Comparative Study on Reinforced Concrete Buildings in Different Seismic Zones of Bangladesh Based on Different Soil Types

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Declaration of Candidate

It is hereby declared that this thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma (except for publication).

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Dedication

We would like to dedicate this thesis to our beloved parents.

Acknowledgements

"In the name of Allah, Most Gracious, Most Merciful"

All praises to Almighty Allah for giving us opportunity to conduct this thesis work and helping us in solving difficulties during our project work.

We would like to express our sincere appreciation to our supervisor Prof. Dr. Md. Tarek Uddin, PEng; Department of Civil and Environmental Engineering, Islamic University of Technology (IUT), for his generous guidance, advice and encouragement in supervising us. His technical and editorial advice was essential for the completion of this academic research. Without his assistance and guidance, the paper would never been accomplished.

Abstract

Bangladesh is situated in an earthquake-prone zone where devastating earthquake occurs frequently. This is especially alarming for different kinds of infrastructures, i.e., building structures. It is necessary to find out the proper economical designs of such buildings that can withstand an earthquake. The objective of the study is to analyze the performance of 8 (G+7) storied reinforced building structures in different seismic zones of Bangladesh for two different soil types (SC & SD) as per Bangladesh national building Code (BNBC), 2020 by using the software ETABS (finite element method). Additionally, storey drift, storey displacement, torsion irregularity, mass irregularity and soft storey have been checked for all cases. Comparisons have been made amongst all cases with respect to aforementioned parameters along with storey shear. The results show that the building model has passed the inspection in lower seismic zones for a certain dimension of beam, column, and slab. But failure occurs in higher seismic zones. Results also vary for different soil types. Findings show that the building model passes more for SC soil type than SD soil type in maximum seismic zones. Shear walls have been introduced to those cases where the infrastructure was unable to resist the earthquake. Comparisons have been made between the models with shear wall and without shear wall. Results show that introduction of shear wall decreases storey displacement, drift and shear in most cases. Findings also show that when the shear walls are introduced, it increases the cost of concrete in higher seismic zones as the volume of concrete is higher in those zones than in the lower seismic zones. The information provided in the following research paper will be productive for further study on constructions in different seismic zones in Bangladesh.

Keywords: Seismic Zone, Soil Type, Torsion Irregularity, Mass Irregularity, Soft Storey, Shear Wall, Storey Displacement, Storey Drift, Storey Shear, Construction Cost.

LIST OF SYMBOLS

Z	Seismic Zone Co-efficient
S	Site dependent soil factor
R	Response Reduction Factor
Cd	Deflection Amplification Factor
D	Dead Load
L	Live load
Lr	Roof live load
E	Earthquake load
W	Wind load
C	Cement
FA	Fine Aggregate
CA	Coarse Aggregate

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CHAPTER 1 : INTRODUCTION

1.1 General

Bangladesh happens to be in a zone prone to earthquakes and the country has experienced several earthquakes in the past, which were of minor intensity (Farhan, Siddique and Hossain, 2020).These minor tremors signal possible strikes of powerful earthquakes in the near future (Apu and Das, 2020). Thus, seismic loads must be taken into consideration in the design of our structures (Das, 2014). In buildings, the lateral loads due to earthquakes are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway (Farhan & Jagadeesh, 2019). The risk of significant earthquakes in the future makes the earthquake analysis of the design of any structure necessary. The following study has been undertaken to analyze the possible changes in the seismic behavior of RC building models for different seismic zones for two different soil types (SC and SD). According to BNBC (2020), SC type soil are mainly deep deposits of dense to medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres. On the other hand, SD type of soil are deposits of loose to medium cohesionless soil (with or without some soft cohesive layers) or of predominately soft to firm cohesive soil. The structure has been analyzed in four zones: Zone 1 Bagerhat, Zone 2 Dhaka, Zone 3 Chittagong and Zone 4 Sylhet. The structure for all zones and soil types has been mainly analyzed for sway limitation, storey drift, earthquake storey drift, and torsion irregularity along with stroey displacement and shear. All RC building models have been analyzed without a shear wall, but the RC building model of Zone 4 (Sylhet), which did not pass the limitation for earthquake storey drift, have been analyzed with shear walls. A few research papers have analyzed the seismic behavior of RC buildings models for different seismic zones. For example, (Kakpure and Mundhada, 2017), showed the analysis of two buildings (a G+10 and a G+25 structure) for only seismic zone 3 of India and analyzed the structures using equivalent static analysis method and response spectrum method using ETABS 15 software. (Rabbi and Sadik, 2020) have shown that the seismic analysis of an 8 storied residential building situated in Dhaka city and compared provisions of earthquake and wind analysis using BNBC 1993 and BNBC 2017. However, the number of papers is limited in several areas. For instance, the papers have not analyzed the structure for different seismic zones for the same RC Model for different soil types. Therefore, to address the following gap, the current study highlights the earthquake analysis of the RC building model for different zones in two different soil types.

1.2 Objective

The following study includes the following objectives:

- To perform seismic analysis of RC structure in different seismic zones of Bangladesh in different soil types.
- To study the behavior of a multi storied RC building subjected to lateral load by adopting Static Linear analysis using ETABS 2016.
- To evaluate the corresponding effects of zonal seismic variation and the material cost estimation for both with and without shear wall of RC structure.

1.3 Scope

The scope of the study involves:

- The study of the relationship of storey displacement (for EQ) in X and Y direction for SC type soil and SD type soil for four zones.
- The study of the relationship of storey displacement (for EQ) in X and Y direction for SD type soil in zone 4 for both with and without shear wall.
- The study of the relationship of storey shear (for EQ) in X and Y direction for both SC and SD type soil.
- Finding out the cost estimation of material calculation of M25 Grade Concrete for both with and without shear wall.

1.4 Research Flow

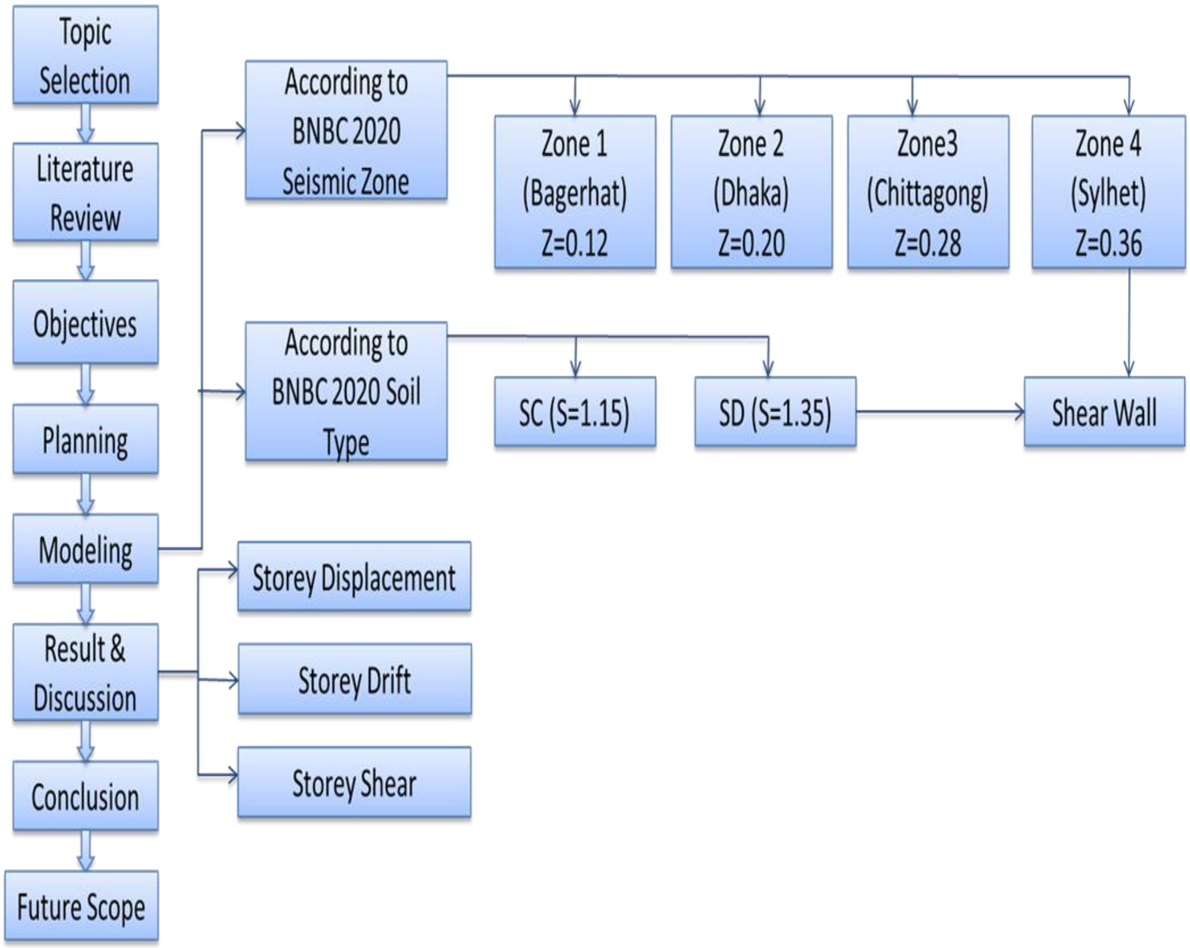

Figure 1: Research Flow

1.5 Thesis Outline

The rest of the thesis chapters will be organized as follows:

- ✓ Chapter 2: Literature Review; The following chapter discusses about the previous studies on the following subject and discusses about the works conducted in those studies.
- ✓ Chapter 3: Methodology; The following chapter discusses about the steps involved in conducting the study.
- ✓ Chapter 4: Results and Analysis; The following chapter discusses about the findings of the proposed study in the form of tabular and graphical representation of the model being analyzed.
- ✓ Chapter 5: Conclusion and Recommendation; The following chapter highlights the key findings of the study. The future directions and recommendations have been given for further explorations of the limitations involved in the study.
- ✓ Chapter 6: References; A list of all the references have been provided in this chapter.

CHAPTER 2 : LITERATURE REVIEW

In the following chapter a compilation of literature review has been conducted which highlights the research that has been published by recognized scholars and researchers in the following field. Some of the major research papers and their important findings have been highlighted in this following chapter. (Muhaned Abass Mohammed, 2020) have proposed in his study proposed about four different shapes of same area multistorey model and tested the model under ETABS for various parameters. The proposed study have later highlighted the seismic analysis and design by ETABS with IS code and BS code to conduct a comparative analysis of IS Code and BS Code in seismic analysis of structures by ETABS. (Balaji.U. A1, 2016) studied a residential building which is G+13 storied. The building was analyzed for earthquake loads using ETABS. The paper also has highlighted the model by considering severe seismic zones and the behavior is assessed by taking types II soil condition.

(Sallal, 2018) presented a building which was designed and analyzed under effect of earthquake and wind pressure using ETABS software. In the following paper a 18 x 18 m and eight stories structure were modeled using ETABS software. (Kakpure and Mundhada, 2017) presented a review of the previous work done on earthquake analysis for multi storied buildings. (Mahesh and Rao, 2014) discussed about a residential G+11 multi-story building for earthquake and wind load using ETABS and STAAD PRO V8i. The following study have also carried out the analysis by considering three different types of seismic zones and three different soil types namely Hard, Medium and Soft. (Kakpure and Mundhada, 2017) discussed about two tall buildings (a G+10 and a G+25 structure), presumed to be situated in seismic zone III, are analyzed by using two different methods viz. equivalent static analysis method and response spectrum method, using ETAB 15 software. The following paper also highlights the parameters like storey displacement, axial load, bending moments for comparative study. (Fernandes, 2015) discussed in his paper an analytical study to find response of different regular and irregular structures and an analysis has been made by taking 15 storey building by static and dynamic methods using ETABS 2013.

(Kamble and Awchat, 2018) have analyzed a high rise (G+20 storied) building using STAAD Pro and ETABS. The project also involved the dynamic analysis of RC building with shear wall to know about the seismic behavior of the structure. The following study includes test results of base shear and story drift. (Malviya, Pahwa and Scholar, 2017) studied the seismic analysis of high rise multistorey reinforced concrete symmetrical and asymmetrical frame building with the help of SAP software. (Haque, 2016) have conducted a study to carry out the static and dynamic analysis over different regular and irregular shaped RCC building frames according to the Bangladesh National Building Code 2006. The following study have also analyzed four different shaped (W-shape, L-shape, Rectangle, Square) ten storied RCC building frames using ETABS and SAP 2000 for the seismic zone 3 (Sylhet) in Bangladesh.

