis, storey drifts and column reaction forces of an exterior, an interior and a corner column have been obtained. Using formulas of BNBC-2006, time period and base shear of all the buildings have been determined. After obtaining all the study parameters, each of the parameters have been compared for buildings with different heights (with soft storey and without soft storey).

4.2 Presentation and Explanation of Results

In this thesis base shear, time period, drift, column reaction forces values (with and without soft storey) of the buildings under consideration have been determined using Numerical Analysis (ETABS). After that, the following parameters are compared by means of tables and graphs and also with necessary explanation for better understanding. The obtained results have been summarized both in tabular and graphical form for better representation:

4.2.1 Time Period of Buildings (With and Without Soft Storey):

Time Period of Buildings (With and Without Soft Storey)					
Building Storey	6	9	12	15	20
With Soft Storey (sec)	.646	.875	1.086	1.284	1.593
Without Soft Storey (sec)	.646	.875	1.086	1.284	1.593

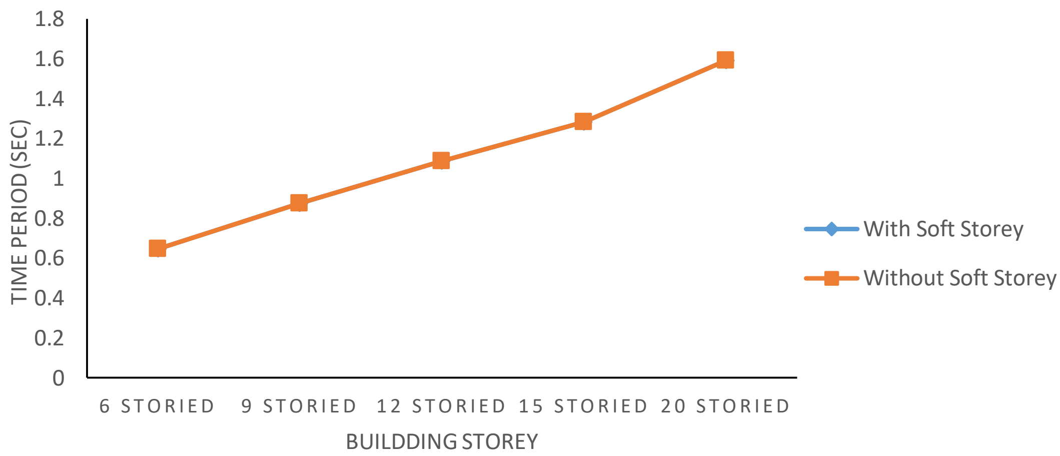


Figure 4.1(a): Variation of time period of buildings (with and without soft storey)

4.2.2 Base Shear of Buildings (With and Without Soft Storey):

Time Period of Buildings (With and Without Soft Storey)					
Building Storey	6	9	12	15	20
With Soft Storey (kN)	656.95	810.85	936.94	1054.4	1214.03
Without Soft Storey (kN)	671.7	822.89	947.21	1063.74	1222.08

Figure 4.1(a) shows variation of time period for buildings with and without ground soft story. From this figure, it has been observed that, time periods increase with the increase of building storey. For buildings with and without soft storey, the time periods are observed to be almost same.

Figure 4.1(b) shows variation of base shear for buildings with and without ground soft story. From this figure, it has been observed that, base shear values increase with increase of building storey. For buildings with and without soft storey, the base shear values are found to have slight variations.

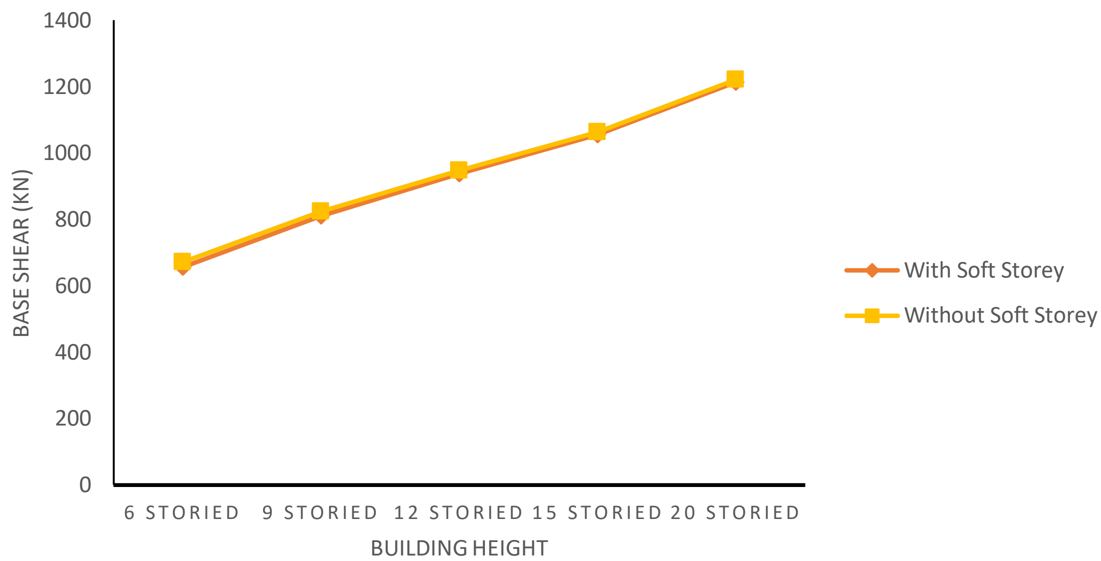


Figure 4.1(b): Variation of base shear of buildings (with and without soft storey)

4.2.3 Support Reactions of Columns for Various Combinations:

In the entire structure, there are four different dimensions of columns (C1, C2, C3 and C4). For the convenience of study, three columns with different location and the location of column are corner column, Interior column and exterior column.

i) Corner Column C1: With & Without Soft Storey

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WX (DCON3)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	94.59359	143.5303	197.8523	356.2731	359.5815
Without Soft Storey (kips)	99.598555	148.5756	202.9235	261.36	364.6818

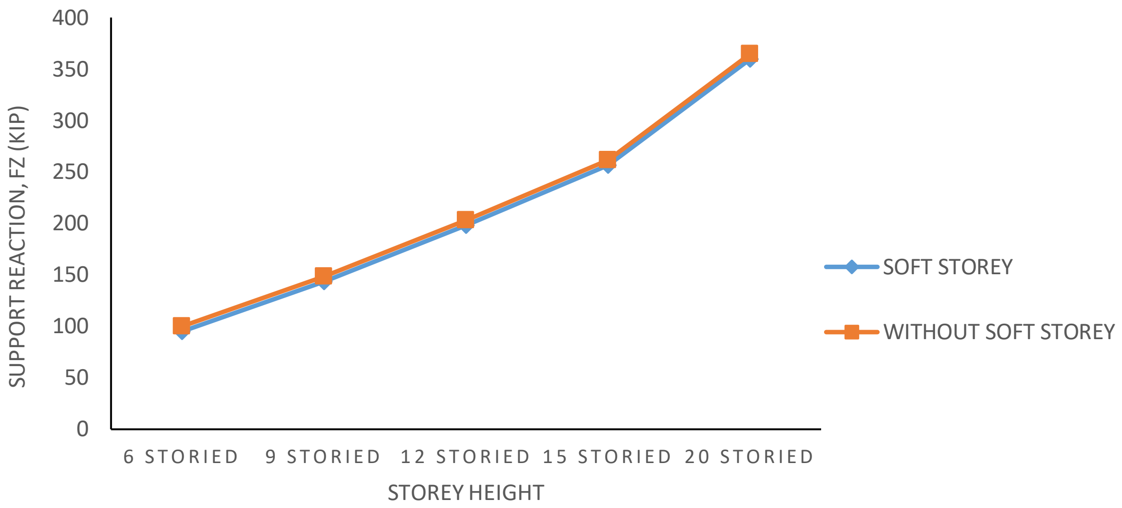


Figure 4.2(a): Comparison of Support Reaction for (+Wx) Combination DCON3

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WX (DCON4)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	79.06039	128.2419	182.6368	241.0647	344.2776
Without Soft Storey (kips)	84.10995	133.3331	187.7515	246.1951	349.4215

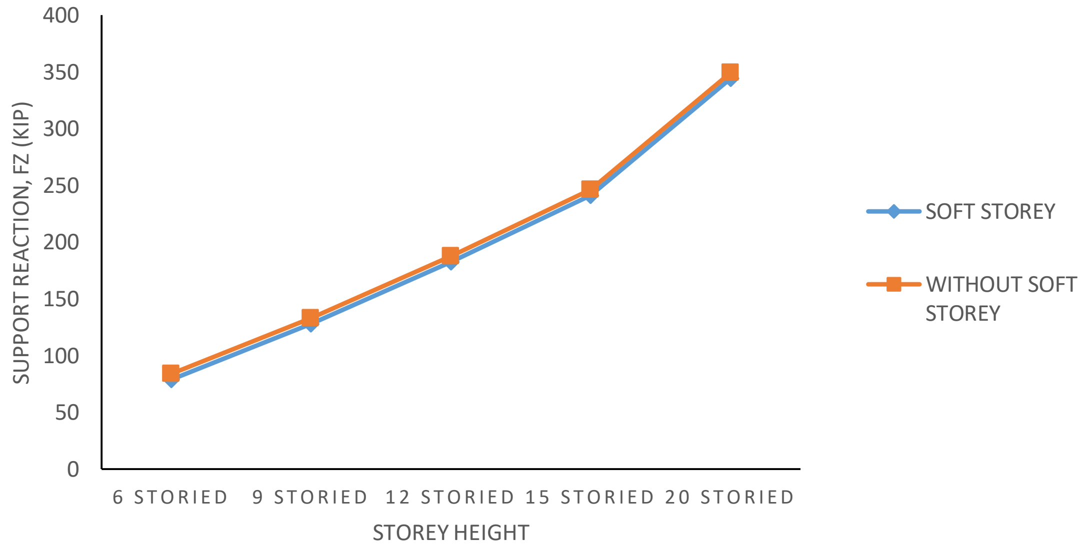


Figure 4.2(b): Comparison of Support Reaction for (-Wx) Combination DCON4

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WY (DCON5)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	86.827	135.8861	190.2446	248.6689	351.9296
Without Soft Storey (kips)	91.85415	140.9533	195.3375	253.7775	357.0517

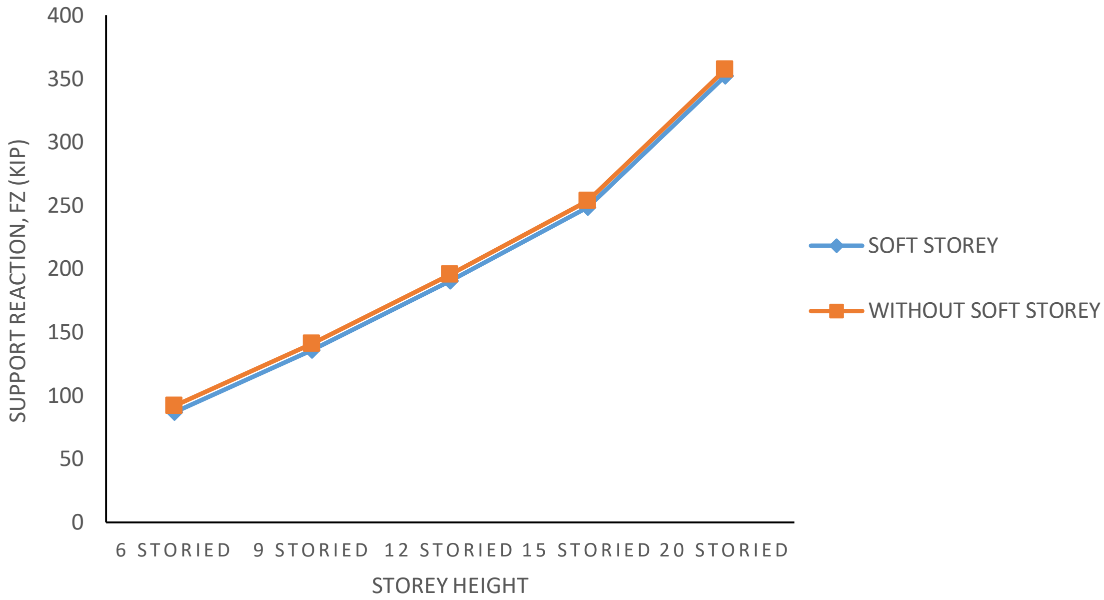


Figure 4.2(c): Comparison of Support Reaction for (+Wy) Combination DCON5

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WY (DCON6)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	86.827	135.8861	190.2446	248.6689	351.9296
Without Soft Storey (kips)	91.85425	140.9533	195.3375	253.7775	357.0517

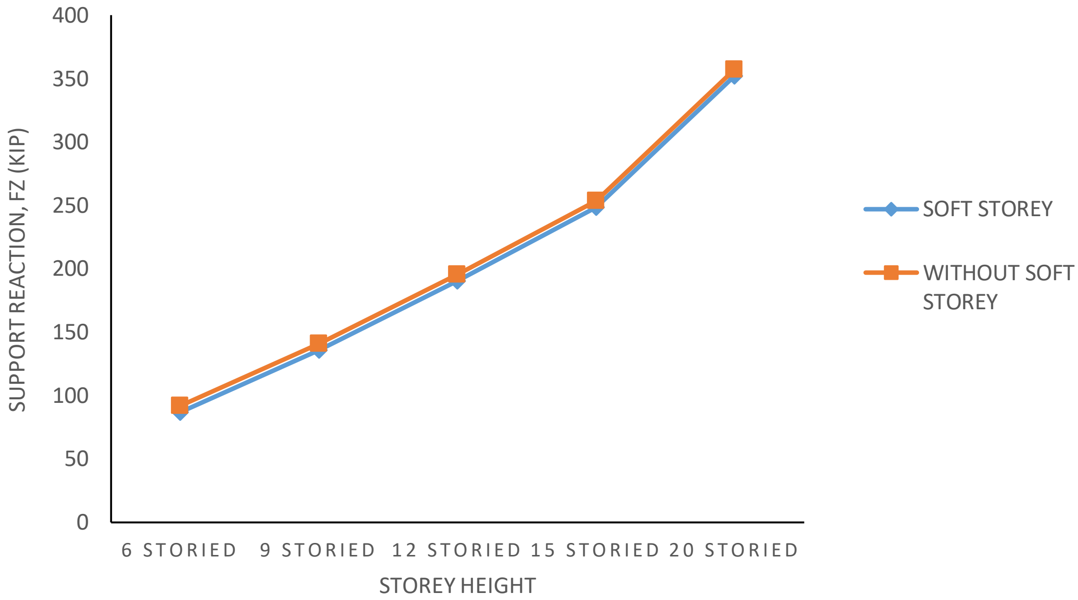


Figure 4.2(d): Comparison of Support Reaction for (-Wy) Combination DCON6

The figures 4.2(a), (b), (c) and (d) show the comparison of support reactions for the load combination of wind lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQX (DCON15)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	79.25078	129.6905	184.9938	244.1549	348.1626
Without Soft Storey (kips)	84.29726	134.7707	190.0974	249.2732	353.2943