CHAPTER 3 : METHODOLOGY

3.1 Method of Analysis

Equivalent Static Analysis was used to do the research, which was enhanced by ETABS 2016.

Equivalent static analysis is a simple methodology for design purposes that replaces the impact of dynamic loading from a projected earthquake with a static force distributed laterally on a structure.It also based on linear static analysis, may be utilized for simpler and more regular designs with low to medium height structure. The equivalent lateral force approach distributes a portion of the seismic force (base shear) to each floor capable of transferring lateral loads. Static forces are created and applied to stiff (or semi-rigid) diaphragms or vertical parts (columns, wall) that may carry computed forces as a consequence of this procedure. Each code specifies the constraints of utilizing such a procedure. The most typical constraints are structural regularity and height.

The storey's mass contains additional masses as well as dynamic masses from transformed loads.

Diaphragms ensure that earthquake loads are distributed proportionally on vertical parts. The generated force should be applied to the diaphragm's center of mass. Seismic force is not carried by a diaphragm or panel that is not positioned at the plane of the story top. In the absence of diaphragms, masses of nodes situated at the plane of story top (floor plane) are considered. The proportionate to mass force distribution must next be carried out.

This approach calculates and distributes design base shear on each level, and it is anticipated that the building would respond in basic mode according to its respective rules.Torsion irregularity, s oft story, and mass irregularity have been checked in accordance with the most recent BNBC (2020) codes.

3.1.1 Torsion Irregularity

According to the recent codes (2.5.5.3.1) of BNBC (2020), torsion irregularity happens to be as the condition where the maximum storey drift at one end of the structure transverse to an axis happens to be more than 1.2 times the average of the storey drifts at the ends of the two structures but if maximum storey drift cross 1.4 times than the average storey drift, then it is called as extreme torsional irregularity.

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3.1.2 Soft Storey

According to the codes (2.5.5.3.2) of BNBC (2020), Soft storey has been checked which is mainly occur if lateral stiffness is less than 70% from the lateral stiffness of above storey or less than 80% from the average lateral stiffness of above three consecutive stories. But in case of extreme soft storey, lateral stiffness is less than 60% from the above storey's lateral stiffness or less than70% from the average lateral stiffness of above three.

3.1.3 Mass Irregularity

Mass irregularity refers that the seismic weight of a particular storey is more than twice of seismic weight of its adjoining stories (without roofs).

3.1.4 Sway Limitation

The sway limitation also known as the horizontal deflection at the top level of the building or structure due to wind loading shall not exceed 1/500 times the total height of the building above ground(BNBC, 2020).

This sway property can turn out to be a governing factor in member proportioning of large Reinforced Concrete (RC) buildings (Chowdhury & Hossain, 2005)

3.1.5 Storey Drift

Storey Drift is the horizontal displacement of one level of building or structure relative to the level above or below due to the design gravity (dead and live loads) or lateral forces (for example wind and earthquake loads)(BNBC, 2020). For the structure allowable storey drift limit (Earthquake) is $0.020h_{sx}$ where h_{sx} is the storey height below level x.

3.1.6 Storey Displacement

Storey displacement is known as the lateral displacement of the storey relative to the base. The lateral load bearing system can be maximum lateral displacement of the building. According to the codes (2.5.7.5) of BNBC (2020), the storey shear is the summation of lateral forces in a particular storey and all others stories above that. It can be calculated by following formula:

$$V_x = \sum_{i=x}^{n} F_i$$

3.1.7 Cost Estimation

Cost has been estimated for three cases-

i) The model without shear wall and

ii) The model with shear wall

Initially, the amount of materials for 1 m^3 of concrete was approximated. The projected quantity was then multiplied by the needed volume of concrete in each of the two situations.

3.2 Details of Model

In this study, ETABS 2016 was used to analyze an 8-storey (G+7) Reinforced Concrete building model with a plan area of (60 * 50) square feet for various seismic zones in Bangladesh, as well as two distinct soil types for every zone. The seismic co-efficient and wind velocity numbers fluctuate depending on the zone. The vertical earthquake impact was computed using soil types and seismic zones. The area, various characteristics, and measurements of various building elements have been kept constant in all scenarios. For the eight-story structure under consideration in the study, the sizes of beams, columns, and slabs have been approximated roughly. The column and shear wall's support condition is fixed support.

In compliance with BNBC 2020 standards, several load situations such as dead load, live load, seismic load, and wind load, as well as their combinations, were used.

Table 1: Materials Properties

Components	**Values (unit)**
Compressive strength of concrete	4000 psi
Modulus of elasticity of concrete	3600ksi
Shear modulus of concrete	1500ksi
Unit Weight of concrete	150 pcf
Poisson’s ratio of concrete	0.2
Yield stress of steel	60000 psi
Poisson’s ratio of steel	0.3

Table 2: Details of Building

Parameters	Values (unit)
Plan Area dimension	(60 * 50) sq ft
Structure type	RCC building structure
Occupancy category	II
Importance factor,I	1
Exposure type	A
Topographical factor, Kzt	1
Gust factor, G	0.85

Directionality factor, Kd	0.85
No of floor	8 storey (G+7)
Elevation of the Building	78 ft
Bottom storey height	8 ft
Typical floor height	10 ft
Span between bays in X direction	12 ft
Span between bays in Y direction	10 ft

Table 3: Dimensions of Member

Components	Values (unit)
Floor beam size	20 in * 14 in
Ground beam size	22 in * 16 in
Column size	17 in * 17 in
Ground Column size	19 in * 19 in
Slab thickness	5 inch
Wall thickness (exterior)	10 inch
Wall thickness (interior)	5 inch

Table 4: Load Considered

Parameters		Values (unit)
Partition wall load	Exterior wall	0.90 kip/ft
	Interior wall	0.45 kip/ft
	Parapet wall	0.15 kip/ft
Live load		41.77 psf
Floor Finish		25.06 psf
Roof live load		60.57 psf

Table 5: Seismic and Wind Parameters

Zone	Location	Wind Speed(mph)	Z	Soil Type	S	Seismic design category	R	Omega	Cd
1	Bagerhat	173.36	0.12	SC	1.15	B	3	3	2.5
				SD	1.35	C	5	3	4.5
2	Dhaka	147	0.2	SC	1.15	C	5	3	4.5
				SD	1.35	D	8	3	5.5
3	Chittagong	179	0.28	SC	1.15	D	8	3	5.5
				SD	1.35	D	8	3	5.5
4	Sylhet	136.7	0.36	SC	1.15	D	8	3	5.5
				SD	1.35	D	8	3	5.5

3.2.1 Load Combination

3.2.1.1 Load Combination for Strength Design & Serviceability

According to the codes (2.7.3.1) of BNBC (2020), basic combinations of load effects for Strength design method & the code (2.7.5) , Load combination for serviceability are as follows:

Table 6: Load Combination

Strength Design	Serviceability
1) 1.4D	1) D+L
2) 1.2D+1.6L+0.5Lr	2) D+0.5L
3) 1.2D+1.6Lr+(L or 0.8W)	3) D+0.5L+0.7W
4) 1.2D+1.6W+L+0.5Lr	
5) 1.2D+E+L	
6) 0.9D+1.6W	
7) 0.9D+E	

3.2.1.2 Earthquake Load Effect:

According to the recent code (2.5.13) of BNBC (2020), The seismic load effect, E, shall be determined in accordance with the following:

1. For use in load combination 5 in table 3.6, E shall be determined in accordance with the following equation,

   $E = E_h + E_v$

2. For use in load combination 7 in table 3.6, E shall be determined in accordance with following equation,

   $E = E_h - E_v$

   Where, E = total seismic load effect

   E_h = effect of horizontal seismic forces

   E_v = effect of vertical seismic forces

3.2.1.3 Vertical Earthquake Loading, E_v :

According to the recent code (2.5.13.2) of BNBC (2020), The maximum vertical ground acceleration shall be taken as 50 percent of the expected horizontal peak ground acceleration (PGA). The vertical seismic load effect %º may be determined as:

$$E_v = 0.5\,(a_h)D$$

a_h = expected horizontal peak ground acceleration (in g) for design= (2/3)ZS

D= Effect of dead load

S= site dependent soil factor

By taking all the criteria we have got the Table 7 for equation 5 & equation 6 for different zone & soil type:

Table 7: Load Combination due to Vertical Effects

Zone	Soil Type	Equation 5	Equation 7
1	SC	1.246D+E+L	0.854D+E
		1.246D-E+L	0.854D-E
	SD	1.254D+E+L	0.846D+E
		1.254D-E+L	0.846D-E
2	SC	1.277D+E+L	0.823D+E
		1.277D-E+L	0.823D-E
	SD	1.29D+E+L	0.81D+E
		1.29D-E+L	0.81D-E
3	SC	1.307D+E+L	0.793D+E
		1.307D-E+L	0.793D-E
	SD	1.326D+E+L	0.774D+E
		1.326D-E+L	0.774D-E
4	SC	1.338D+E+L	0.762D+E
		1.338D-E+L	0.762D-E
	SD	1.362D+E+L	0.738+E
		1.362D-E+L	0.738-E

3.3 ETABS model generation:

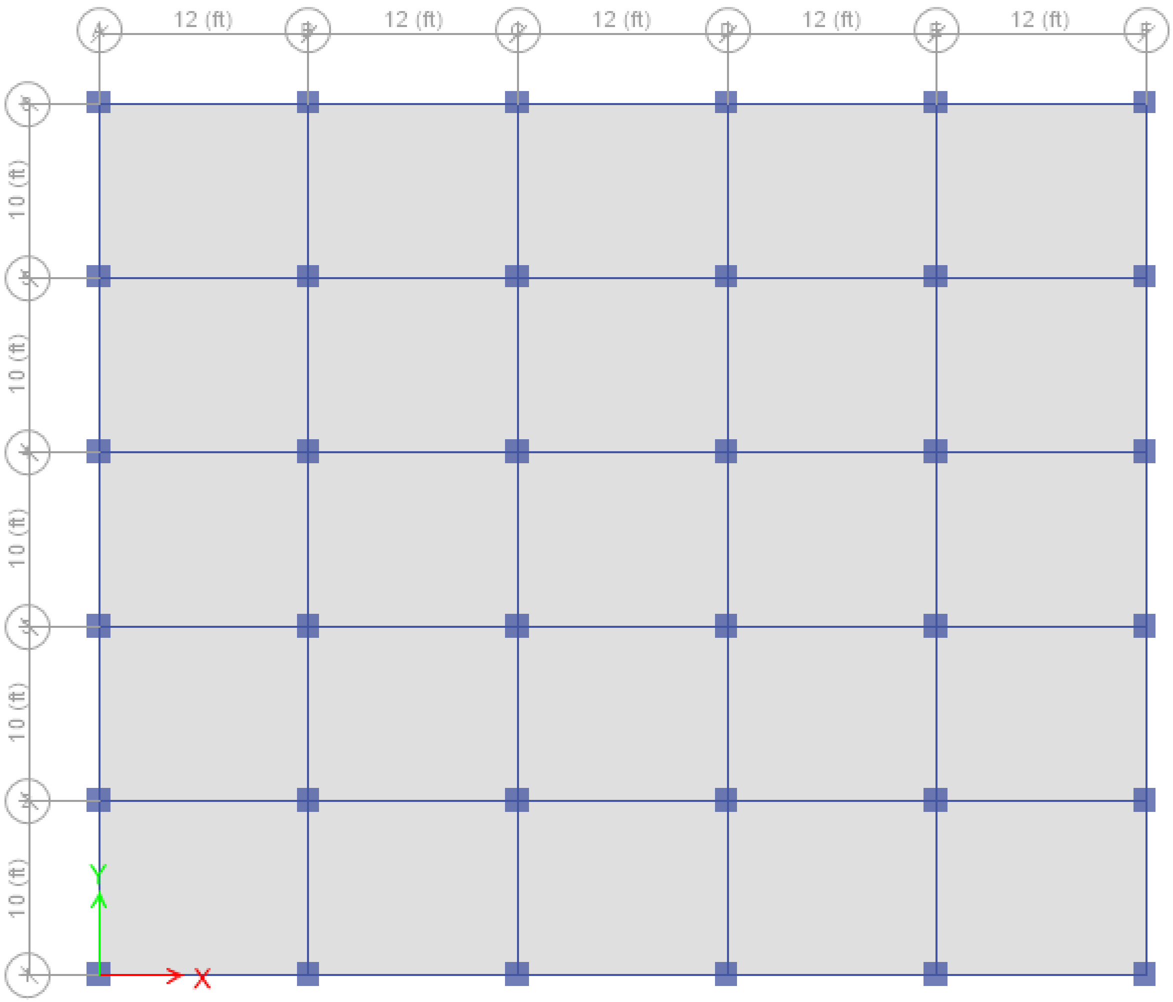

Figure 2: Plan View of Model

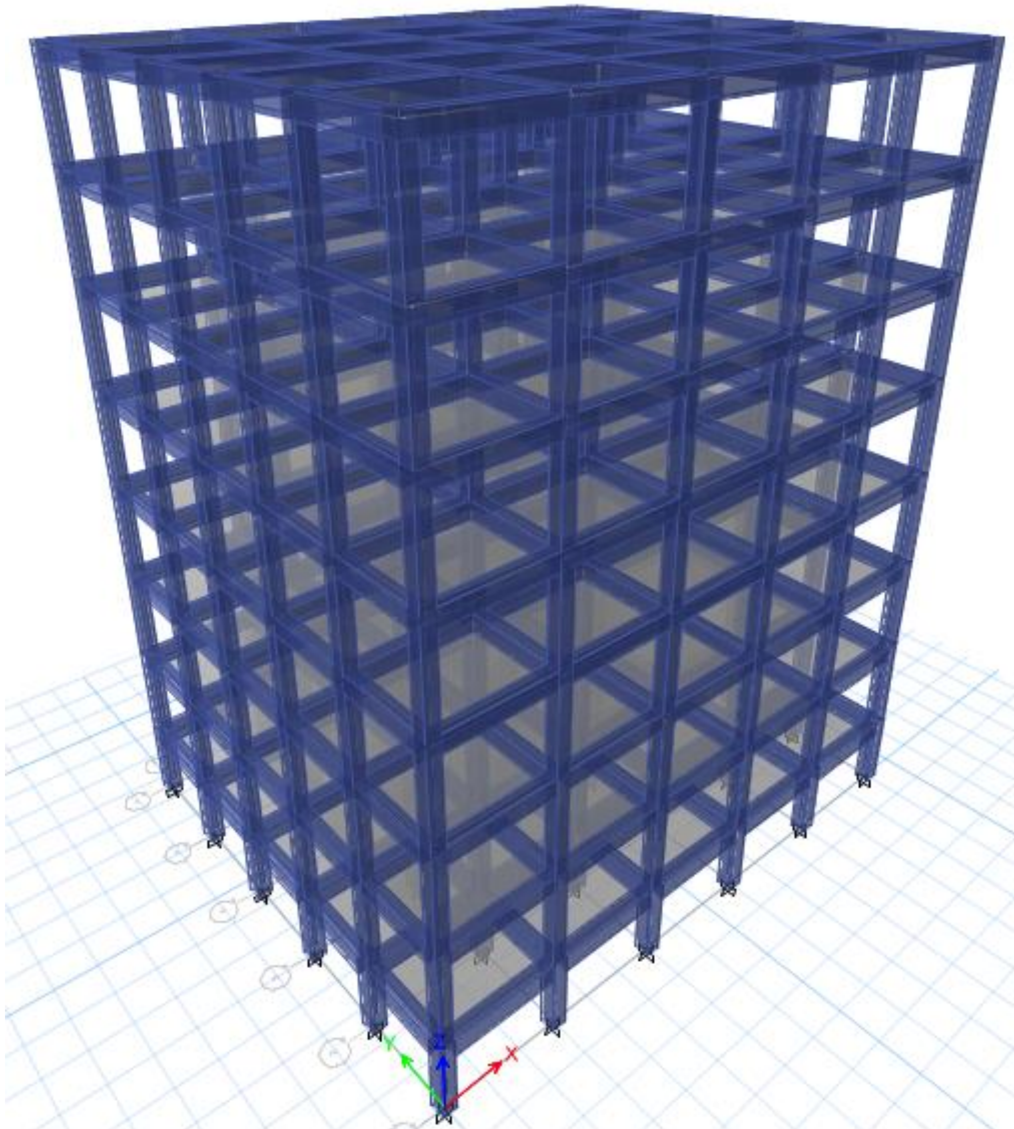

Figure 3: 3D View of Model

CHAPTER 4 : RESULT AND ANALYSIS

4.1 Limitations Check

Table 8 summarizes the allowable limit and the results obtained when the structure has been analysed in four different zones for two different soil types using both shear wall and without shear wall. The structure has been checked for sway limitation, storey drift, earthquake storey drift, and torsion irregularity. The structure has also been checked for soft storey and mass irregularity. In all cases, the model has passed the limitations of soft storey and mass irregularity and that has been shown in Table 9, Table 10 and Table 11. Firstly, the table shows the sway limitation, which has an allowable limit of 1.68. All four zones without shear wall and Zone 4 with shear wall have passed this limitation. Next, the table shows the storey drift, which has an allowable limit of 0.48. Again, all the zones have passed this limitation except Zone 4 for soil type SD, which has a storey drift factor of 0.54, higher than the limitation of 0.48. Finally, the Earthquake Storey Drift has also been analysed, which has an allowable limit of 2.4. The Earthquake Storey Drift has also failed for Zone 4 soil type SD. The highest value of X and Y directions has been taken here.

Additionally, the EQ storey drift has failed in Zone 4 with soil type SD (8” Core Wall). The table also shows the limitation of torsion irregularity (1.2). All the zones have passed this limitation without any shear wall. However, Zone 4, SD (8” Core Wall) and SD (10” Core Wall) have failed to pass the limitation as both the torsion irregularity exceeded the extreme torsion irregularity limit (1.4). As a result, Zone 4 (for soil type SD) has been tested with 8” SW at four corners and in this case the torsion irregularity has passed the limitation. The maximum torsion irregularity of all storeys has been shown here. Also, it has been shown at which storey the torsion becomes maximum. For the first two cases, 1st storey shows the maximum torsion. But, for the last case, top storey or roof shows the maximum value for torsion.

Therefore, rest of the study has been conducted using the last model, where there are four shear walls at the four corners. All comparisons have been made with this model.

Table 8: Limitations Check

Zone	Soil Type	Sway limitation	Storey Drift	Earthquake (EQ) Storey Drift	Torsion Irregularity
	Allowable limit	**1.68**	**0.48**	**2.4**	**1.2**
			Without Shear Wall		
Zone	**Soil Type**				
1	SC	0.99	0.304	0.76	1.132
	SD	0.99	0.29	1.285	1.132
2	SC	0.71	0.304	1.37	1.132
	SD	0.71	0.2976	1.63	1.132
3	SC	1.17	0.3923	2.15	1.132
	SD	1.05	0.4166	2.29	1.132
4	SC	0.62	0.342	1.88	1.132
	SD	0.62	0.54	2.9458	1.132
			With Shear Wall		
4	SD (8" Core Wall)	0.99	0.4599	2.5294	1.626 (1st Floor)
	SD (10" Core Wall)	0.6235	0.3975	2.1865	1.889 (1st Floor)
	SD (8" Shear Wall at four corners)	0.349	0.2488	1.368	1.059 (Roof)

Table 9: Soft Storey and Mass Irregularity Check for Model Without Shear Wall

Soft Storey Check				Mass Irregularity Check		
Criteria for soft storey		Less than 70%	Less than 80%	Criteria for mass irregularity		More than twice of adjacent storeys
Storey No. (all zones & soil type)	Lateral Stiffness	With above storey	With three above storeys	Storey No. (all zones & soil type)	Seismic Weight	With Adjacent Storeys
Roof	1049.85	-	-	Roof	16086.98	Need not to be considered
6th Floor	1386.67	132.08	-	6th Floor	32364.18	1
5th Floor	1421.46	102.51	-	5th Floor	32364.18	1
4th Floor	1433.46	100.84	111.47	4th Floor	32364.18	1
3rd Floor	1445.05	100.81	102.21	3rd Floor	32364.18	1
2nd Floor	1480.41	102.45	103.29	2nd Floor	32364.18	1
1st Floor	1750.79	118.26	120.50	1st Floor	32364.18	1.04
Ground	5601.73	319.96	359.37	Ground	33589.41	1.04

Table 10: Soft Storey Check for Models with Shear Wall

Storey No.	8” at centre		10” at centre		8” at four corners	
	With above storey	With three above storeys	With above storey	With three above storeys	With above storey	With three above storeys
Roof	-	-	-	-	-	-
6th Floor	213.12	-	232.93	-	244.57	-

5th Floor	132.16	-	136.28	-	145.27	-
4th Floor	116.86	167.28	119.74	175.33	126.93	193.30
3rd Floor	113.92	136.53	116.34	142.58	123.32	158.77
2nd Floor	117.15	133.68	119.80	139.45	128.07	156.83
1st Floor	133.19	153.50	137.25	161.34	147.73	183.58
Ground	234.83	344.72	279.72	359.12	284.48	386.96

Table 11: Mass Irregularity Check for Models with Shear Wall

Storey No.	8” at centre		10” at centre		8” at four corners	
	Seismic Weight	With Adjacent Storeys	Seismic Weight	With Adjacent Storeys	Seismic Weight	With Adjacent Storeys
Roof	14767.9	Need not to be considered	14828.33	Need not to be considered	13769.94	Need not to be considered
6th Floor	30470.83	1	30591.7	1	27157.77	1
5th Floor	30470.83	1	30591.7	1	27157.77	1
4th Floor	30470.83	1	30591.7	1	27157.77	1
3rd Floor	30470.83	1	30591.7	1	27157.77	1
2nd Floor	30470.83	1	30591.7	1	27157.77	1
1st Floor	30470.83	1.04	30591.7	1.04	27157.77	1.04
Ground	31549.68	1.04	31682.64	1.04	28144.68	1.04