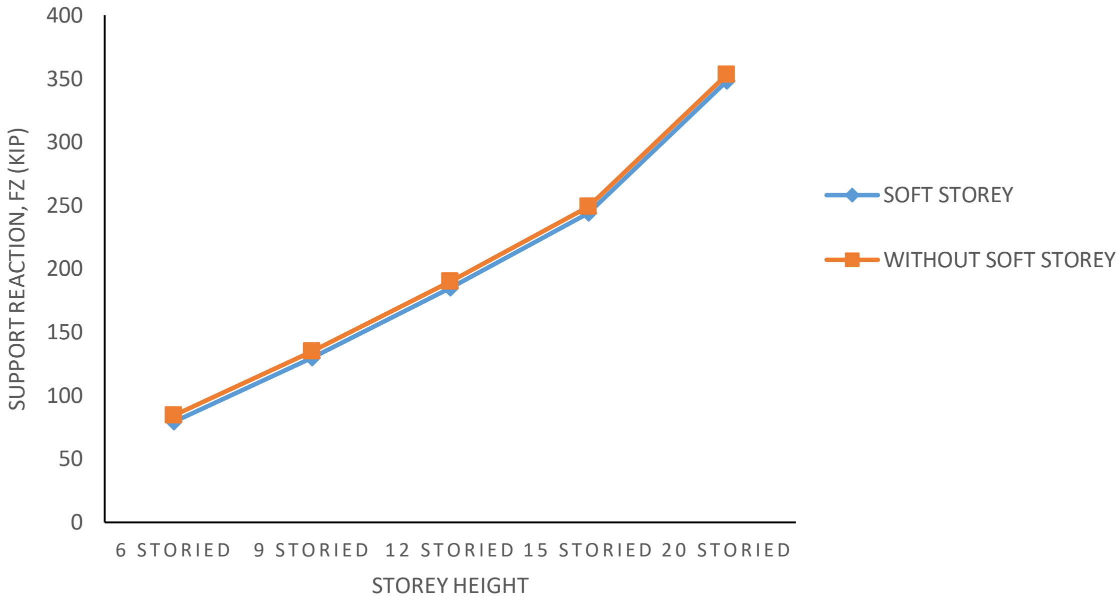


Figure 4.3(a): Comparison of Support Reactions for (+EQx) Combination DCON15

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQX (DCON16)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	94.40321	142.0816	195.4953	253.189	355.6963
Without Soft Storey (kips)	99.41123	147.1359	200.5779	258.2819	360.8091

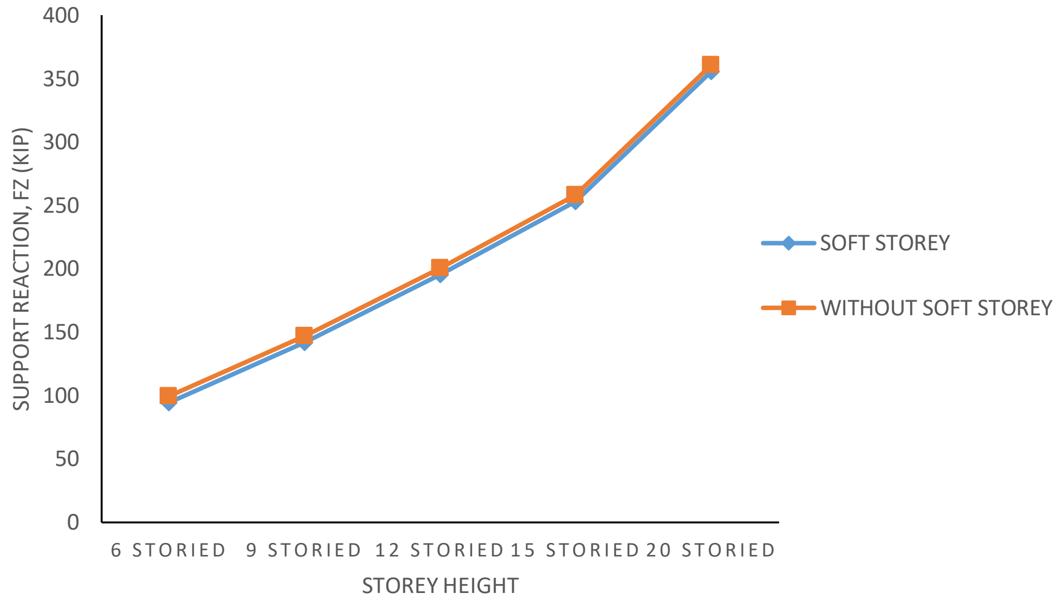


Figure 4.3(b): Comparison of Support Reaction for (-EQx) Combination DCON16

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQY (DCON17)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	84.64916	133.7781	188.5202	247.1674	350.5636
Without Soft Storey (kips)	89.69006	138.8556	193.6217	252.2833	355.6924

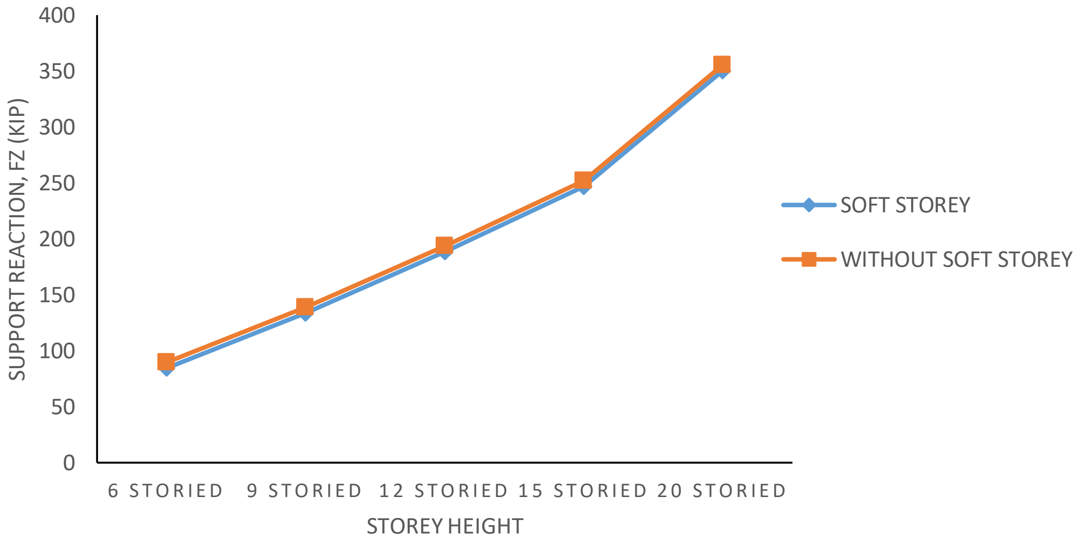


Figure 4.3(c): Comparison of Support Reaction for (+EQy) Combination DCON17

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQY (DCON18)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	89.00482	137.995	191.9689	250.1704	353.3955
Without Soft Storey (kips)	94.01844	143.051	197.0533	255.2718	358.4109

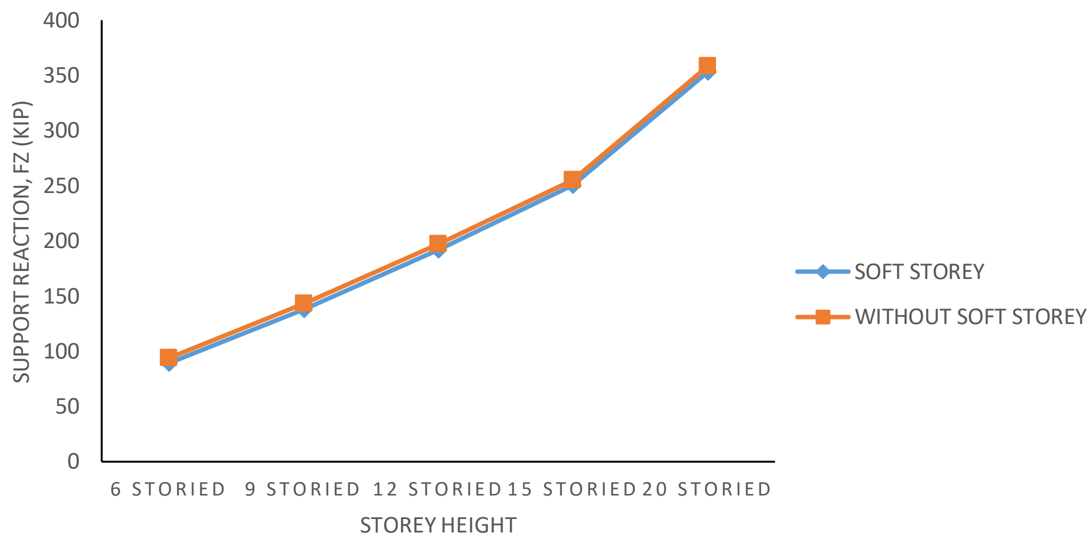


Figure 4.3(d): Comparison of Support Reaction for (-EQy) Combination DCON18

The figures 4.3(a),(b),(c), (d) show the comparison of support reactions for the load combination of wind lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

ii) Exterior Column C2: With & Without Soft Storey

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WX (DCON3)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	278.7483	384.172	384.172	64.4092	699.8134
Without Soft Storey (kips)	298.3026	403.4768	497.0686	593.4948	718.84

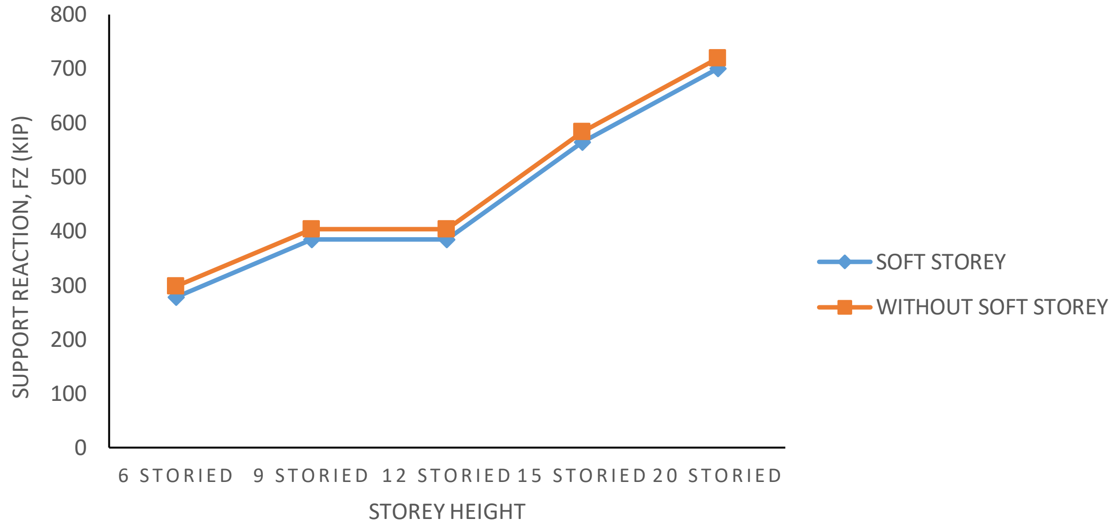


Figure 4.4(a): Comparison of Support Reaction for (+Wx) Combination DCON3

The figure 4.4(a) show the comparison of support reactions for the load combination of wind lateral load in X directions. From these demonstrations, the support reaction in 6 and 12 storied are gradually increased but in the 12 storied there is a break point and rest of the storey support reaction dramatically rise. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WX (DCON4)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	282.7118	387.0996	480.2	566.374	701.5485
Without Soft Storey (kips)	302.1911	406.3342	499.2975	585.3947	720.5117

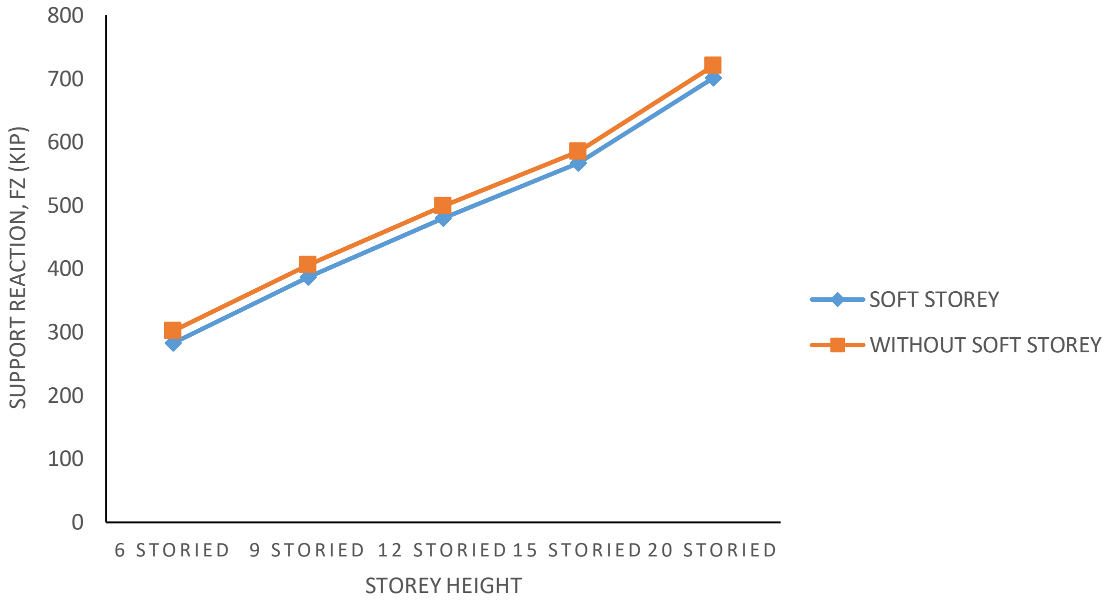


Figure 4.4(b): Comparison of Support Reaction for (-Wx) Combination DCON4

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WY (DCON5)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	280.73	385.6358	419.0521	565.3916	700.681
Without Soft Storey (kips)	300.2469	404.9055	498.183	584.4448	719.6758

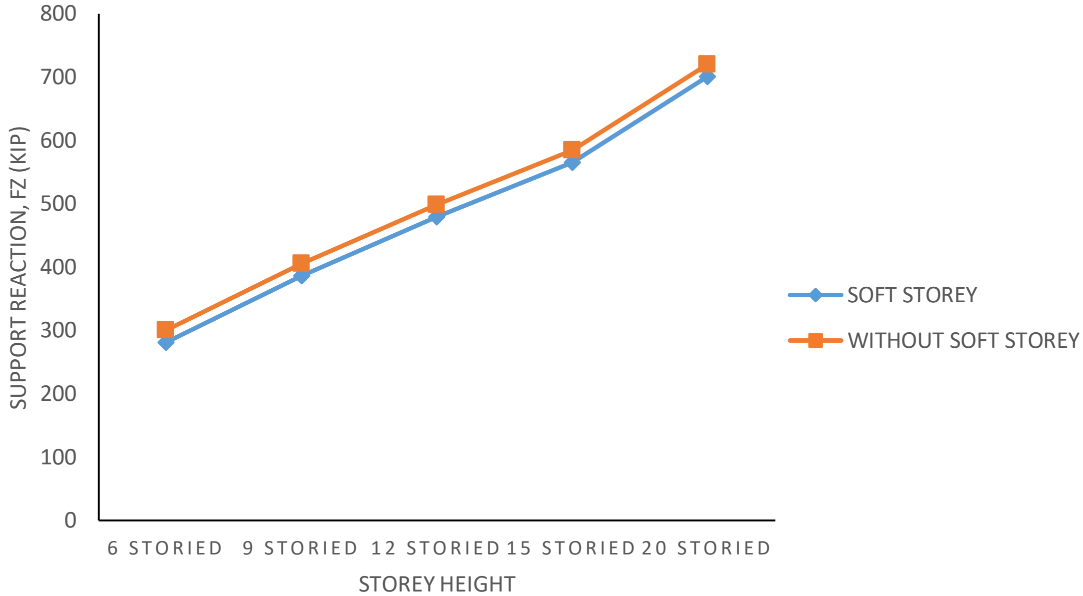


Figure 4.4(c): Comparison of Support Reaction for (+Wy) Combination DCON5

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WY (DCON6)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	280.73	385.6358	419.0521	565.3916	700.681
Without Soft Storey (kips)	300.2469	404.9055	498.183	584.4448	719.6758

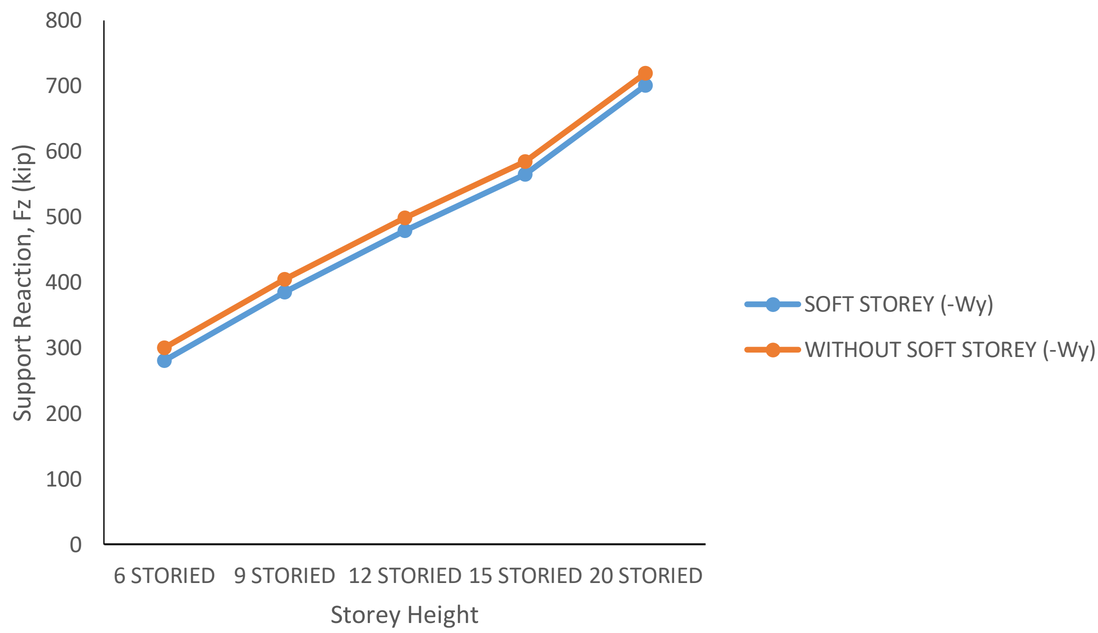


Figure 4.4 (d): Comparison of Support Reaction for (-Wy) Combination DCON6

The figures 4.4(b),(c),(d) show the comparison of support reactions for the load combination of wind lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQX (DCON15)					
Building Storey	6	9	12	15	20
With Soft Storey	282.7007	386.839	479.8425	565.951	791.0778
Without Soft Storey	302.1891	406.0874	498.9564	584.9897	720.061

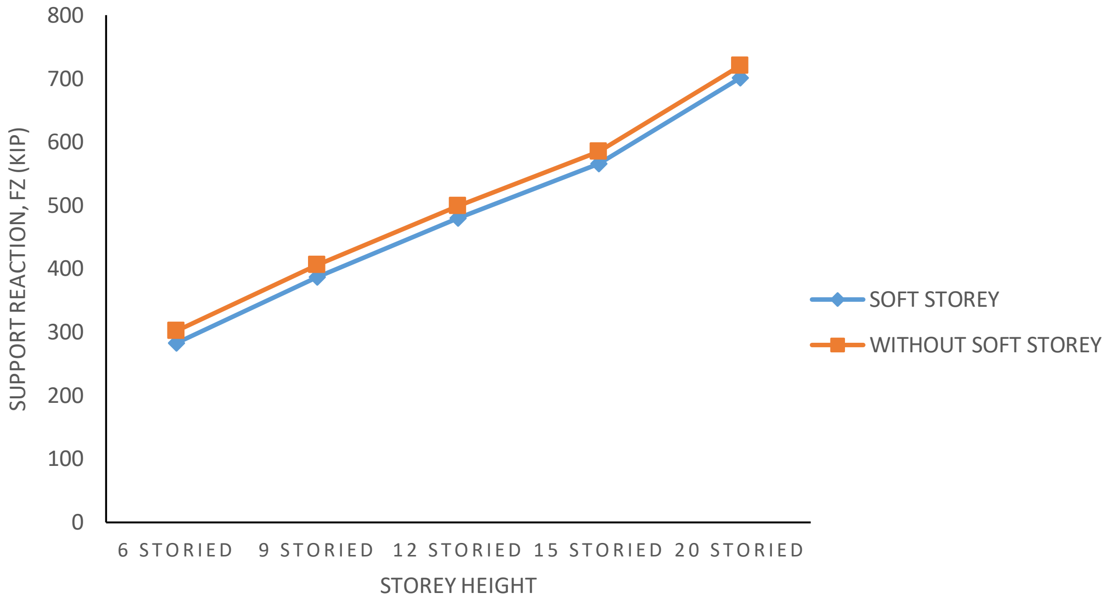


Figure 4.5(a): Comparison of Support Reaction for (+EQx) Combination DCON15

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQX (DCON16)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	278.7594	384.4326	478.2617	564.8322	791.0778
Without Soft Storey(kips)	298.3046	403.7235	497.4097	583.8998	719.2908

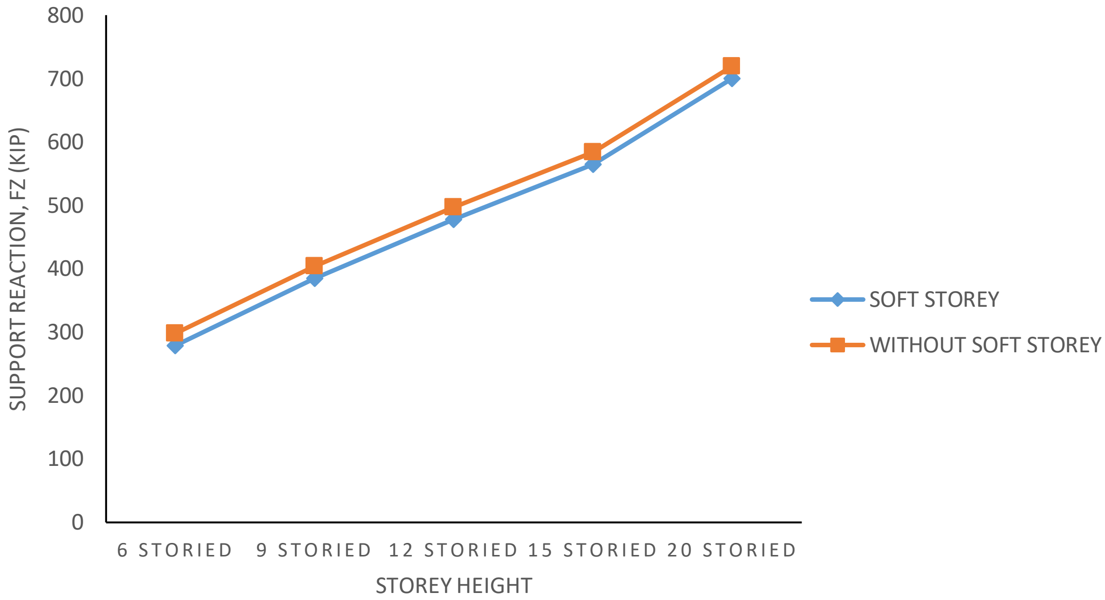


Figure 4.5(b): Comparison of Support Reaction for (-EQx) Combination DCON16

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQY (DCON17)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	274.8195	380.6942	475.415	562.4257	698.137
Without Soft Storey(kips)	294.0794	399.7413	494.3789	581.3386	717.0093

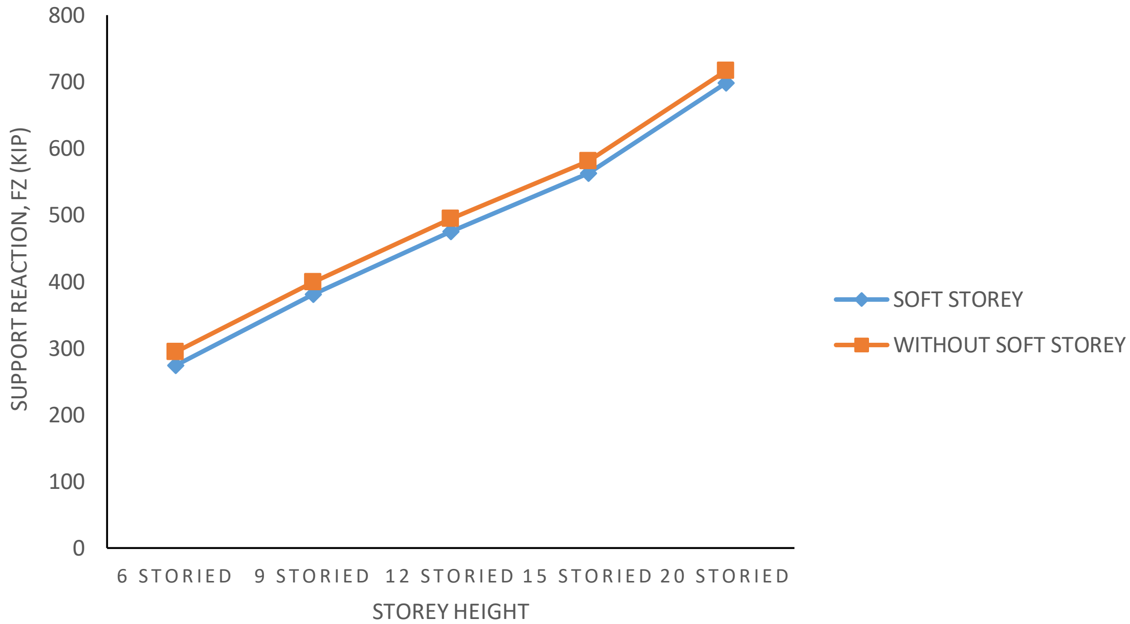


Figure 4.5(c): Comparison of Support Reaction for(+EQy)Combination DCON17

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQY (DCON18)					
Building Storey	6	9	12	15	20
With Soft Storey (kips)	286.6406	390.5774	482.6892	568.3576	703.225
Without Soft Storey (kips)	306.4143	410.0697	501.9872	587.5509	722.3423

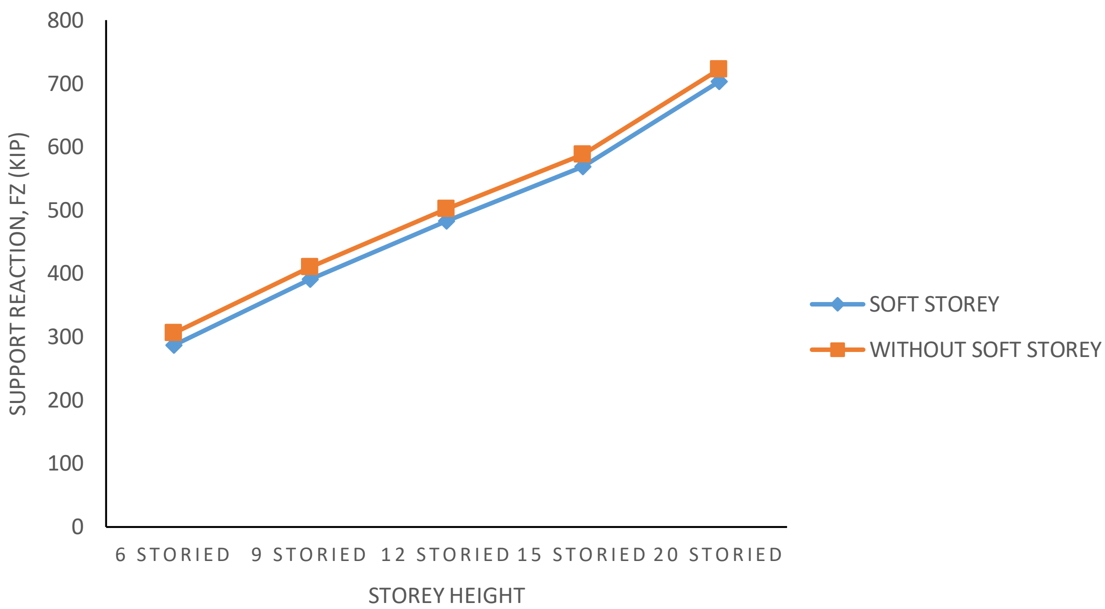


Figure 4.5(d): Comparison of Support Reaction for (-EQy) Combination DCON18

The figures 4.5(a),(b),(c),(d) show the comparison of support reactions for the load combination of earthquake lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

iii) Interior Column C3: With & Without Soft Storey

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WX (DCON3)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	112.9649	175.7146	238.2208	298.969	396.5507
Without Soft Storey(kips)	120.4645	183.1866	245.6634	306.3892	403.9482

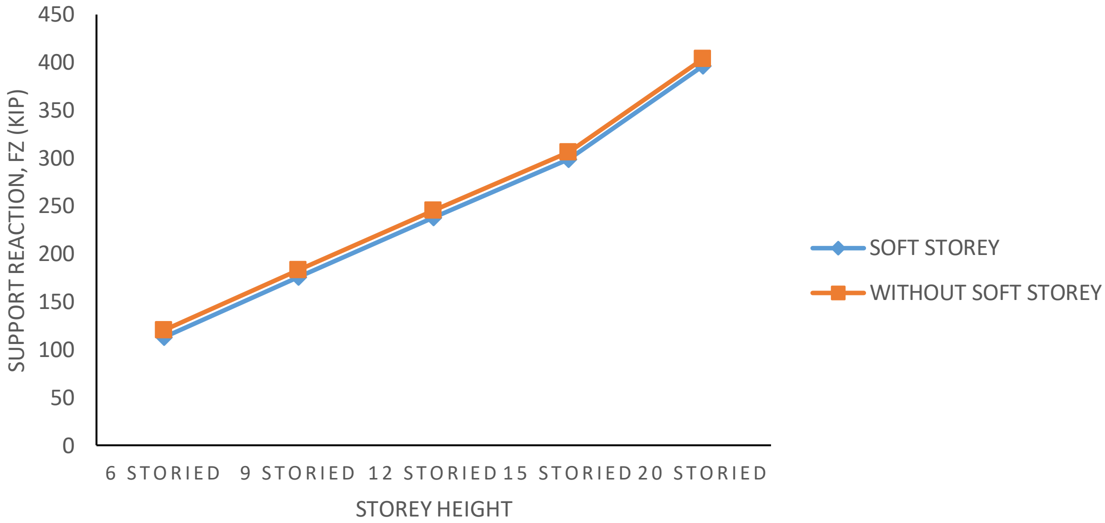


Figure 4.6(a): Comparison of Support Reaction for (+Wx) Combination DCON3

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WX (DCON4)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	125.6798	188.704	250.9923	311.5864	409.0697
Without Soft Storey(kips)	133.3285	196.3228	258.5828	319.1556	416.6182