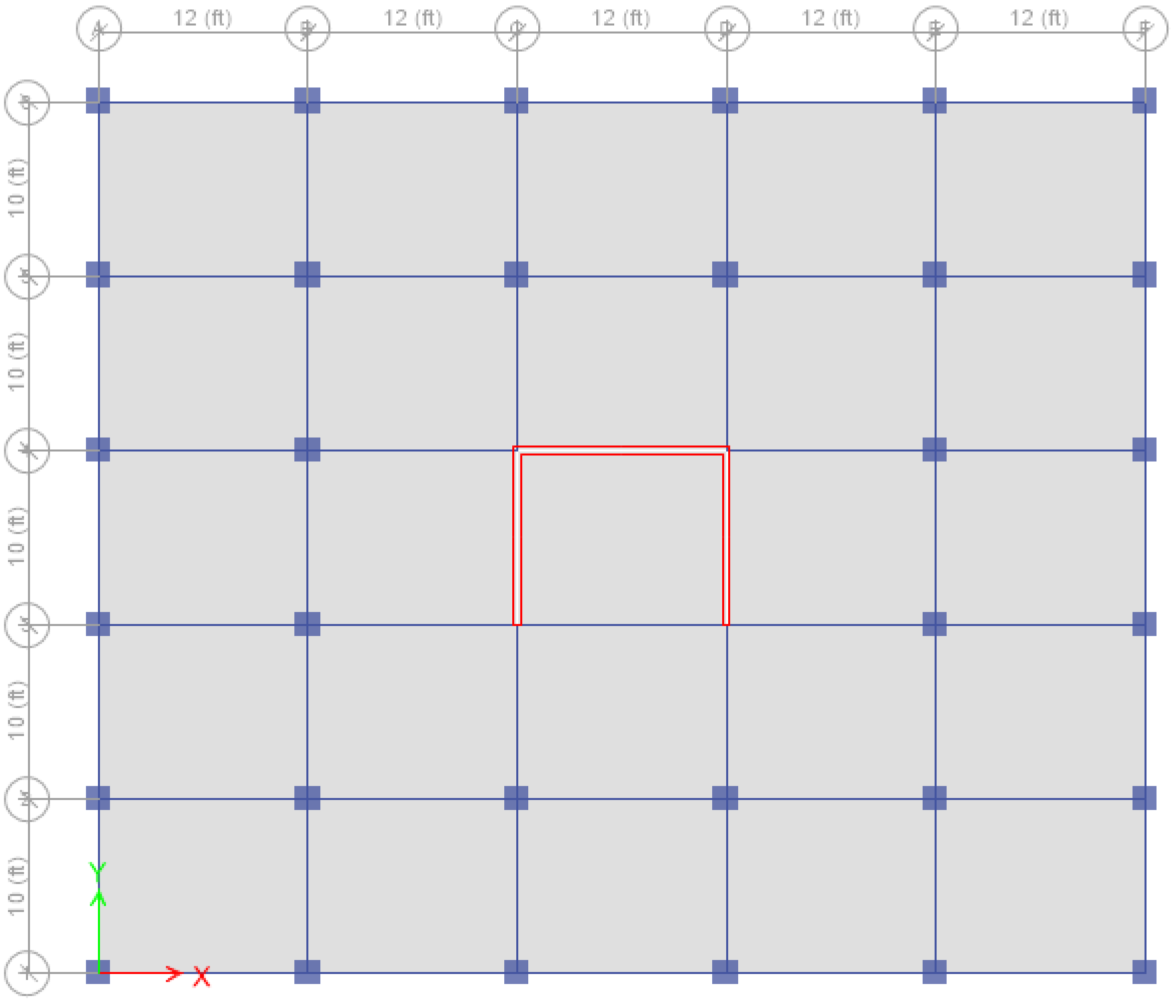

Figure 4: Plan View of the Model with Core Wall

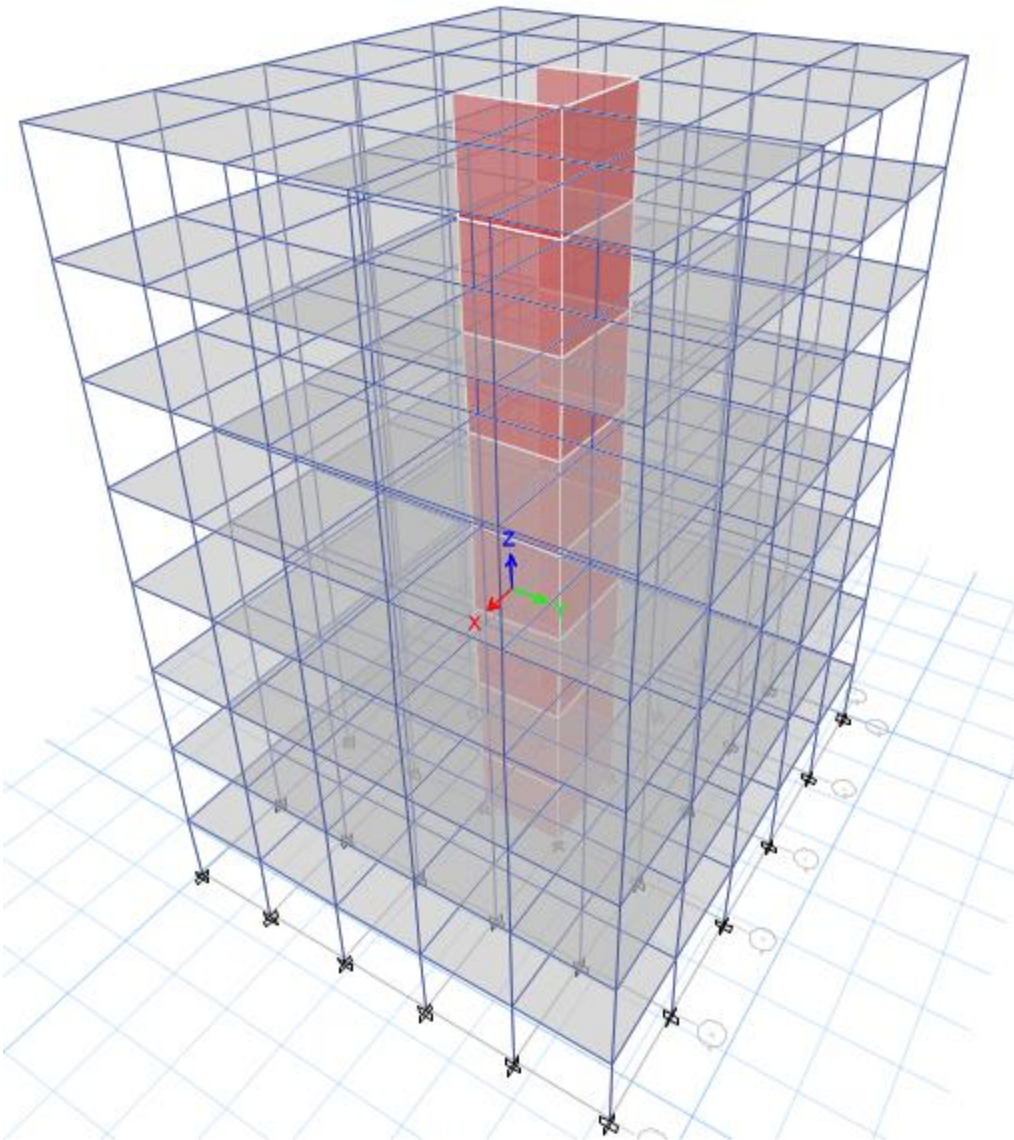

Figure 5: 3D View of the Model with Core Wall

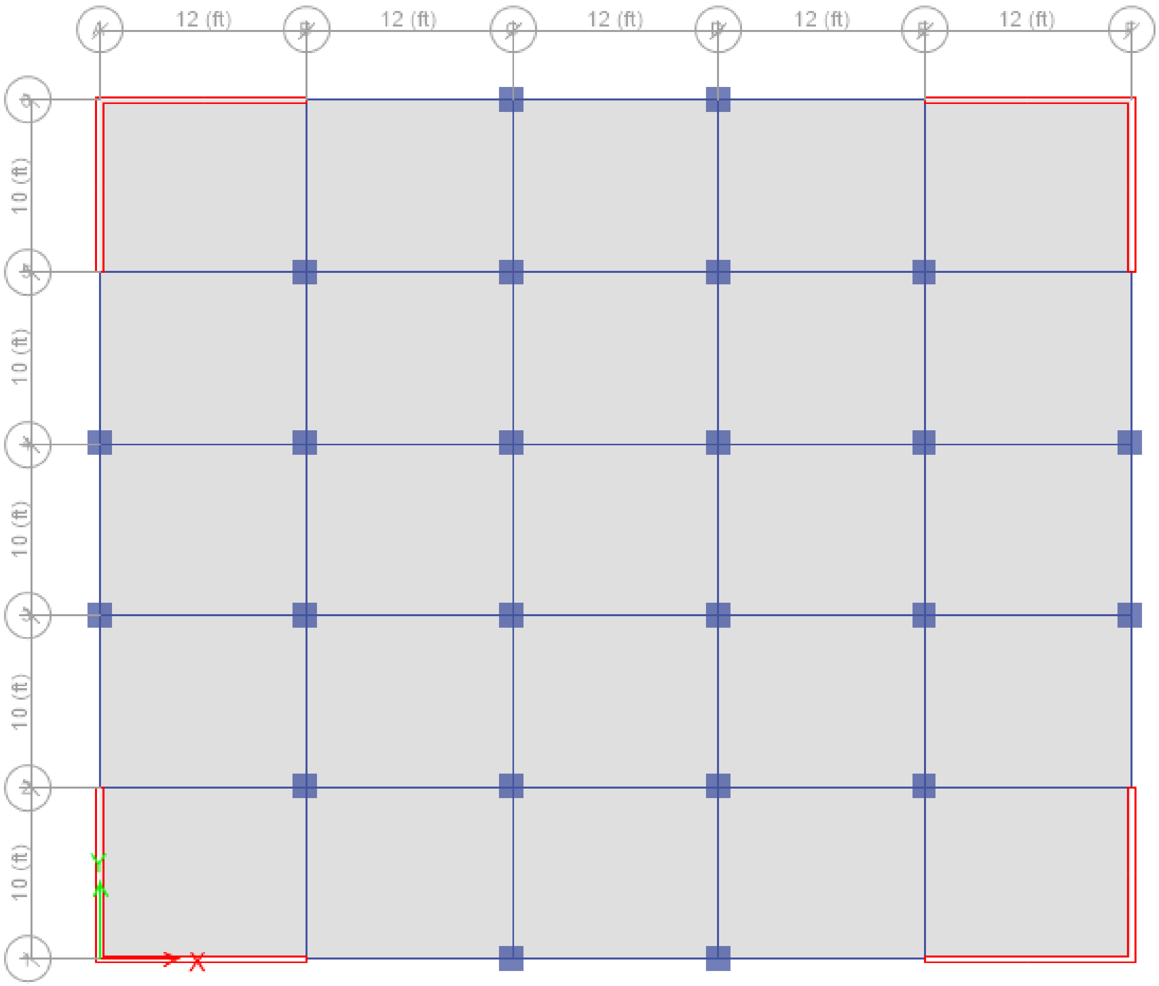

Figure 6: Plan View of the Model with Shear Wall at Four Corners

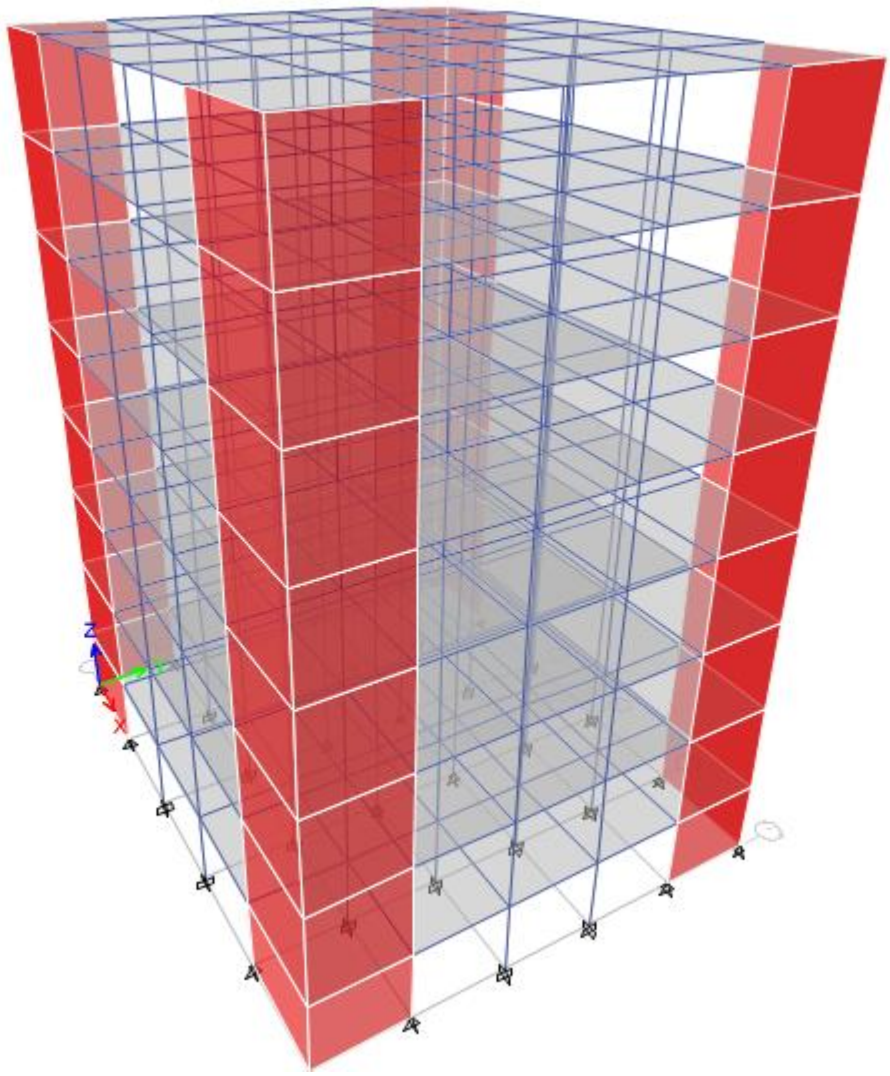

Figure 7: 3D View of the Model with Shear Wall at Four Corners

4.2 Storey Displacement

4.2.1 Storey Displacement in SC Type Soil

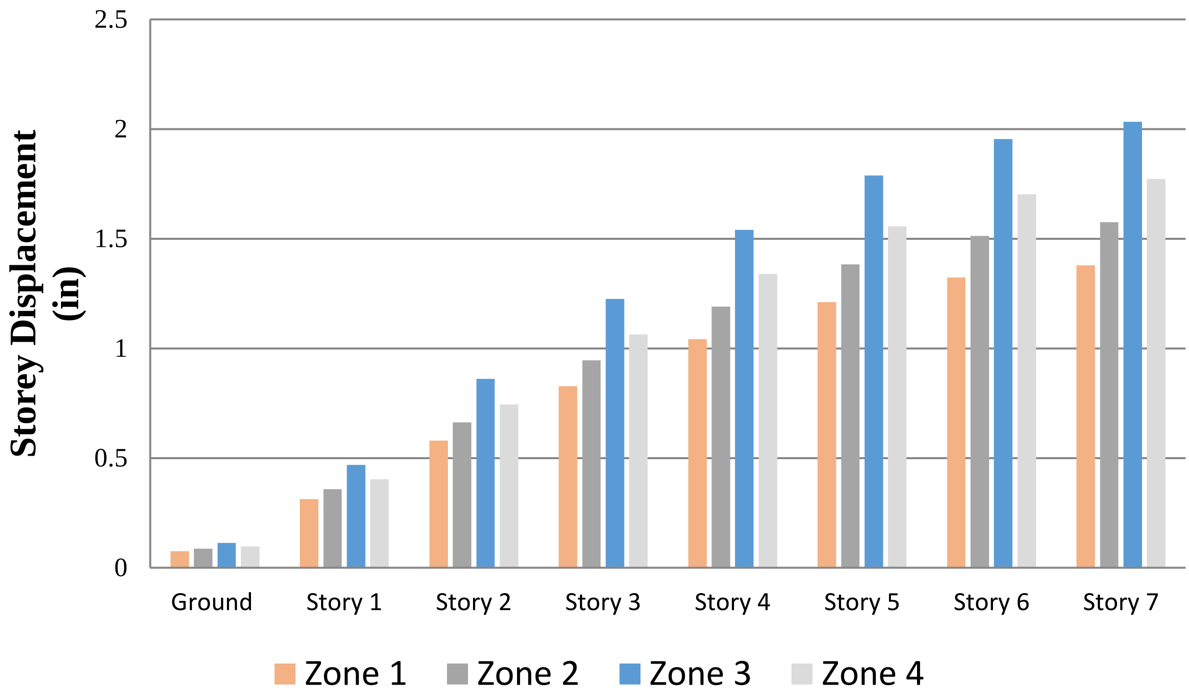

Figure 8: Storey Displacement for Earthquake Load in X Direction for SC Type Soil