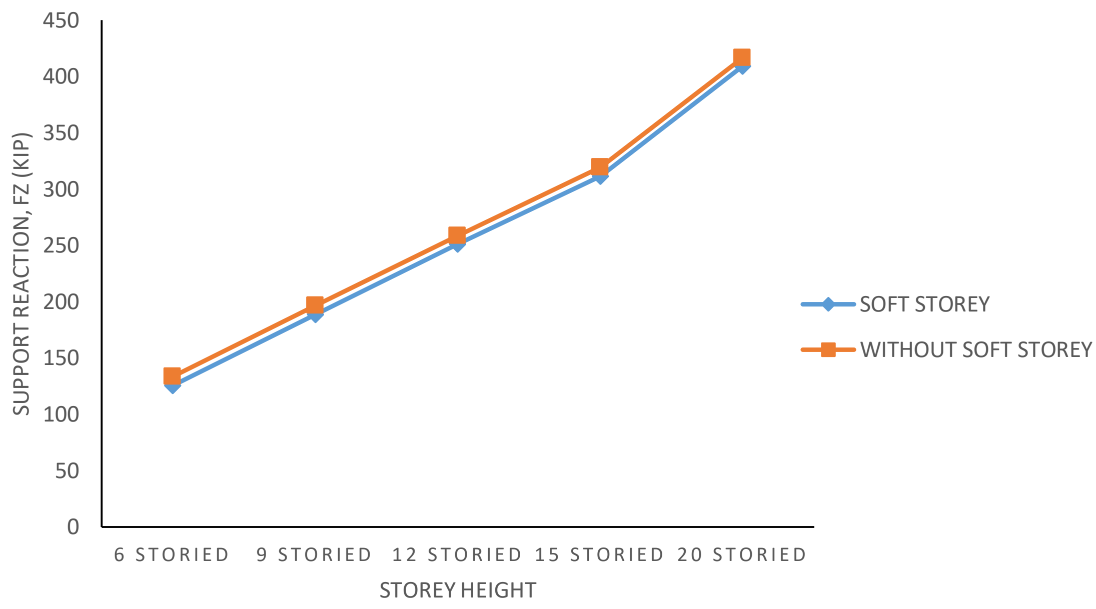


Figure 4.6(b): Comparison of Support Reaction for (-Wx) Combination DCON4

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.275WY (DCON5)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	119.3223	182.2093	244.6065	305.2777	402.8102
Without Soft Storey(kips)	126.8965	189.7547	252.1231	312.7724	410.2832

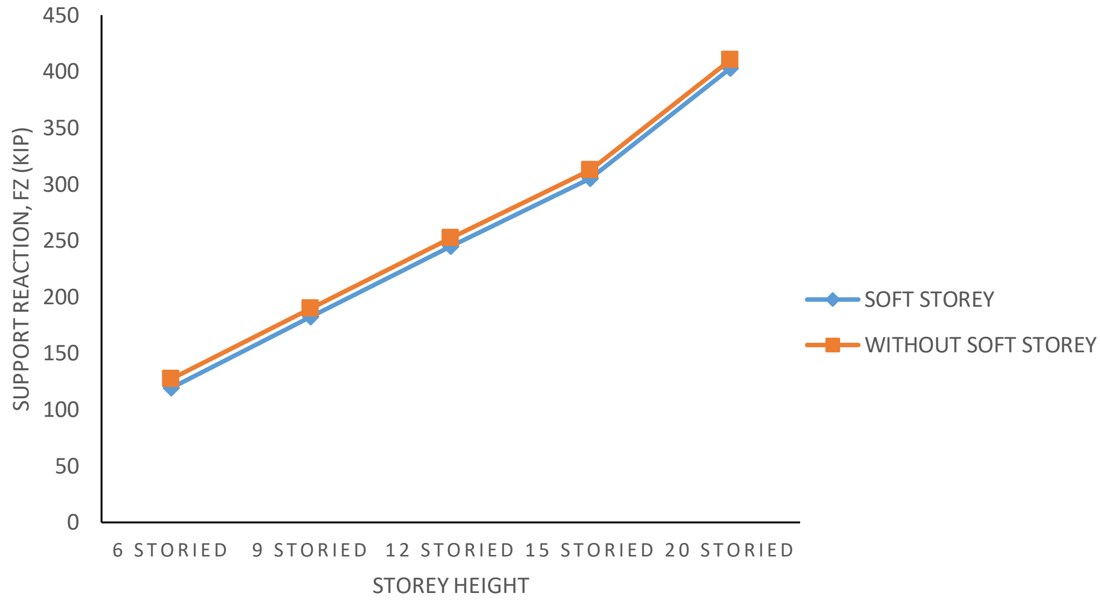


Figure 4.6(c): Comparison of Support Reaction for (+Wy) Combination DCON5

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.275WY (DCON6)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	119.3223	182.2093	244.6065	305.2777	402.8102
Without Soft Storey(kips)	126.8965	189.7547	252.1231	312.7724	410.2832

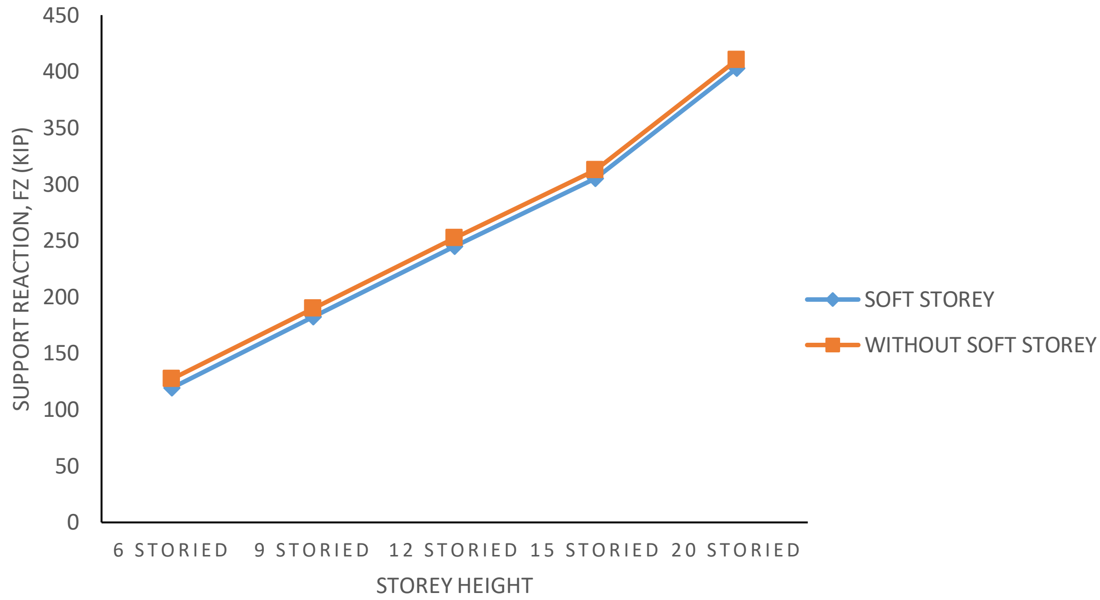


Figure 4.6(d): Comparison of Support Reaction for (-Wy) Combination DCON6

The figures 4.6(a),(b),(c),(d) show the comparison of support reactions for the load combination of wind lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQX (DCON15)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	125.2579	187.3015	248.8848	308.9549	405.8483
Without Soft Storey(kips)	132.905	194.9091	256.4549	316.4943	413.3575

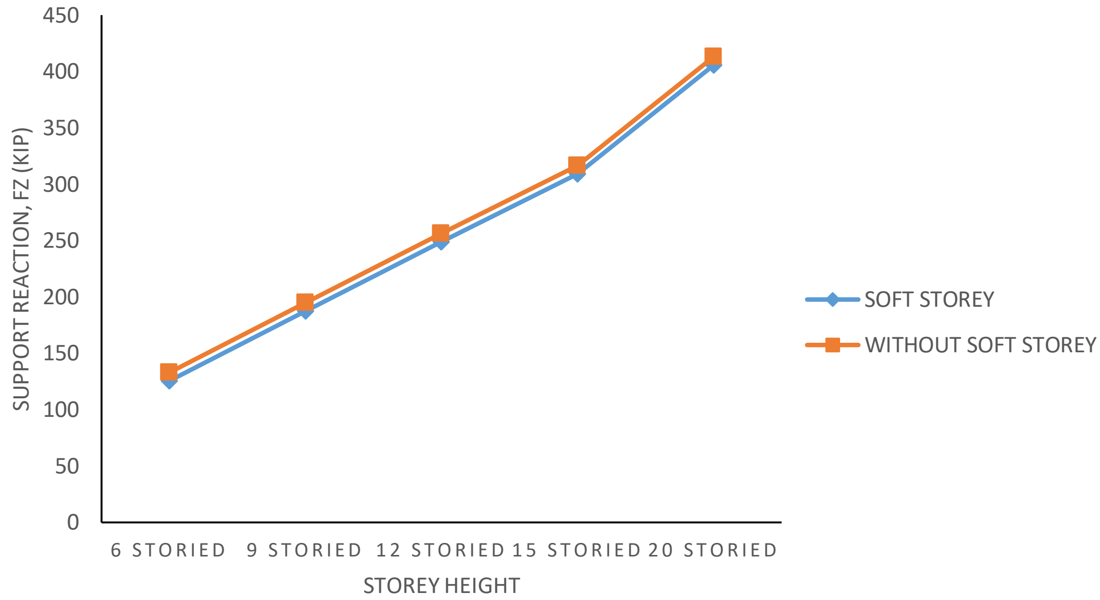


Figure 4.7(a): Comparison of Support Reaction for (+EQx) Combination DCON15

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQX (DCON16)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	113.3868	177.1171	240.3283	301.6006	399.6875
Without Soft Storey(kips)	120.888	184.6004	247.7913	309.0505	407.2125

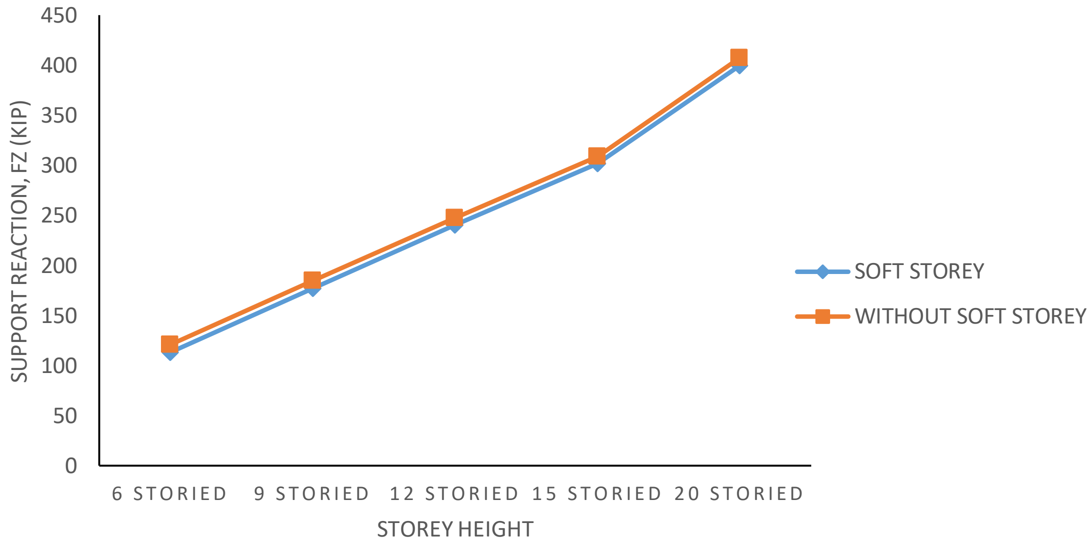


Figure 4.7(b): Comparison of Support Reaction for (-EQx) Combination DCON16

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW+1.4025EQY (DCON17)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	112.3199	176.2736	240.1965	301.6559	399.6875
Without Soft Storey(kips)	119.9947	183.9057	247.7818	309.2088	407.2125

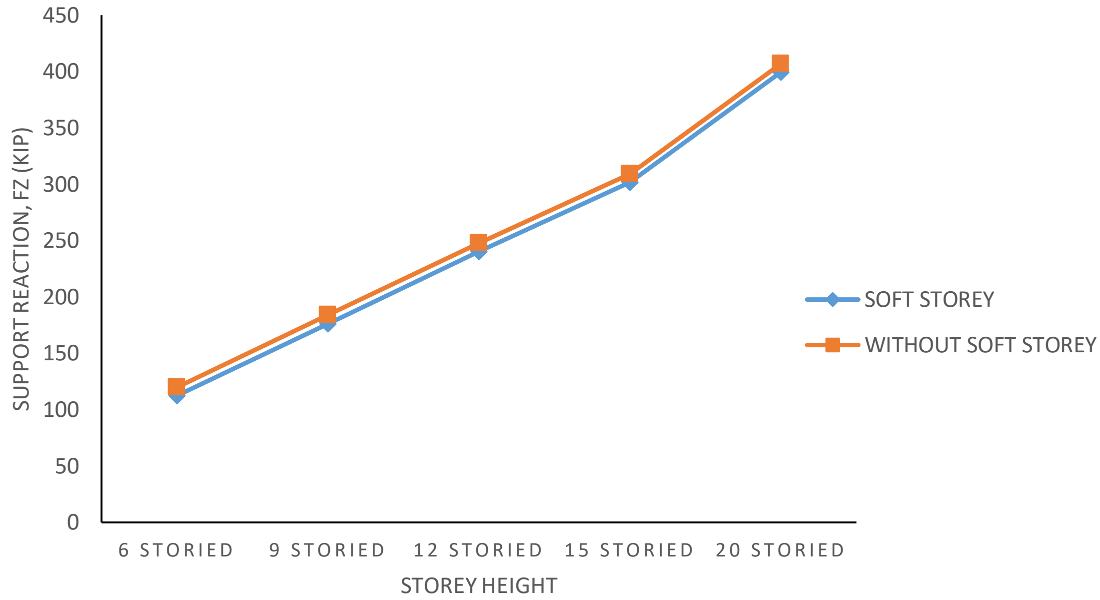


Figure 4.7(c): Comparison of Support Reaction for (+EQy) Combination DCON17

Load Combination: 1.05DL+1.05FF+1.275LL+1.05PW-1.4025EQY (DCON18)					
Building Storey	6	9	12	15	20
With Soft Storey(kips)	126.3248	188.145	249.0165	308.8995	405.9329
Without Soft Storey(kips)	133.7983	195.6037	256.4644	316.336	413.3536

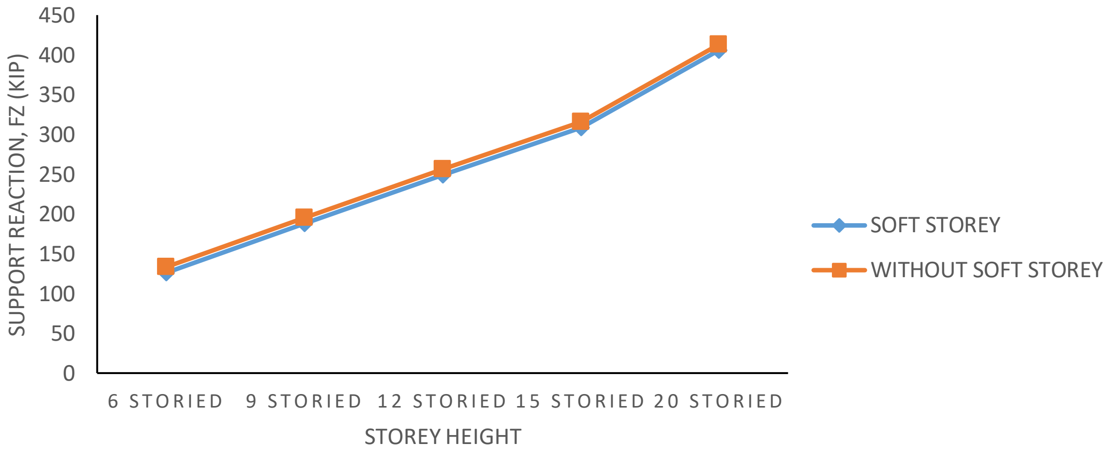


Figure 4.7(d): Comparison of Support Reaction for (-EQy) Combination DCON18

The figures 4.7(a),(b),(c),(d) show the comparison of support reactions for the load combination of earthquake lateral load in both X and Y directions. From these demonstrations, the support reactions are observed to increase gradually with buildings of higher elevations for both types of buildings (with and without ground soft storey) and the trend is almost linear. In the graph, support reaction values are larger in buildings without soft storey than that with soft storey (because there is no infill wall in ground floor in these buildings).

4.2.4 Comparison of Storey Drift Values

6 Storied

Time Period of Buildings (With and Without Soft Storey)							
Building Storey	Base	1	2	3	4	5	6
With Soft Storey(inch)	7.30702E-05	0.000190704	0.000183041	0.000164743	0.00014591	0.0001098	7.85041E-05
Without Soft Storey(inch)	6.2661E-05	0.0001399	0.0001627	0.0001546	0.0001359	0.000109	7.85013E-05

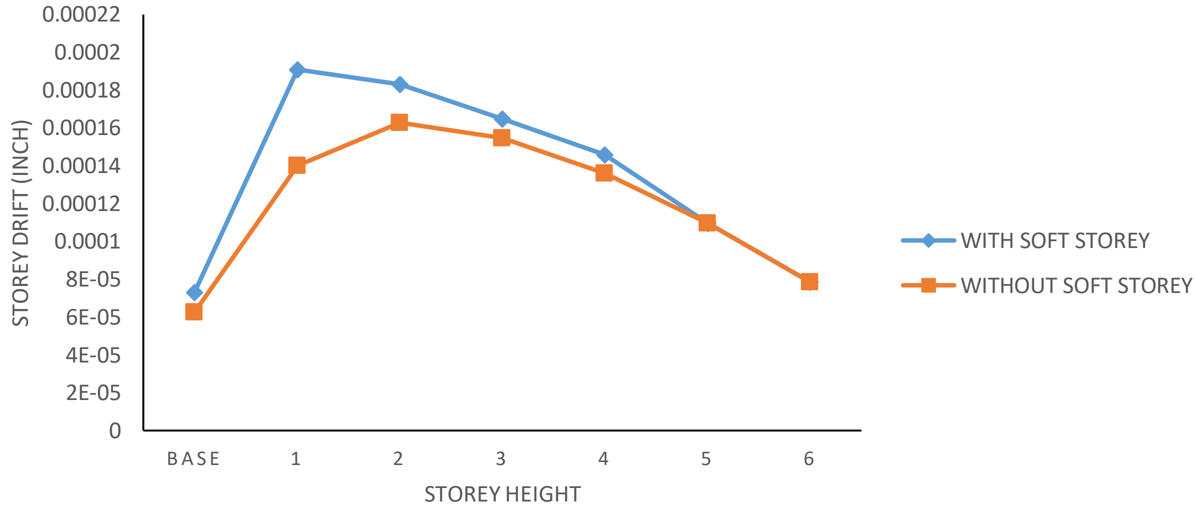


Figure 4.8(a): Comparison of Storey Drift in X Direction for EQx (6 Storied)

The figures 4.8(a) shows the comparison of storey drift in X direction for EQx with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .000073 inch where 1st floor value is .00019 inch. Again, without soft storey the drift value in the base is .000062 inch where 1st floor value is .000139 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 2nd storey relative displacement is decreased in soft storey building and this trend is continued up to 6 storey. But without soft storey's building, storey drift is increased from base to 2nd floor then it decreased gradually up to 6 storey.

Time Period of Buildings (With and Without Soft Storey)							
Building Storey	Base	1	2	3	4	5	6
With Soft Storey(inch)	6.32E-05	1.03E-04	0.000122155	0.000135816	0.000130632	0.000122705	0.000109743
Without Soft Storey(inch)	5.42E-05	8.19E-05	0.000111863	0.00012556	0.000127443	0.000122559	0.000109627

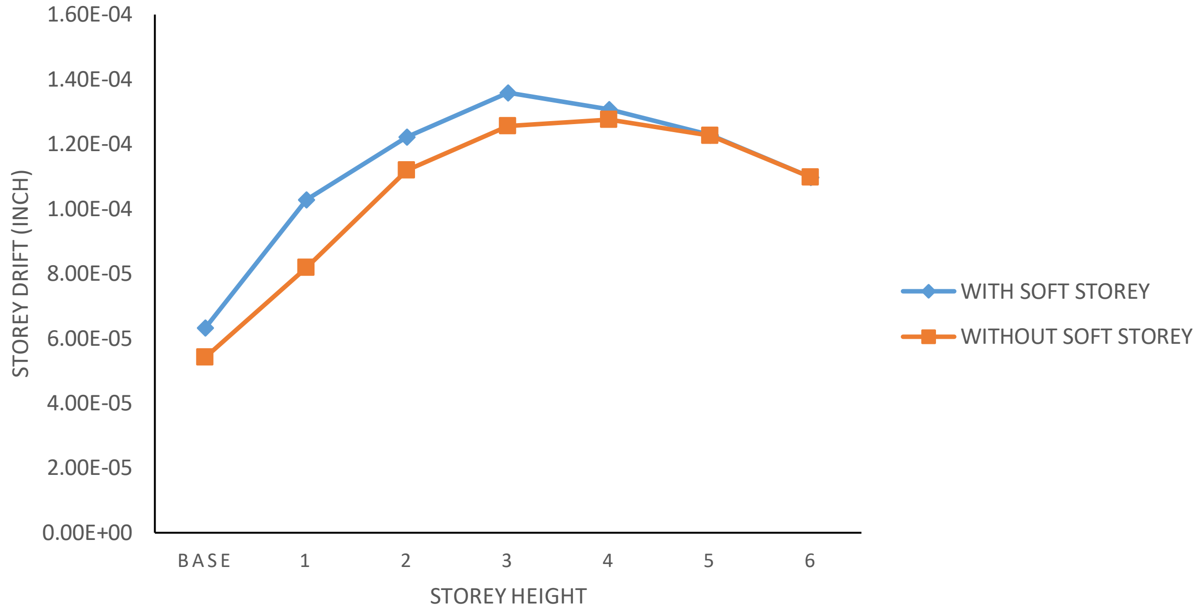


Figure 4.8(b): Comparison of Storey Drift in Y Direction for EQy (6 Storied)

The figure 4.8(b) shows the comparison of storey drift in Y directions for EQy with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .000063 inch where 1st floor value is .000103 inch. Again, without soft storey the drift value in the base is .0000542 inch where 1st floor value is .0000819 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 3rd storey relative displacement is decreased in soft storey building and this trend is continued up to 6 storey. And without soft storey's building, storey drift is increased from base to 3nd floor then it decreased gradually up to 6 storey.

Time Period of Buildings (With and Without Soft Storey)							
Building Storey	Base	1	2	3	4	5	6
With Soft Storey(inch)	9.37E-05	0.000178	0.0001947	0.0001725	0.0001401	0.000101	6.39E-05
Without Soft Storey(inch)	9.31E-05	0.0001772	0.0001943	0.0001724	0.0001401	0.000101	6.39E-05

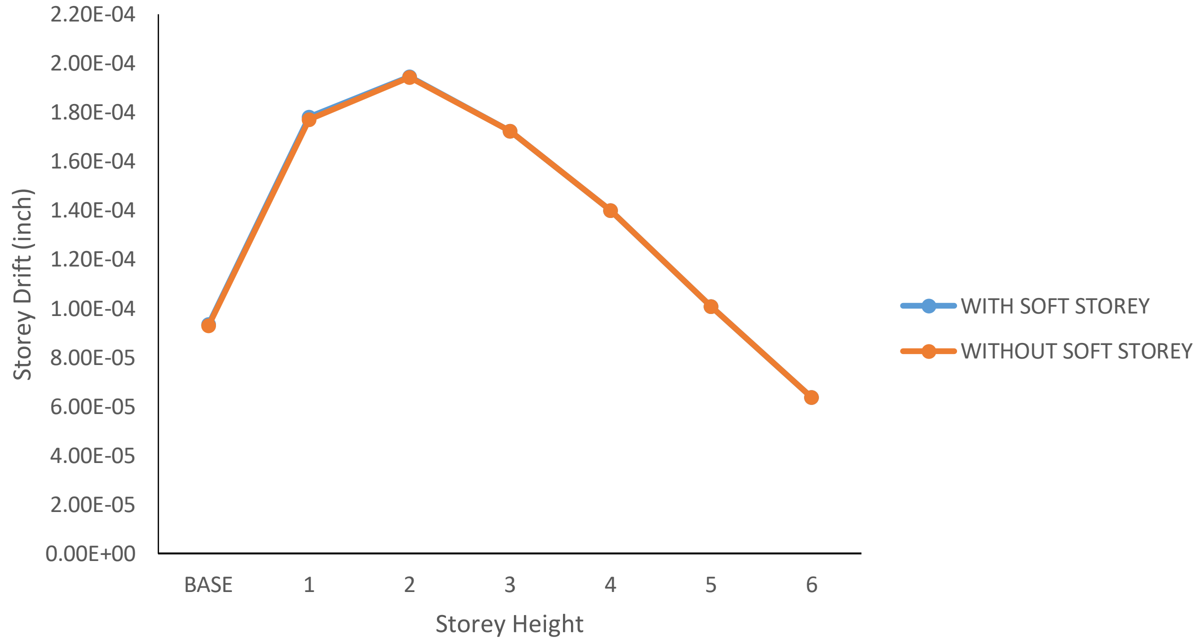


Figure 4.8(c): Comparison of Storey Drift in X Direction for Wx (6 Storied)

The figure 4.8(c) shows the comparison of storey drift in X directions for Wx with and without soft storey, the relative displacement is observed from 1st to 2nd floor.

9 Storied

Time Period of Buildings (With and Without Soft Storey)										
Building Storey	Base	1	2	3	4	5	6	7	8	9
With Soft Storey(inch)	6.26E-05	2.17E-04	1.86E-04	1.68E-04	1.31E-04	9.68E-05	5.74E-05	3.48E-05	2.67E-05	2.35E-05
Without Soft Storey(inch)	5.23E-05	1.17E-04	1.35E-04	1.28E-04	1.11E-04	8.68E-05	5.74E-05	3.48E-05	2.67E-05	2.35E-05

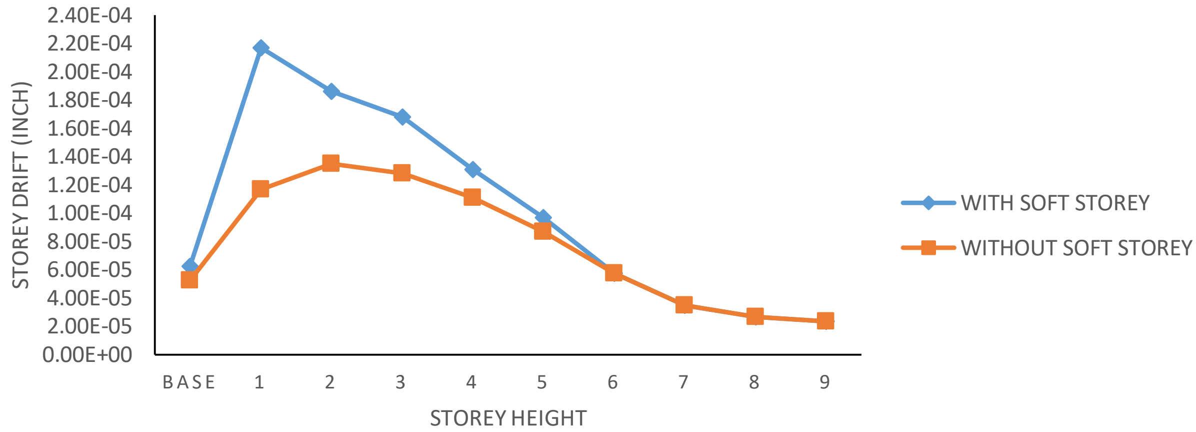


Figure 4.9(a): Comparison of Storey Drift in X Direction for EQx (9 Storied)

The figure 4.9(a) shows the comparison of storey drift in X direction for EQx with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .000062 inch where 1st floor value is .00021 inch. Again, without soft storey the drift value in the base is .000052 inch where, 1stfloor value is .00011 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Then relative displacement decreasesd gradually in soft storey building and this trend is continued up to 9 storey. But without soft storey's building, storey drift is increased from base to 2nd floor then it decreased gradually up to 9 storey.