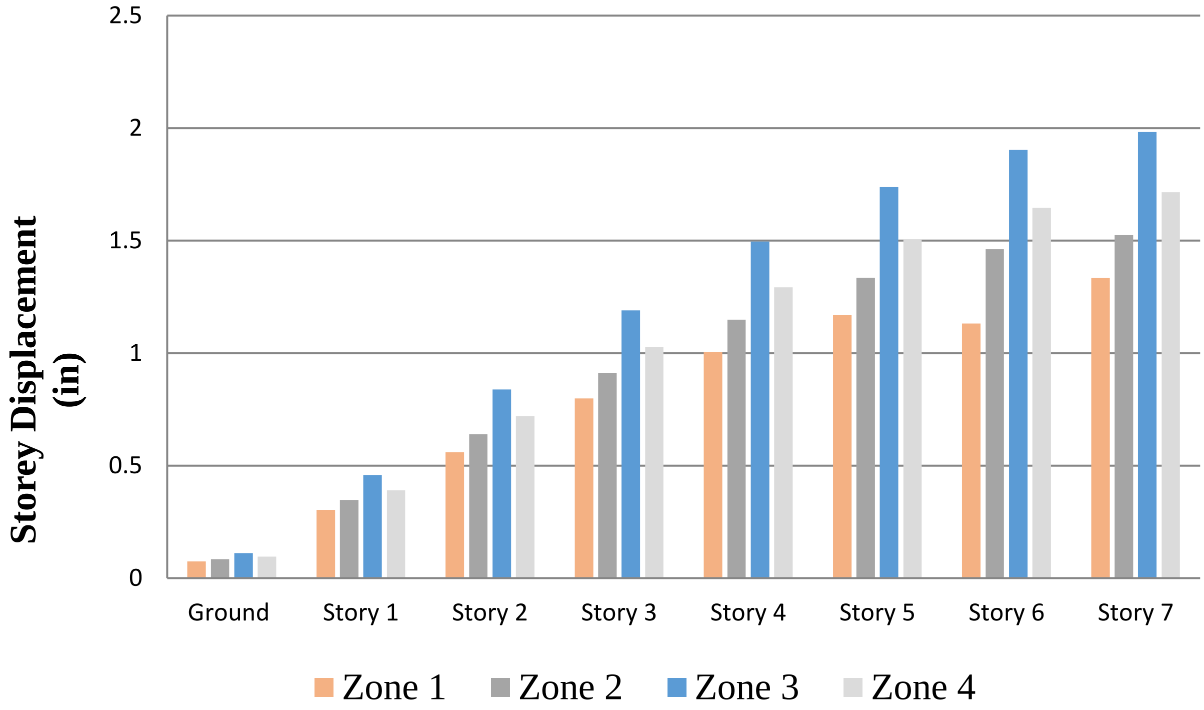

Figure 9: Storey Displacement for Earthquake Load in Y Direction for SC Type Soil

From Figures 8, it can be observed that in X direction, Storey 7 has the highest displacement value which are 1.38 inch, 1.58 inch, 2.03 inch and 1.77 inch for the four zones respectively. On the other hand, ground floor has the lowest displacement value which are 0.07 inch, 0.08 inch, 0.11 inch and 0.09 inch for the four zones respectively. The displacement increases with the increase of storeys. Same changes happen in Y direction as shown in figure 9.

From these two figures 8 and 9, it can be seen that Zone 3 has larger displacement than any other zone in all storeys for both X and Y directions when the soil type is SC. On the other hand, Zone 1 shows the lowest displacement value. The values do not show much differences when the comparison is made between both directions for a particular soil type and zone.

4.2.2 Storey Displacement in SD Type Soil

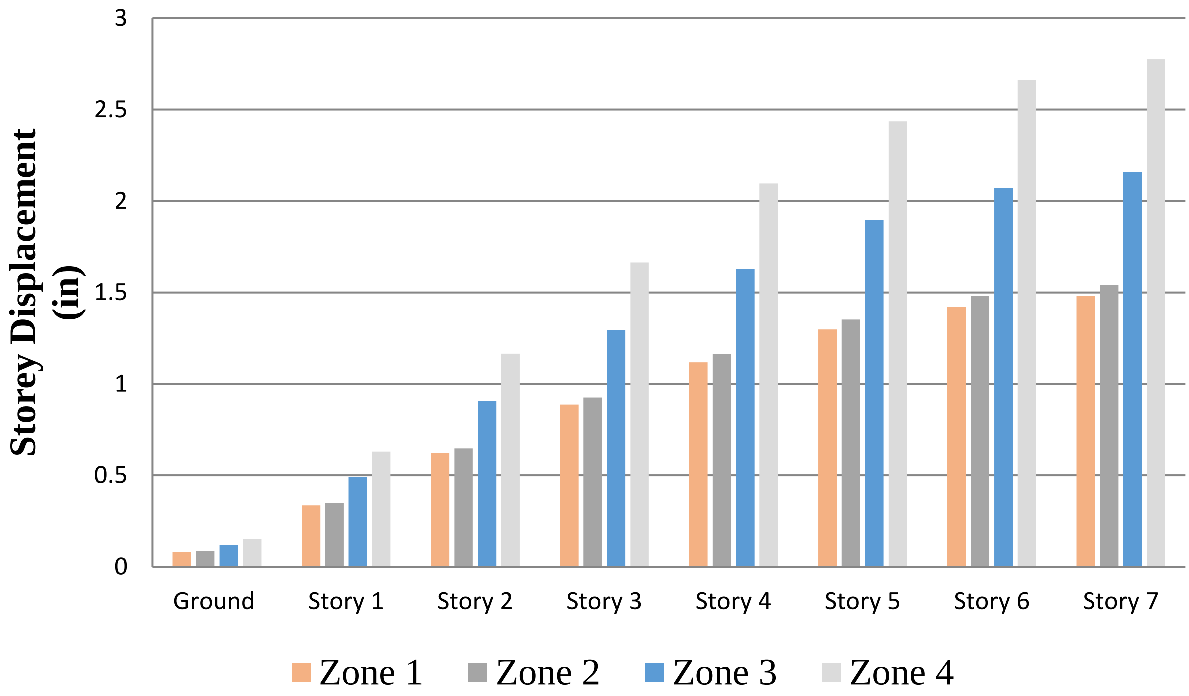

Figure 10: Storey Displacement for Earthquake Load in X Direction for SD Type Soil

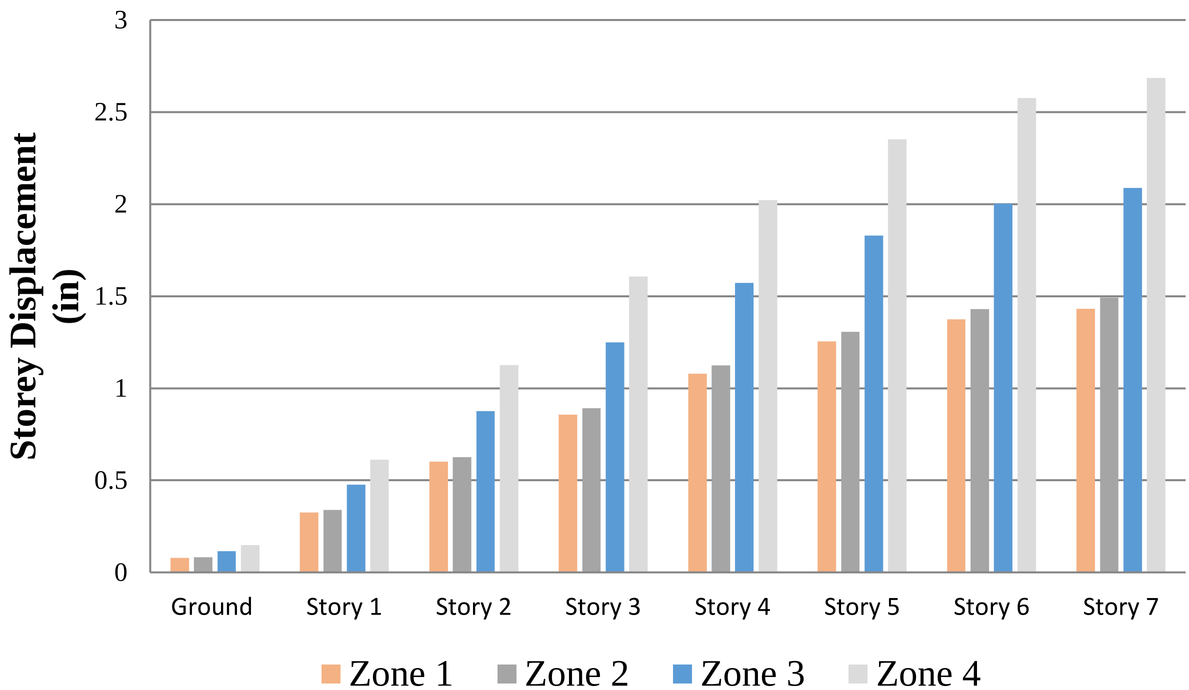

Figure 11: Storey Displacement for Earthquake Load in Y Direction for SD Type Soil

From Figures 10, it can be observed that in X direction, Storey 7 has the highest displacement value which are 1.48 inch, 1.54 inch, 2.15 inch and 2.77 inch for the four zones respectively. On the other hand, ground floor has the lowest displacement value which are 0.08 inch, 0.08 inch, 0.11 inch and 0.15 inch for the four zones respectively. The displacement increases with the increase of storeys. Same changes happen in Y direction as shown in figure 11.

From these two figures 10 and 11, it can be seen that Zone 4 has larger displacement than any other zone in all storeys for both X and Y directions when the soil type is SD. Followed by, Zone 3, Zone 2 and Zone 1. The values do not show much differences when the comparison is made between both directions for a particular soil type and zone.

When the comparison is made between the two soil types, it can be seen that for some cases, the values are same. The values in SC type soil are greater than SD type soil for very few cases. For most of the cases, values of displacement in SD type soil are much higher than SC type soil.

4.2.3 Storey Displacement After Introducing Shear Wall

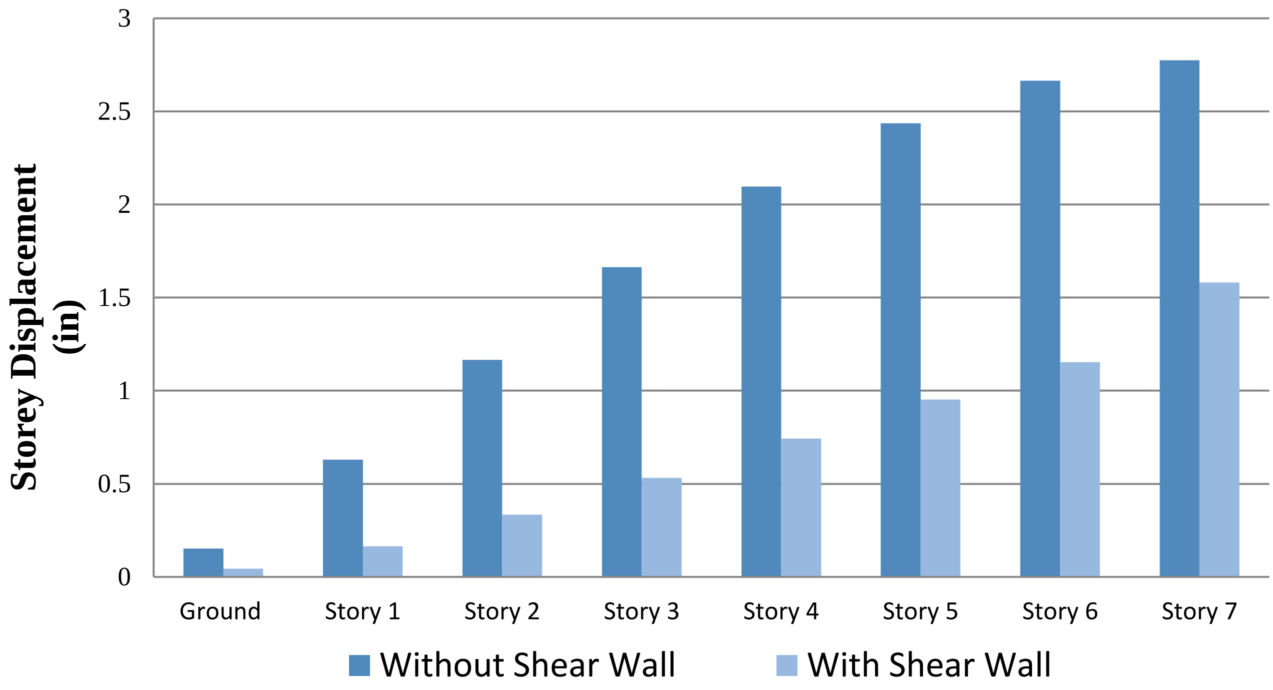

Figure 12: Storey Displacement for Earthquake load for SD Type Soil in Zone 4 in X Direction

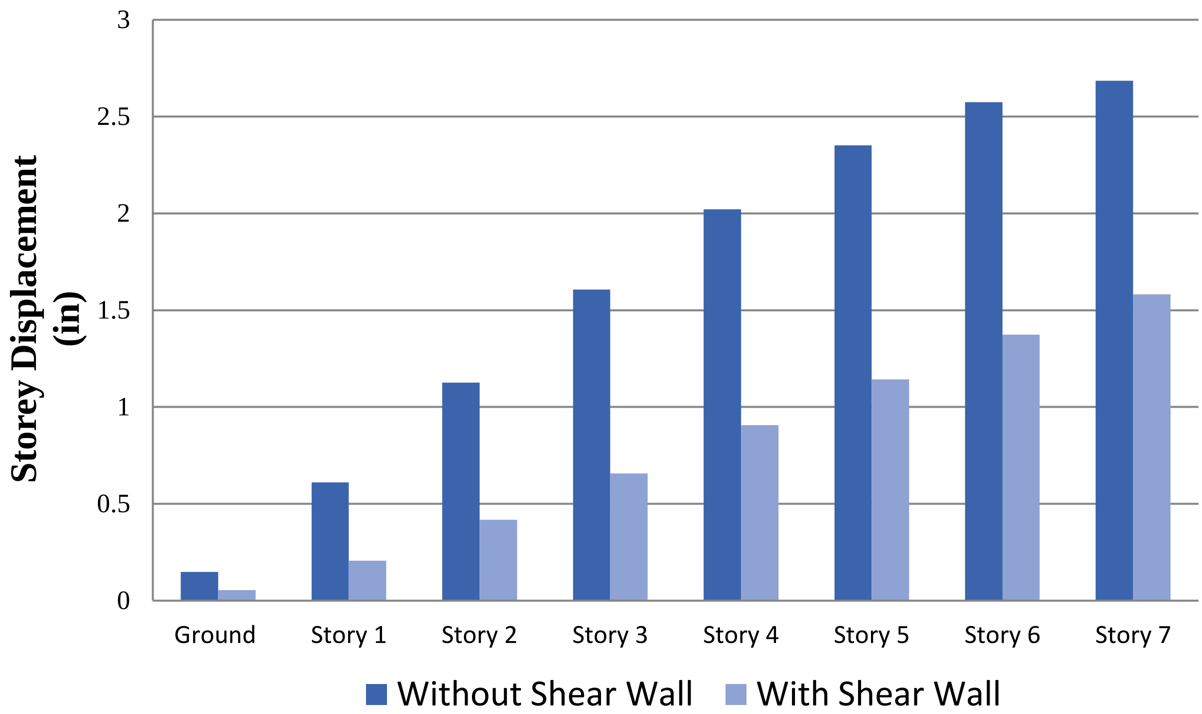

Figure 13: Storey Displacement for Earthquake load for SD Type Soil in Zone 4 in Y Direction

The two figures 12 and 13 given above show that storey displacement becomes much lower in all cases when shear walls are introduced in Zone 4 for SD type soil. The displacement values do not have much difference when they are compared on the basis of X and Y directions for a particular storey and a particular case.

4.3 Storey Drift

4.3.1 Storey Drift in SC Type Soil

From Figures 14, it can be observed that in X direction, Storey 7 has the lowest drift value which are 0.06, 0.06, 0.08 and 0.07 for the four zones respectively. On the other hand, Storey 2 has the highest drift value which are 0.30, 0.30, 0.39 and 0.34 for the four zones respectively. Same changes happen in Y direction as shown in figure 15.

From these two figures 14 and 15, it can be seen that Zone 3 has larger drift than any other zones in all storeys for both X and Y directions when the soil type is SC. On the other hand, Zone 1 and Zone 2 show the lowest drift value. The values do not show much differences when the comparison is made between both directions for a particular soil type and zone.

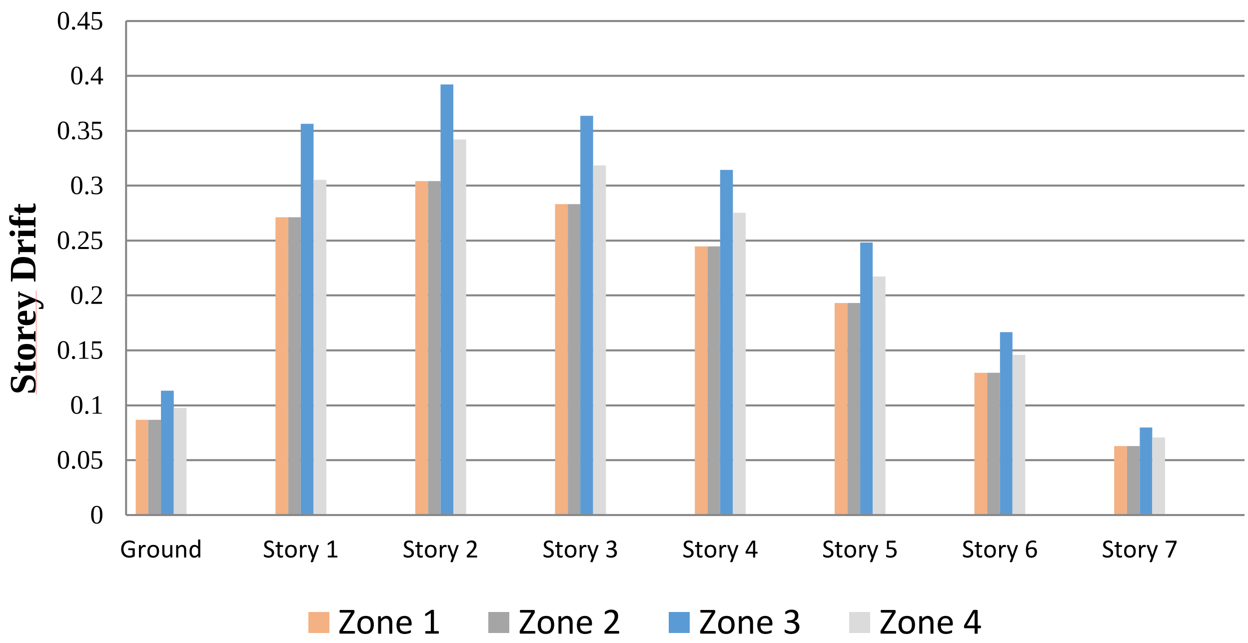

Figure 14: Storey Drift for Earthquake Load in X Direction for SC Type Soil

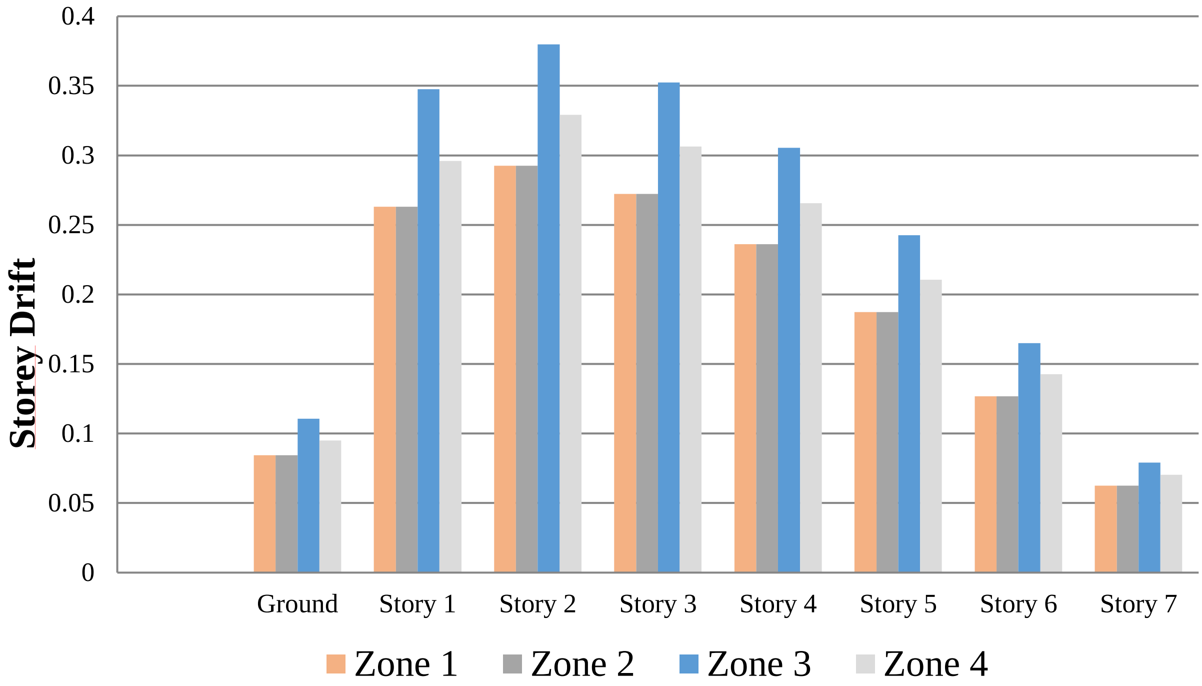

Figure 15: Storey Drift for Earthquake Load in Y Direction for SC Type Soil

4.3.2 Storey Drift in SD Type Soil

From Figures 16, it can be observed that in X direction, Storey 7 has the lowest drift value which are 0.059, 0.06, 0.09 and 0.11 for the four zones respectively. On the other hand, Storey 2 has the highest drift value which are 0.25, 0.26, 0.41 and 0.48 for the four zones respectively. Same changes happen in Y direction as shown in figure 17.

From these two figures 16 and 17, it can be seen that Zone 4 has larger drift than any other zones in all storeys for both X and Y directions when the soil type is SD. On the other hand, Zone 1 shows the lowest displacement value. The values do not show much differences when the comparison is made between both directions for a particular soil type and zone.

When the comparison is made between the two soil types, it can be seen that for some cases, the values are same. The values in SC type soil are greater than SD type soil for very few cases. For most of the cases, values of drift in SD type soil are much higher than SC type soil.