Time Period of Buildings (With and Without Soft Storey)										
Building Storey	Base	1	2	3	4	5	6	7	8	9
With Soft Storey(inch)	5.51E-05	9.10E-05	1.10E-04	1.09E-04	1.02E-04	8.85E-05	7.31E-05	5.64E-05	4.93E-05	4.30E-05
Without Soft Storey(inch)	4.72E-05	7.04E-05	9.38E-05	1.02E-04	9.94E-05	8.85E-05	7.31E-05	5.64E-05	4.93E-05	4.30E-05

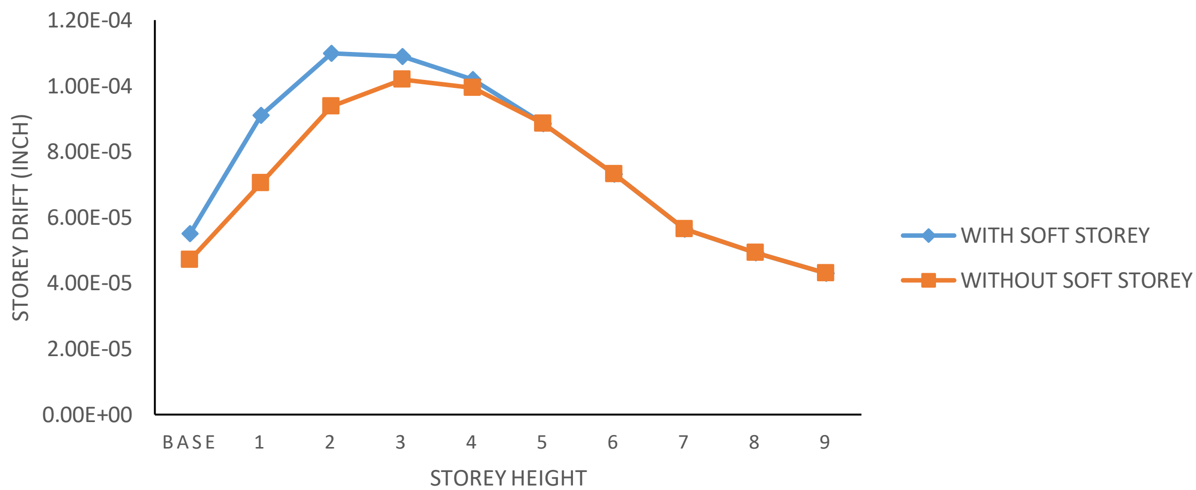


Figure 4.9(b): Comparison of Storey Drift in Y Direction for EQy (9 Storied)

The figure 4.9(b) shows the comparison of storey drift in Y directions for EQy with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000551 inch where 1st floor value is .000091 inch. Again, without soft storey the drift value in the base is .000047 inch where 1st floor value is .0000704 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 2nd storey relative displacement is decreased in soft storey building and this trend is continued up to 9 storey. And without soft storey's building, storey drift is increased from base to 3nd floor then it decreased gradually up to 9 storey.

Time Period of Buildings (With and Without Soft Storey)										
Building Storey	Base	1	2	3	4	5	6	7	8	9
With Soft Storey(inch)	9.36E-05	1.78E-04	1.94E-04	1.71E-04	1.37E-04	9.52E-05	5.57E-05	4.23E-05	3.36E-05	3.04E-05
Without Soft Storey(inch)	9.31E-05	1.77E-04	1.93E-04	1.70E-04	1.37E-04	9.52E-05	5.57E-05	4.23E-05	3.36E-05	3.04E-05

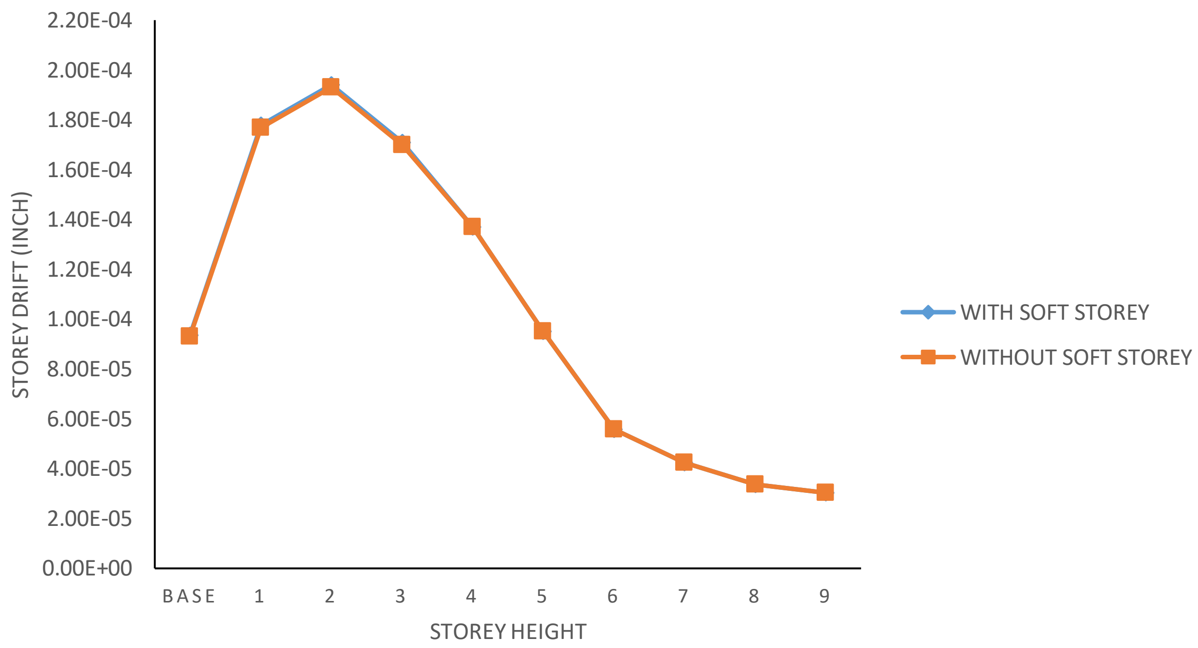


Figure 4.9(c): Comparison of Storey Drift in X Direction for Wx (9 Storied)

The figure 4.9(c) shows the comparison of storey drift in X directions for Wx with and without soft storey, the relative displacement is observed from 1st to 2nd floor.

12 Storey:

Time Period of Buildings (With and Without Soft Storey)													
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12
With Soft Storey(inch)	5.50 E-05	2.20 E-04	1.66 E-04	1.39 E-04	1.07 E-04	8.45 E-05	4.80 E-05	2.81 E-05	2.07 E-05	1.70 E-05	1.51 E-05	1.40 E-05	1.40 E-05
Without Soft Storey(inch)	4.47 E-05	9.99 E-05	1.16 E-04	1.09 E-04	9.43 E-05	7.35 E-05	4.80 E-05	2.81 E-05	2.07 E-05	1.70 E-05	1.51 E-05	1.40 E-05	1.35 E-05

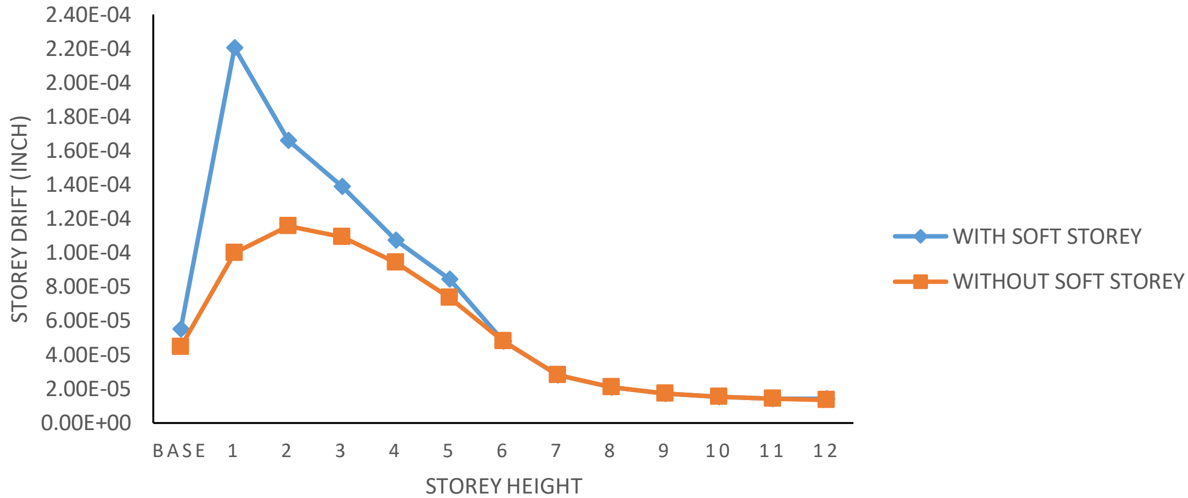


Figure 4.10(a): Comparison of Storey Drift in X Direction for EQx (12 Storied)

The figure 4.10(a) shows the comparison of storey drift in X direction for EQx with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .000055 inch where 1st floor value is .00022 inch. Again, without soft storey the drift value in the base is .0000447 inch where 1st floor value is .000099 inch. So we it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Then relative displacement is decreased in soft storey building and this trend is continued up to 12 storey. But without soft storey's building, storey drift is increased from base to 2nd floor then it decreased gradually up to 12 storey.

Time Period of Buildings (With and Without Soft Storey)													
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12
With Soft Storey(inch)	4.599E-05	7.499E-05	0.0001016	9.927E-05	9.586E-05	8.182E-05	6.582E-05	4.989E-05	3.228E-05	2.644E-05	2.238E-05	2.002E-05	1.809E-05
Without Soft Storey(inch)	3.594E-05	5.36E-05	7.147E-05	7.814E-05	7.578E-05	6.713E-05	5.479E-05	3.987E-05	3.227E-05	2.643E-05	2.238E-05	2.002E-05	1.809E-05

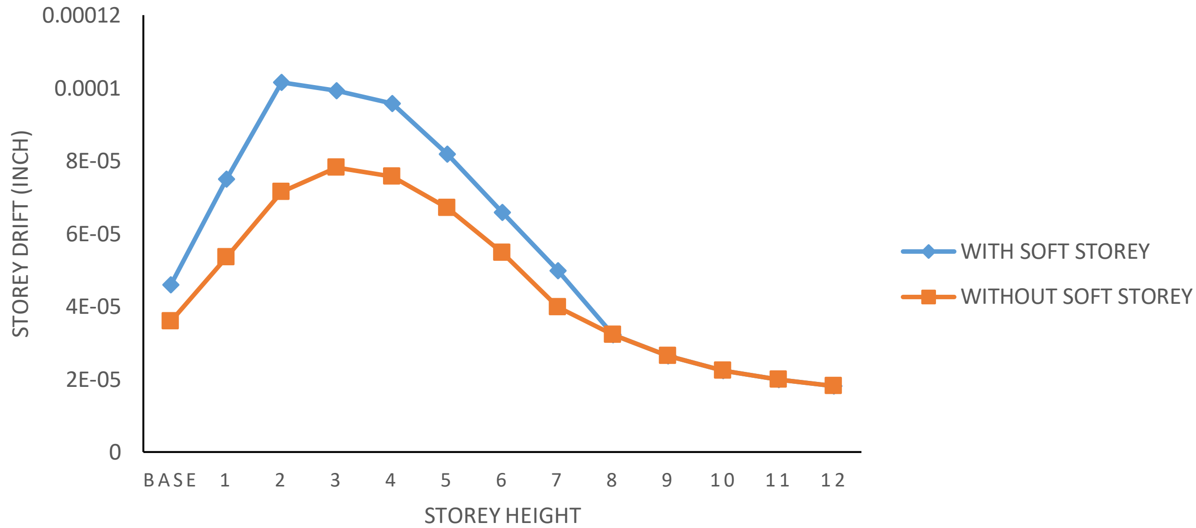


Figure 4.10(b): Comparison of Storey Drift in Y Direction for EQy (12 Storied)

The figure 4.10(b) shows the comparison of storey drift in Y directions for EQy with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000459 inch where 1st floor value is .0000749 inch. Again, without soft storey the drift value in the base is .0000359 inch where 1st floor value is .0000535 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 2nd storey relative displacement is increased in soft storey building then it decreased gradually and this trend is continued up to 12 storey. But without soft storey's building, storey drift is increased from base to 3rd floor then it decreased gradually up to 12 storey.

Time Period of Buildings (With and Without Soft Storey)													
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12
With Soft Storey(inch)	9.373E-05	0.0001782	0.0001942	0.0001706	0.0001372	9.931E-05	5.72E-05	3.985E-05	3.044E-05	2.552E-05	2.304E-05	2.14E-05	2.059E-05
Without Soft Storey(inch)	9.318E-05	0.0001773	0.0001938	0.0001705	0.0001362	9.431E-05	5.42E-05	3.984E-05	3.043E-05	2.55E-05	2.303E-05	2.139E-05	2.058E-05

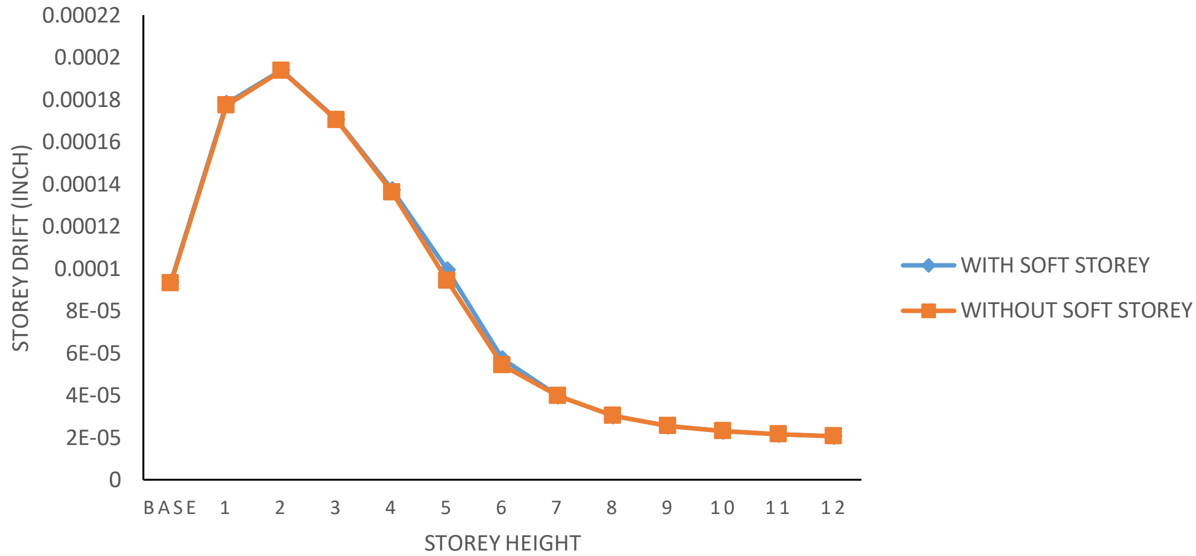


Figure 4.10(c): Comparison of Storey Drift in X Direction for Wx (12 Storied)

The figure 4.10(c) shows the comparison of storey drift in X directions for Wx with and without soft storey, the relative displacement is observed from 4th to 7th storied.

15 Storey:

Time Period of Buildings (With and Without Soft Storey)																
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
With Soft Storey(inch)	6.26E-05	2.17E-04	1.86E-04	1.68E-04	1.31E-04	9.68E-05	5.74E-05	3.48E-05	2.37E-05	1.55E-05	1.12E-05	1.04E-05	9.81E-06	9.40E-06	9.19E-06	0
Without Soft Storey(inch)	3.77E-05	8.45E-05	9.83E-05	9.35E-05	8.19E-05	6.53E-05	4.40E-05	2.47E-05	1.79E-05	1.43E-05	1.25E-05	1.12E-05	1.04E-05	9.81E-06	9.40E-06	9.19E-06

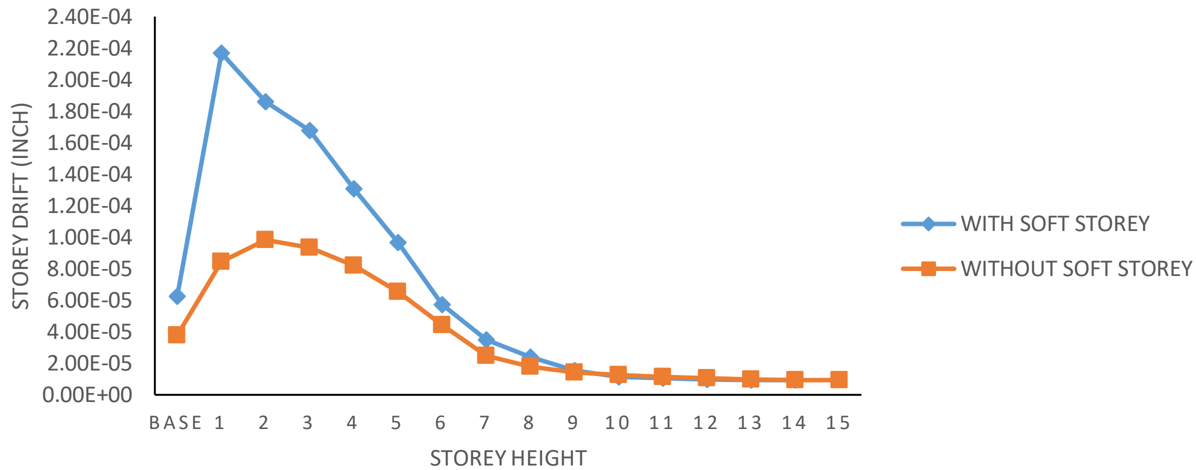


Figure 4.11(a): Comparison of Storey Drift in X Direction for EQx (15 Storied)

The figure 4.11(a) shows the comparison of storey drift in X direction for EQx with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000626 inch where 1st floor value is .000217 inch. Again, without soft storey the drift value in the base is .0000377 inch where 1st floor value is .0000845 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Then relative displacement is decreased gradually in soft storey building and this trend is continued up to 15 storey. But without soft storey's building, storey drift is increased from base to 2nd floor then it decreased gradually up to 15 storey.

Time Period of Buildings (With and Without Soft Storey)																
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
With Soft Storey(inch)	5.51E-05	9.10E-05	1.10E-04	1.09E-04	1.02E-04	8.85E-05	7.31E-05	5.64E-05	4.23E-05	3.00E-05	1.82E-05	1.45E-05	1.26E-05	1.13E-05	1.05E-05	9.81E-06
Without Soft Storey(inch)	3.02E-05	4.51E-05	6.02E-05	6.59E-05	6.39E-05	5.66E-05	4.61E-05	3.31E-05	2.64E-05	2.11E-05	1.72E-05	1.45E-05	1.26E-05	1.13E-05	1.05E-05	9.81E-06

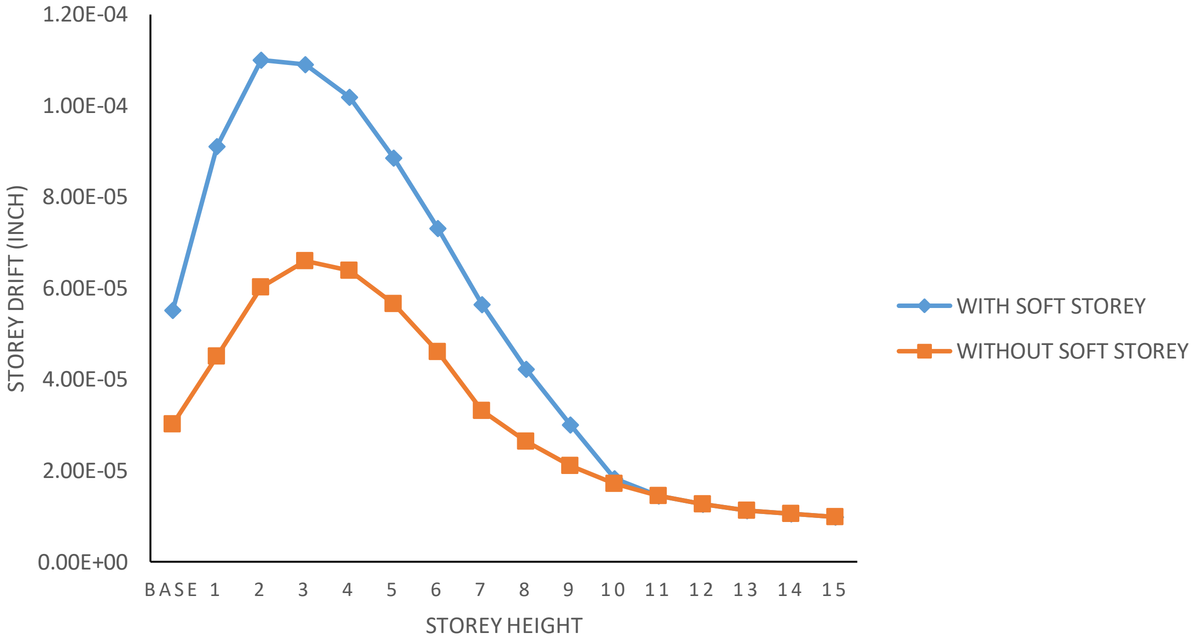


Figure 4.11(b): Comparison of Storey Drift in Y Direction for EQy (15 Storied)

The figure 4.11(b) shows the comparison of storey drift in Y directions for EQy with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000515 inch where 1st floor value is .0000910 inch. Again, without soft storey the drift value in the base is .0000302 inch where 1st floor value is .0000451 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 2nd storey relative displacement is increased in soft storey building then it decreased gradually and this trend is continued up to 15 storey. But without soft storey's building, storey drift is increased from base to 3rd floor then it decreased gradually up to 15 storey.

Time Period of Buildings (With and Without Soft Storey)																
Building Storey	Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
With Soft Storey(inch)	9.37E-05	0.000178	0.0001947	0.0001725	0.0001401	0.000101	6.09E-05	3.92E-05	2.96E-05	2.43E-05	2.15E-05	1.95E-05	1.81E-05	1.71E-05	1.64E-05	1.60E-05
Without Soft Storey(inch)	9.33E-05	1.78E-04	1.94E-04	1.71E-04	1.36E-04	9.43E-05	5.39E-05	3.92E-05	2.96E-05	2.43E-05	2.15E-05	1.95E-05	1.81E-05	1.71E-05	1.64E-05	1.60E-05

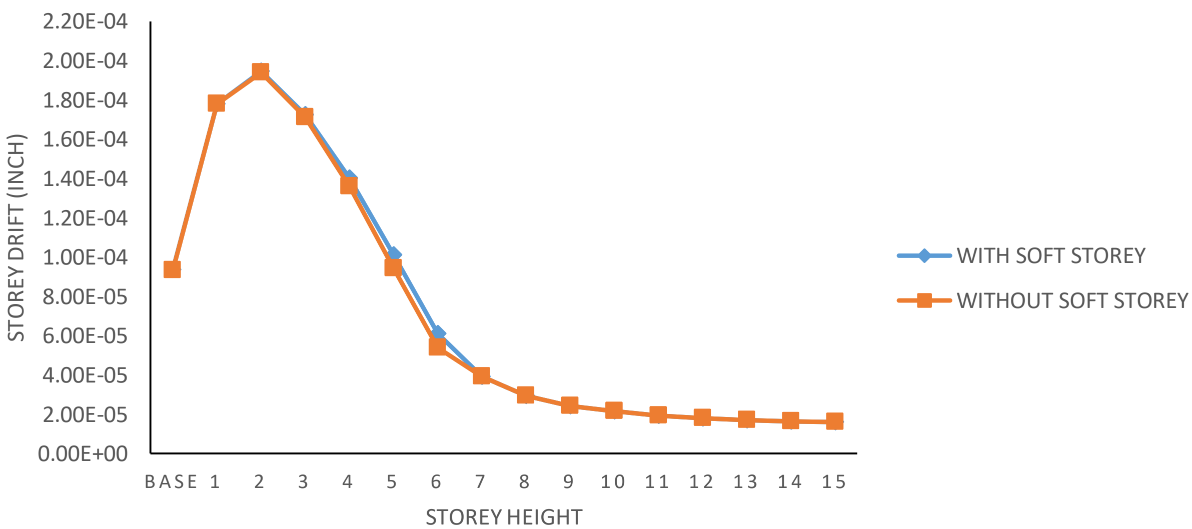


Figure 4.11(c): Comparison of Storey Drift in X Direction for Wx (15 Storied)

The figure 4.11(c) shows the comparison of storey drift in X directions for Wx with and without soft storey, the relative displacement is observed from 3rd to 7th storied.

20 Storied

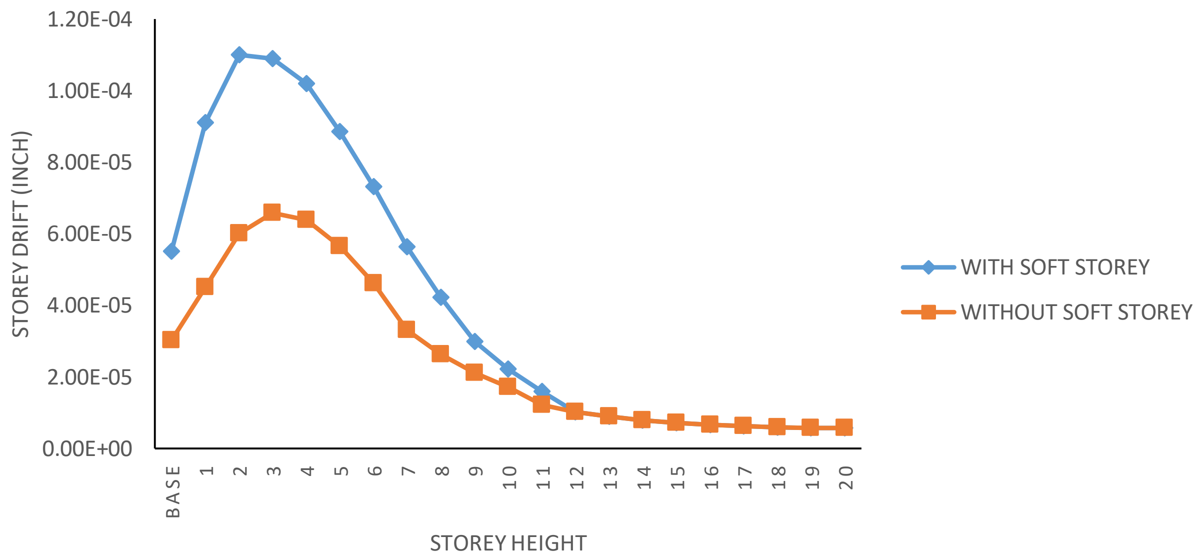


Figure 4.12(a): Comparison of Storey Drift in Y Direction for EQy (20 Storied)

The figure 4.12(a) shows the comparison of storey drift in Y directions for EQy with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000515 inch where 1st floor value is .0000910 inch. Again, without soft storey the drift value in the base is .0000302 inch where 1st floor value is .0000451 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Again, 1st to 2nd storey relative displacement is increased in soft storey building then it decreased gradually and this trend is continued up to 20 storey. But without soft storey's building, storey drift is increased from base to 3rd floor then it decreased gradually up to 20 storey.

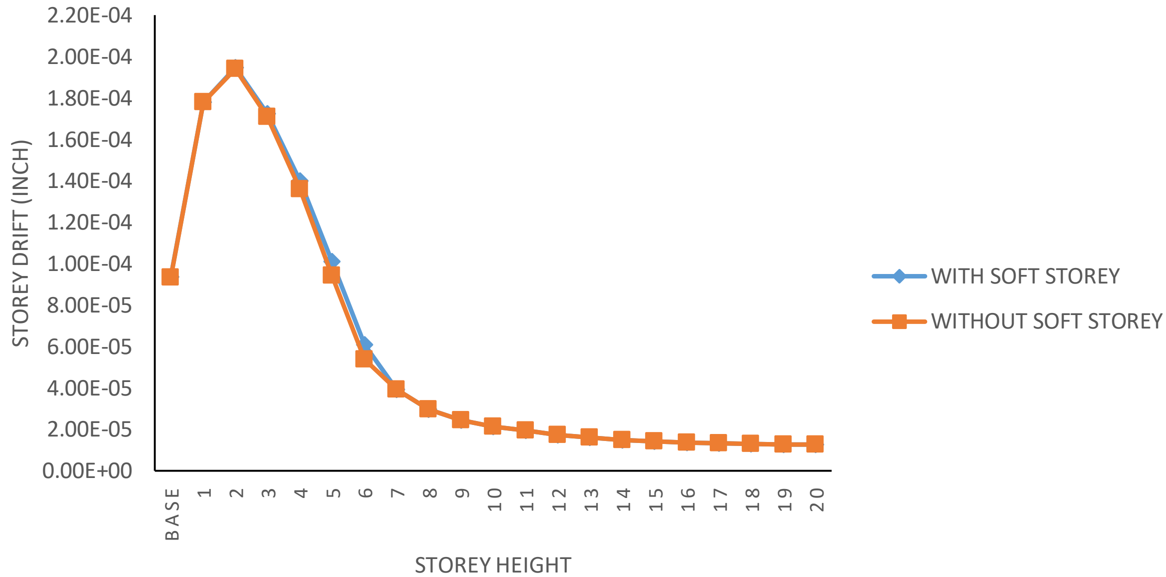


Figure 4.12(b): Comparison of Storey Drift in X Direction for Wx (20 Storied)

The figure 4.12(b) shows the comparison of storey drift in X directions for Wx with and without soft storey, the relative displacement is observed from 3rd to 7th floor.

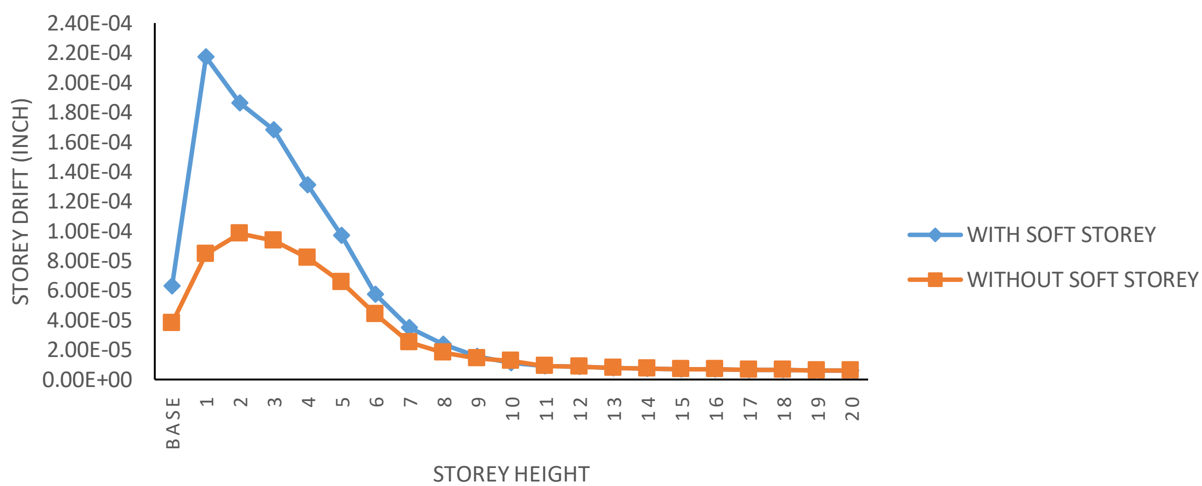


Figure 4.12(c): Comparison of Storey Drift in X Direction for EQx (20 Storied)

The figure 4.12(c) shows the comparison of storey drift in X direction for EQx with and without soft storey. For the graph of storey drift with soft storey, the drift value in the base is .0000626 inch where that in the 1st floor is .000217 inch. Again, without soft storey the drift value in the base is .0000377 inch, where that in the 1st floor value is .0000845 inch. So it may be concluded that, the 1st storey relative displacement with soft storey building is larger than the base. Then relative displacement is decreased gradually in soft storey building and this trend is continued up to 20 storey. But without soft storey's building, storey drift is increased from base to 2nd floor then it decreased gradually up to 20 storey.