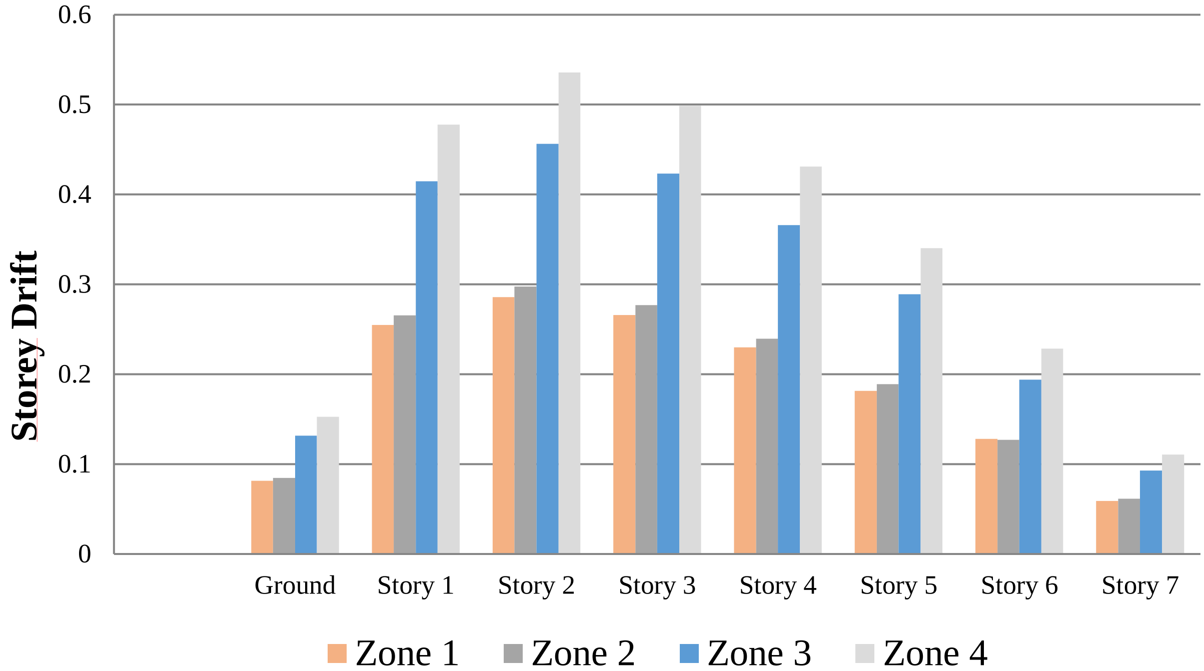

Figure 16: Storey Drift for Earthquake Load in X Direction for SD Type Soil

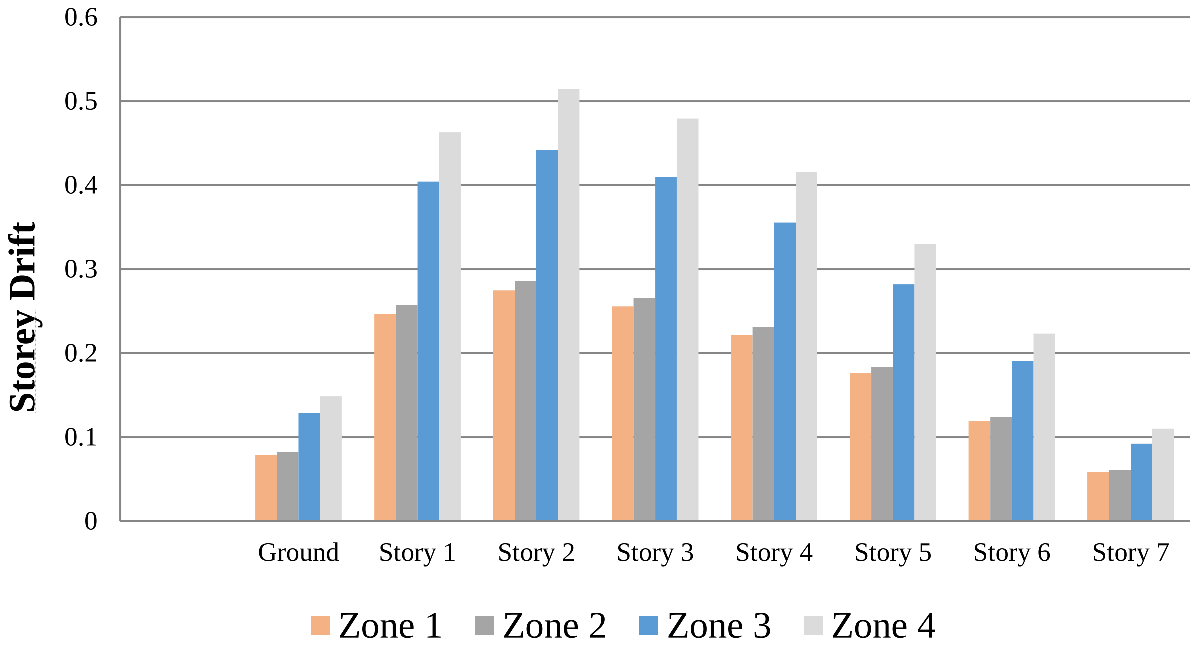

Figure 17: Storey Drift for Earthquake Load in Y Direction for SD Type Soil

4.3.3 Storey Drift After Introducing Shear Wall

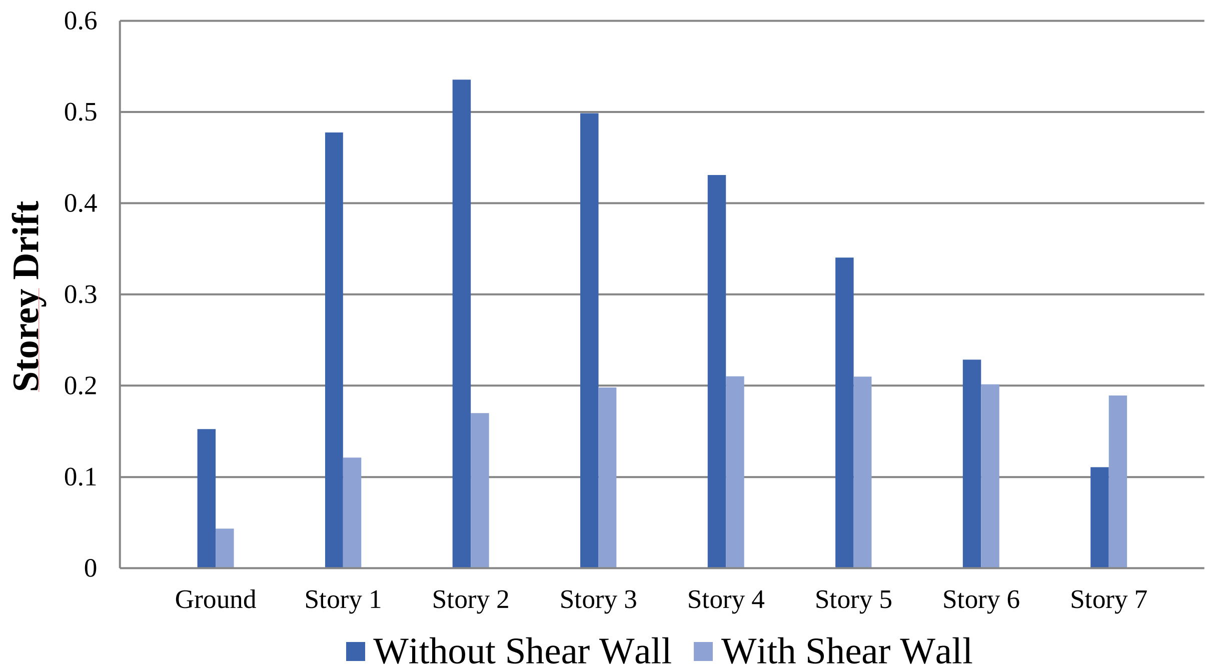

Figure 18: Storey Drift for Earthquake load for SD Type Soil in Zone 4 in X Direction

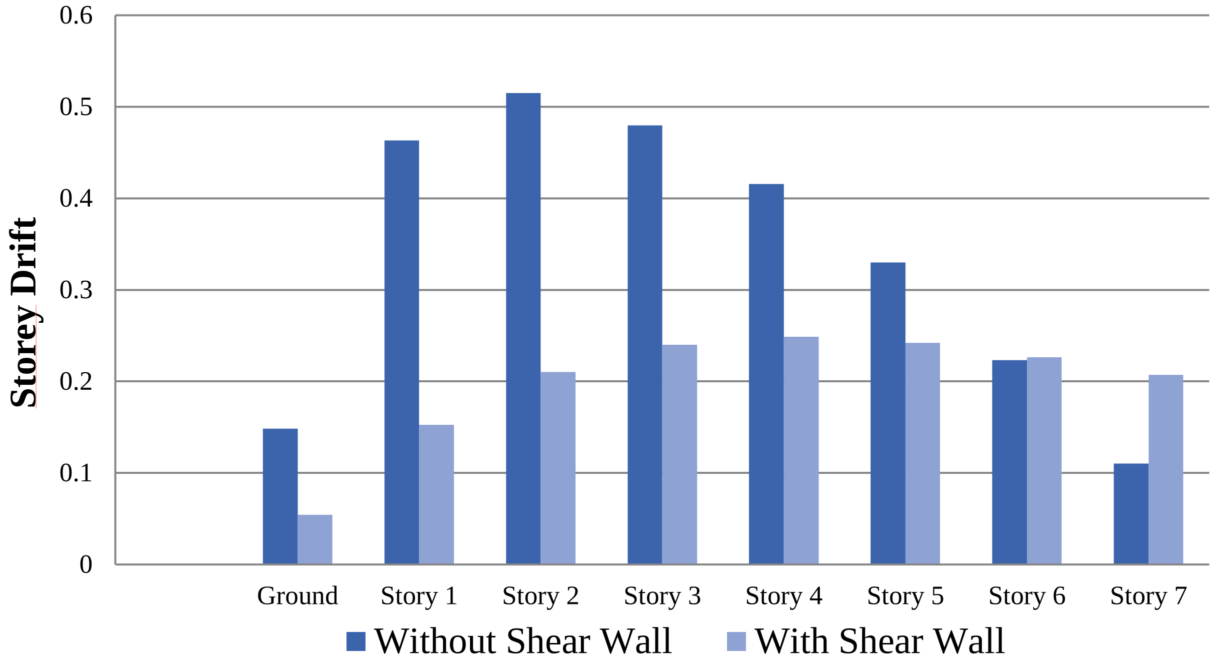

Figure 19: Storey Drift for Earthquake load for SD Type Soil in Zone 4 in Y Direction

The two Figures 18 and 19 show that drift becomes much lower in all storeys (except Storey 7) and in both directions when shear walls are introduced in Zone 4 for SD type soil. Only in storey 7, the drift value is much larger with the shear wall. The drift values do not have much difference when they are compared on the basis of X and Y directions for a specific storey and a specific case.

4.4 Storey Shear

4.4.1 Storey Shear in SC Type Soil

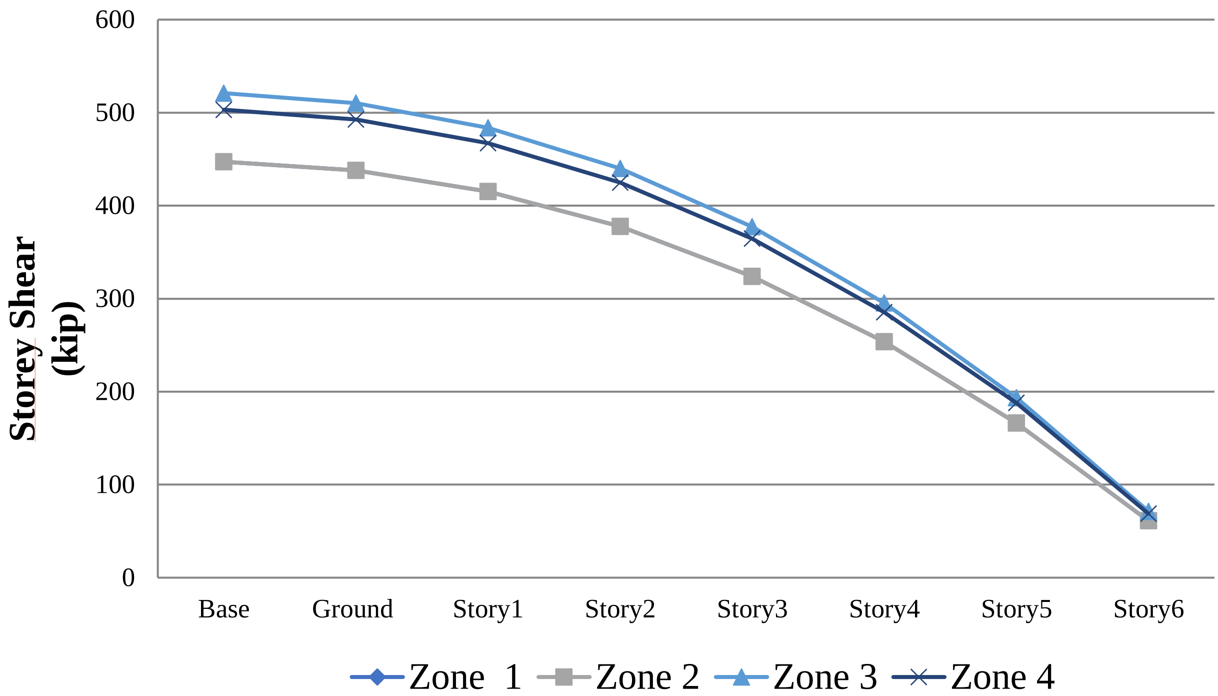

Figure 20: Storey Shear for Earthquake Load in X and Y Directions for SC Type Soil

The figure 20 shows that Base has the highest shear value which are 447.23 kip, 447.23 kip, 520.96 and 503.14 for the four zones respectively. On the other hand, Storey 6 has the lowest shear value which are 61.16 kip, 61.16 kip, 71.33 kip and 68.81 kip for the four zones respectively. The last storey or Storey 7 does not have any shear value. In Figure 4.17, it is shown that shear in all storeys for Zone 1 are as same as shear in all storeys in Zone 2 when the soil type is SC. It also can be seen that in SC type soil, Zone 3 has the highest shear values in all storeys. But the difference between Zone 3 and Zone 4 is very little.