4.3Comparisonof Storey Drifts in all soft storey buildings

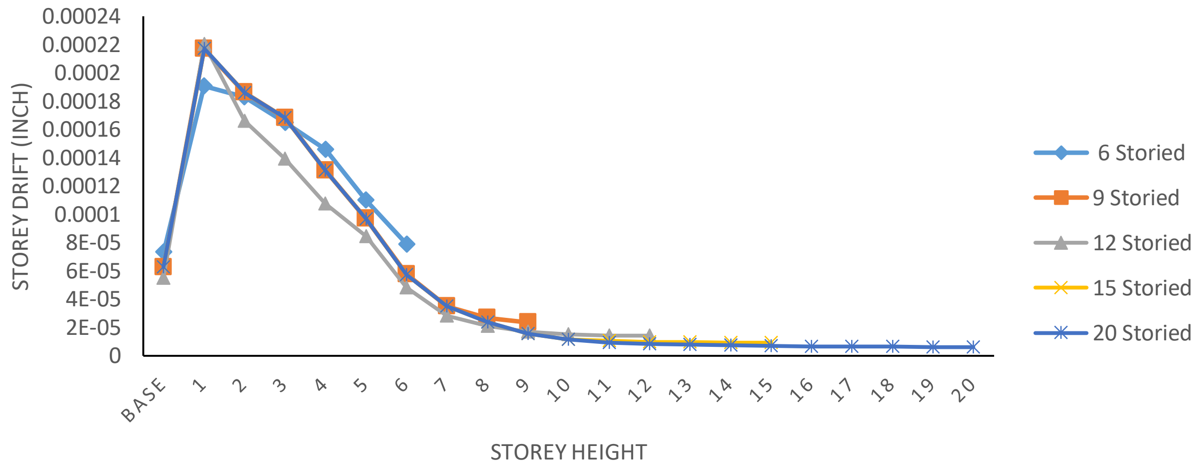


Figure 4.13(a): Comparison of Storey Drift for EQx in buildings (With Soft Storey Buildings)

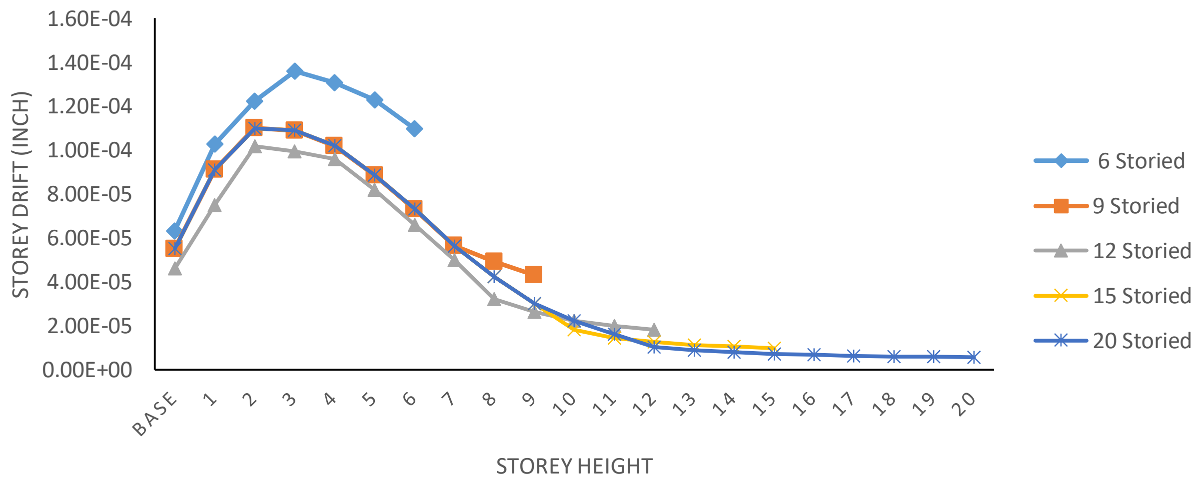


Figure 4.13(b): Comparison of Storey Drift for EQy in buildings (With Soft Storey Buildings)

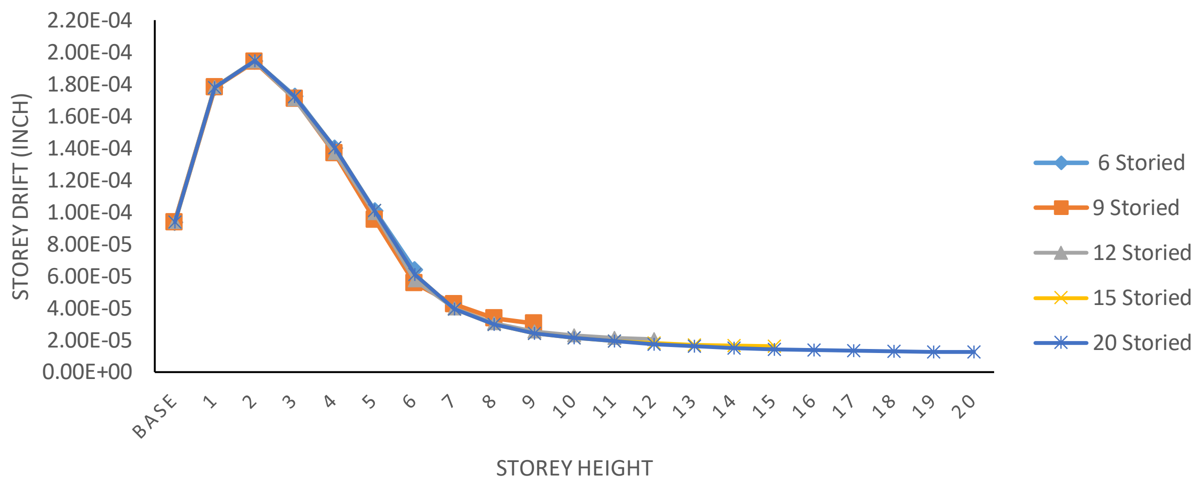


Figure 4.13(c): Comparison of Storey Drift for Wx in buildings (With Soft Storey Buildings)

4.4Comparison of Storey Drifts in all without soft storey buildings

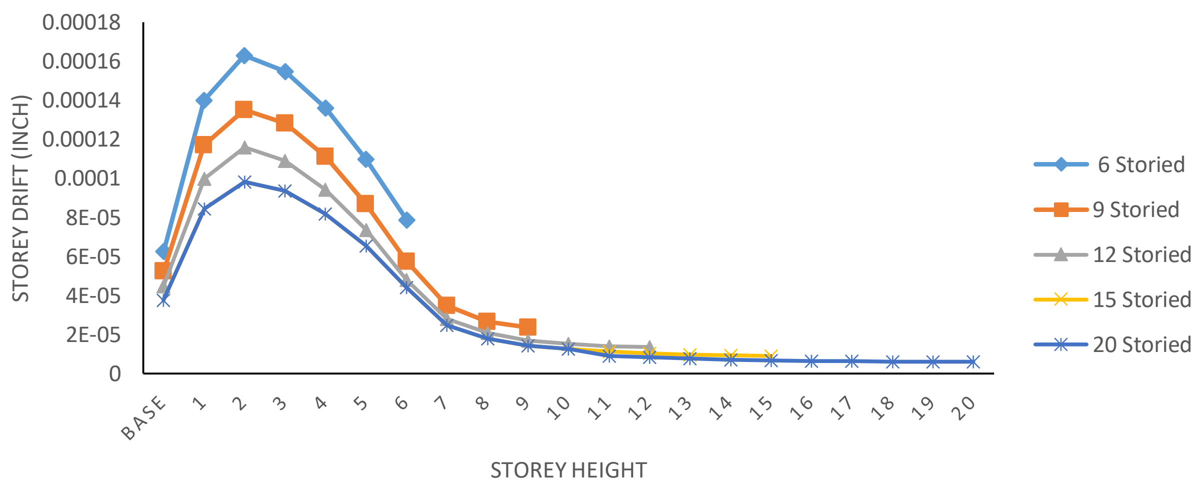


Figure 4.14(a): Comparison of Storey Drift for EQx in buildings (Without Soft Storey Buildings)

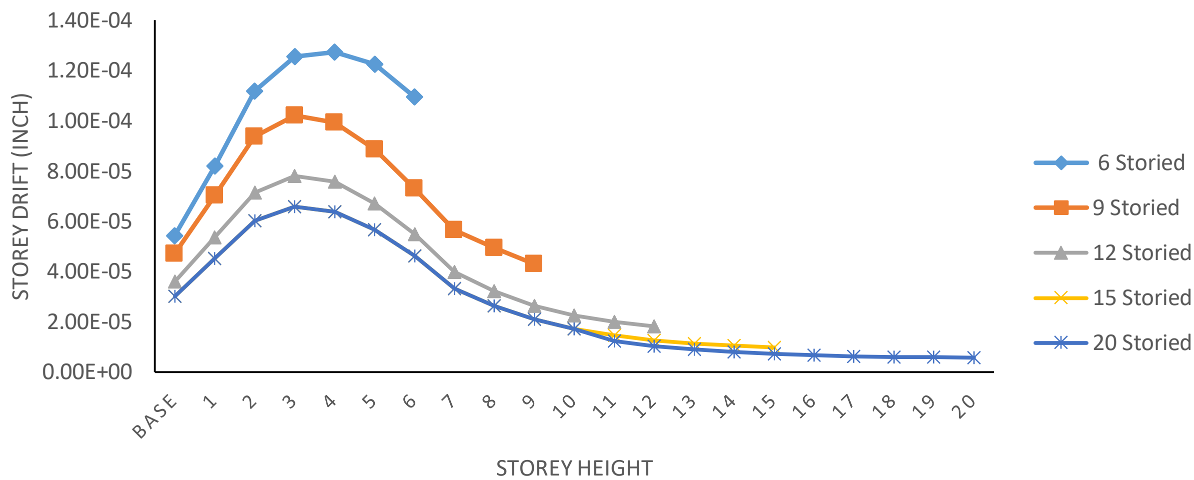


Figure 4.14(b): Comparison of Storey Drift for EQy in buildings (Without Soft Storey Buildings)

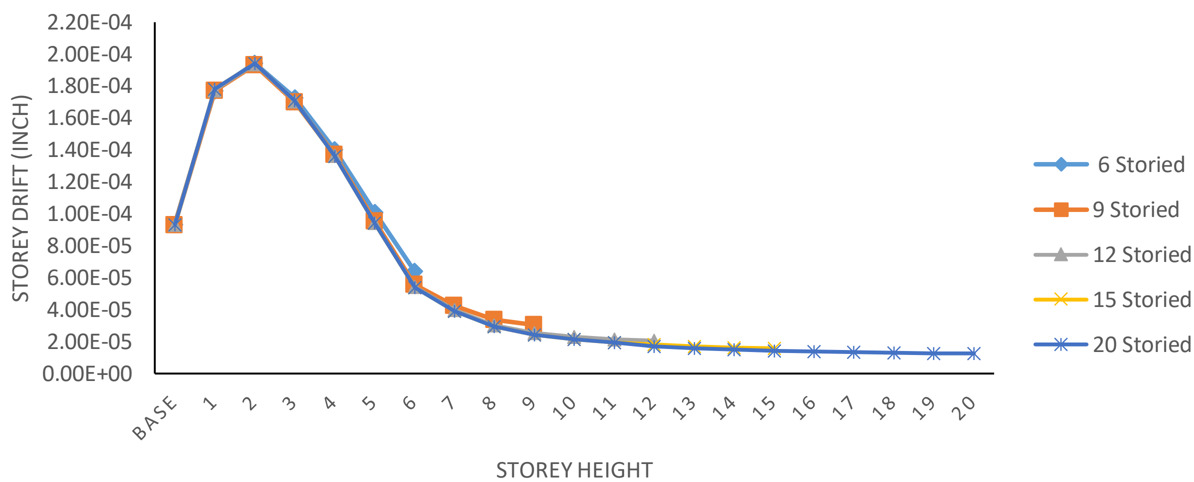


Figure 4.14(c): Comparison of Storey Drift for Wx in buildings (without Soft Storey Buildings)

4.5 Remarks

The present study investigates analysis of a number of RCC buildings with and without soft stories. The obtained results have been presented and explanations of the possible variations of the results have also been compiled. The following chapter will conclude the findings and will point out directions for future studies.

CHAPTER 5

CONCLUSIONS

5.1 General

The thesis emanated with an aim to conduct study of a number of RCC multistoried buildings to observe the effect of ground soft story on structural performance of these buildings. In this regard, a number of parameters have been determined (base shear, time period, story drift and column reaction force). For organizing the study, the theoretical background of the study is discussed. Then in chapter-2, the details of building study have been summarized with necessary theories. In chapter-3, the detailed step-by-step methodology for present study have been discussed. The subsequent chapter is the summarization of computational investigation and comparative study of obtained results from research work. The results of the present study are informative and hopefully would be useful for practical purposes.

5.2 Outcomes of the Study

The present study comes with a number of significant outcomes, which are expected to fulfill the aims of the study and at the same time will point towards some important directions:

- For consisting the same storied buildings, time periods (with and without ground soft storey) are found to be almost same.
- Base shear values for same storied buildings (with and without ground soft storey) are found to have slight variations with each other.
- Storey drift (for buildings with and without ground soft storey) for earthquake load acting in X direction increases initially upto 1st storey from base, which eventually tends to decrease with the increase of number of stories above base.
- Storey drift (for buildings with and without ground soft storey) for earthquake load acting in Y direction increases initially upto 2st or 3rd storey from base, after reaching the peak value, it eventually tends to decrease with the increase of number of stories above base.
- For storey drift (for buildings with and without ground soft storey) for wind load in X direction, initially no major observation is noted, but slight amount of deviation in relative displacement is observed from 3rd to 7th floor. After 7th floor, no variation in story drift values is observed.
- For the cases of support reactions (for interior, exterior and corner columns) for load combinations involving wind and earthquake loads, slight variation is observed for the

same story buildings (with and without ground soft storey). This is true for all types of buildings.

5.3 Future Scopes and Recommendations

Based on the study, it may be recommended that:

- The present study may be extended to investigate the effect of soft storey at the other floors (rather than ground floor).
- Similar study may be conducted for steel structures and composite structures.
- The study may also be carried out to observe the effect of dimension change of the frame elements (e.g. beams, columns, slabs) on building drifts having soft stories.
- The study may be carried out for buildings involving different types of slab systems (i.e.waffle slab, flat slab, flat plate slab, ribbed slab etc.).

APPENDIX

Table 1: Structure Importance, C_1 for Wind Loads

Structure Importance Category	Structure Importance Coefficient, C_1
I Essential Facilities	1.25
II Hazardous Facilities	1.25
III Special occupancy structure	1.00
IV Stan	1.00
V) Low Rick structure	0.80

Table 2: Seismic Zone Coefficient, Z

Seismic Zone	Zone Coefficient
1	0.075
2	0.15
3	0.25

(Tables from BNBC-2006)

REFERENCES

- Bangladesh National Building Code (BNBC), 2006