4.4.2 Storey Shear in SD Type Soil

The figure 21 shows that Base has the highest shear value which are 420.01 kip, 437.51 kip, 612.51 kip and 787.52 kip for the four zones respectively. On the other hand, Storey 6 has the lowest shear value which are 57.43 kip, 59.83 kip, 83.76 kip and 107.69 kip for the four zones respectively. The last storey or Storey 7 does not have any shear value. In Figure 4.18, it is shown that for SD type soil, Zone 1 and Zone 2 have almost similar storey shear values. It also can be seen that in SD type soil, Zone 4 has the highest shear values in all storeys. The difference between Zone 3 and Zone 4 is greater.

When the comparison is made between the two soil types, it can be seen that for some cases, the values are same. The values in SC type soil are greater than SD type soil for very few cases. For most of the cases, values of shear in SD type soil are much higher than SC type soil.

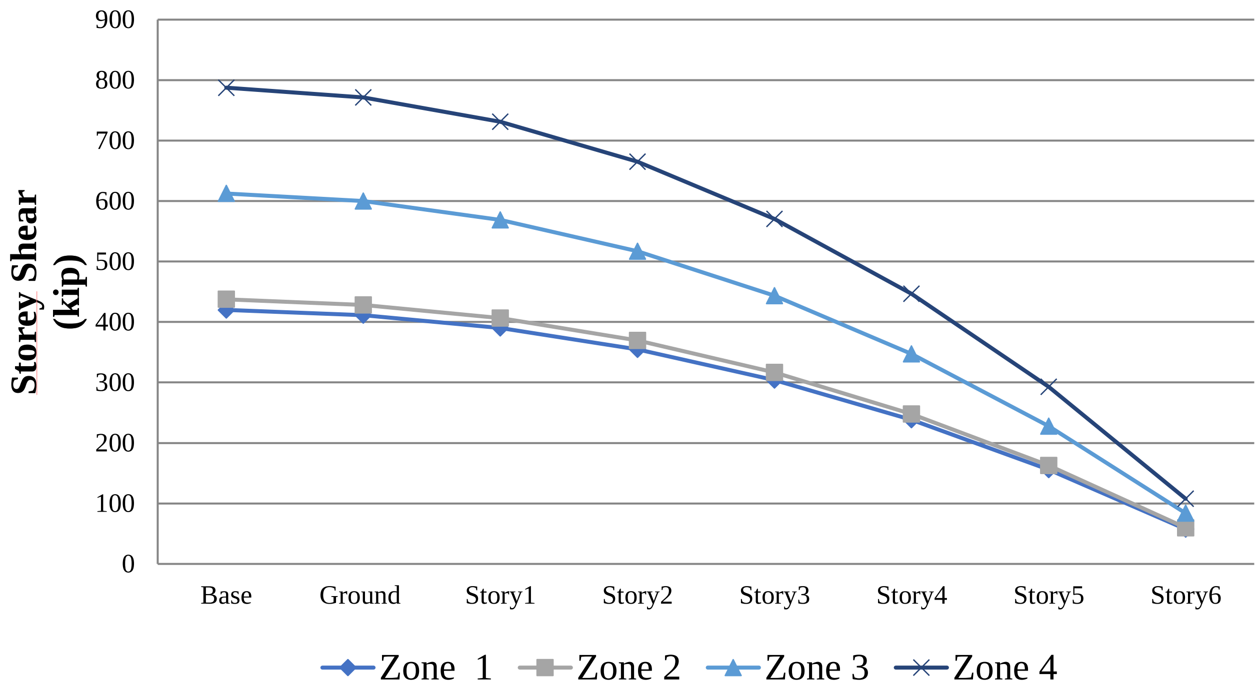

Figure 21: Storey Shear for Earthquake Load in X and Y Directions for SD Type Soil

4.4.3 Storey Shear After Introducing Shear Wall

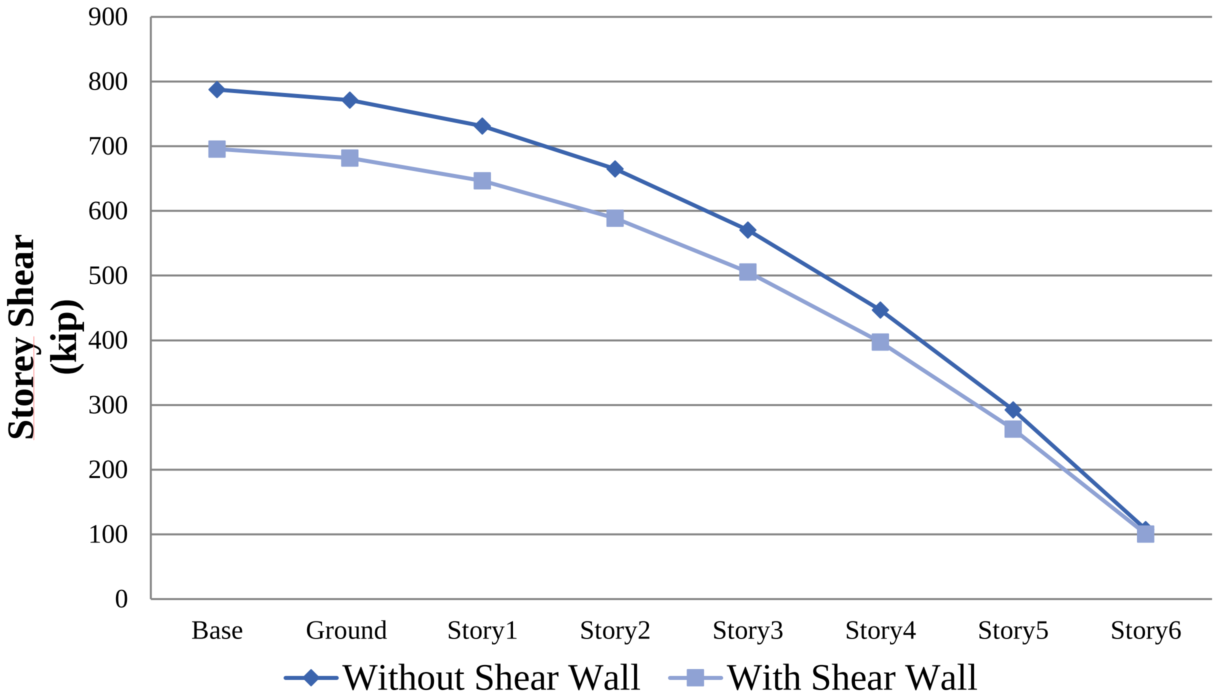

Figure 22: Storey Shear for Earthquake load in X and Y Directions for SD Type Soil in Zone 4

Figure 22 shows that shear becomes much less in all storeys when the shear wall is introduced. The differences become less as the storey is increased.

4.5 Cost Estimation for Concrete

Cost has been estimated for M25 grade concrete. At first, materials for 1 m^3 of concrete has been calculated. Then, the amount has been multiplied with the required volume of concrete. Volume of concrete has been found out from ETABS.

4.5.1 Material Calculation for M25 Grade Concrete

Let,

C : FA : CA = 1 : 1 : 2   (1+1+2 = 4)

Dry volume = Wet Volume x 1.54-1.57

CEMENT

(1/4) x 1.54 = 0.385 m^3

Volume of cement in kg = 0.385 x 1440 kg/ m^3 = 403.2 kg

No. of bags needed = 403.2/50 = 8.064 bags   (1 bag of cement = 50 kg)

FINE AGGREGATES

(1/4) x 1.54 = 0.385 m^3 = 14.82 cft   (1 m = 3.28 ft)

COARSE AGGREGATES

(2/4) x 1.54 = 0.77 m^3 = 29.64 cft

WATER

Let, W/C =0.45

So, W = 0.45 x 403.2 = 181.44 kg = 181.44 L

4.5.2 Volume Estimation from ETABS

Model Without Shear Wall

Table 12: Volume Estimation for the Model without Shear Wall

Section	Element Type	Total Weight	Total Weight of Concrete		Unit per Unit Volume	Total Volume Of Concrete	
		kip	kip	lb	pcf	ft^3	m^3
Column	Column	758.625	3708.45	3748050	150	24987	706.095748
Ground Column	Column	108.3					
Beam	Beam	1173.9583					
Ground Beam	Beam	207.1667					
Slab	Floor	1500					

Model With Shear Wall

Table 13: Volume Estimation for the Model with Shear Wall

Section	Element Type	Total Weight	Total Weight of Concrete		Unit per Unit Volume	Total Volume Of Concrete	
		kip	kip	lb	pcf	ft^3	m^3
Column	Column	758.625	4177.05	4177050	150	27847	786.915127
Ground Column	Column	108.3					
Beam	Beam	1173.9583					
Ground Beam	Beam	207.1667					
Slab	Floor	1500					
Wall	Wall	429					

4.5.3 Material Amount

Model Without Shear Wall

- Cement = 5694 Bags
- Fine Aggregates = 10465 cft
- Coarse Aggregates = 20929 cft
- Water = 128115 L

Model With Shear Wall

- Cement = 6346 Bags
- Fine Aggregates = 11663 cft
- Coarse Aggregates = 23325 cft
- Water = 142777 L

4.5.4 Unit Cost

Unit cost has been taken following the current market price for each material.

- CEMENT : BDT 470 per Bag
- FINE AGGREGATES : BDT 50 per cft
- COARSE AGGREGATES : BDT 200 per cft
- WATER : BDT 30 (100 L)

4.5.5 Total Cost

Table 14: Total Cost of Concrete

Model Type	Cement (BDT)	Fine Aggregate (Sand) (BDT)	Coarse Aggregate (BDT)	Water (BDT)	Total (BDT)
Without Shear Wall	34,16,400	6,27,900	41,85,800	51,246	82,81,346
With Shear Wall	38,07,600	6,99,780	46,65,000	57,110.8	92,29,490.8

Table 14 shows that if shear walls are introduced, the cost increases for each material. Total cost increases for around 10 lakhs BDT.

CHAPTER 5 : CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the analysis of a model in different seismic zones and different soil types, it is found that the model analysed for soil type SD in Zone 4 does not fulfill the criteria of storey drift and earthquake storey drift. Different comparisons have taken place amongst all the cases for the model (including the model in soil type SD in Zone 4) on the basis of storey displacement, storey drift and storey shear for earthquake load. In all three cases, Zone 3 has the highest value in SC type soil and Zone 4 has the highest value in SD type soil. Different models have been made introducing shear walls of different thicknesses in different places for soil type SD in Zone 4. The model becomes most efficient when four shear walls of 8” thickness each are placed in the four corners of the model. Analyzing the comparisons between the models with and without shear wall in Zone 4 for SD soil type, it is observed that for storey displacement and storey shear, values of the model with shear wall are less than those of the model without the shear wall in all cases. For storey drift, the same things happen except for storey 7. From the cost estimation analysis, it can be said that the cost of concrete gets higher than normal when the model is made with shear walls.

5.2 Recommendation and Future Scopes

The cost of reinforcement has not been estimated in this study. It is recommended to estimate the cost of reinforcement so that the whole cost of the structure can be budgeted. The sizes of column and beam have been kept the same in the whole model. Therefore, estimated cost might not be effective. It is also recommended to take different corner, peripheral and middle column and beam sizes as per necessity. Furthermore, plan irregularities can be included.

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