STUDY OF SEISMIC PERFORMANCES OF RCC BUILDINGS LOCATED IN DIFFERENT SEISMIC ZONES IN BANGLADESH

By

Fatima

Md. Abdul Motin

Mehedi Hasan

Md. Emran Hossain

A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 15B

Spring-2022

STUDY OF SEISMIC PERFORMANCES OF RCC BUILDINGS LOCATED IN DIFFERENT SEISMIC ZONES IN BANGLADESH

By

Fatima	(BCE1803015030)
Md. Abdul Motin	(BCE1803015055)
Mehedi Hasan	(BCE1803015032)
Md. Emran Hossain	(BCE1702011081)

Supervisor

Tahmid Mustafa
Assistant Professor
Department of Civil Engineering
Sonargaon University (SU)

A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 15B

Spring-2022

BOARD OF EXAMINERS

The thesis titled "**Study of Seismic Performances of RCC Buildings Located in Different Seismic Zones in Bangladesh**" submitted by Fatima- ID: BCE1803015030, Md. Abdul Motin- ID:BCE1803015055, Mehedi Hasan-ID: BCE1803015032, Md. Emran Hossain-ID: BCE1702011081, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on Date-of-Defense.

……………………… Chairman

1. Tahmid Mustafa
   Assistant Professor
   Dept. of Civil Engineering,
   Sonargaon University (SU)

…………………………….

2. Internal / External Member Member

…………………………

3. Internal / External Member Member

DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

STUDENT NAME	STUDENT ID.	SIGNATURE
Fatima	BCE1803015030	
Md. Abdul Motin	BCE1803015055	
Mehedi Hasan	BCE1803015032	
Md. Emran Hossain	BCE1702011081	

Dedicated

to

“----Our Parents-----”

ACKNOWLEDGEMENTS

The authors expresses sincere appreciation to Supervisor, **Tahmid Mustafa** Assistant Professor, Department of Civil Engineering, Sonargaon University 147/I, Green Road, Dhaka-1215, Bangladesh, for his cordial guidance and support during my research efforts and course work. His keen interest and valuable suggestions, constructive criticisms and proper advice at every stage made this research valuable. We would like to thanks **Tahmid Mustafa** for his guidance and for serving on the committee. We would also like to thanks **Md. Ferdous Wahid** for his guidance inside and outside the classroom. Most importantly we would like to thanks our parents for continual supporting us. We would also like to thanks **S.M Yasin**, Head, Department of civil Engineering. Finally, the author expresses his gratitude and appreciation to his beloved parents and family members, without my parents blessing the research work was not possible successfully**.**

ABSTRACT

The rapid urban growth is causing further deterioration and increasing the vulnerability of human lives, economy and infrastructures. When natural hazard like earthquake will hit this large metropolitan city, it may create catastrophe and the whole country may suffer. One of the major challenges is to reduce the vulnerability caused by earthquake by taking necessary steps. At the same time, it is very much essential to develop an effective earthquake risk management plan, which requires long-term plan of action and involves multidisciplinary contribution. Considering this situation this paper is about the comparison of vulnerability of different seismic zones in Bangladesh. The properties of beams and columns are used from BNBC-2020 in ETABS model. The building's base shear design is compared to the earthquake base shear design. The global response of the structure is also examined for estimating the safety of the building under demand earthquake loading in terms of capacity curve, hinge placement, and ductility ratio. The current practice of seismic design is limited to demand estimation and analysis and thus cannot guarantee that the design structure meets the initial objectives.

According to BNBC-2020, Bangladesh is divided in four different seismic zones. The behaviors of earthquake forces have been analyzed for both shear wall and without shear wall RCC buildings by ETABS in four different seismic zones. The study shows shear wall buildings performs well than without shear wall buildings in different seismic zones. The base shear, base moment and drifts are higher in zone-4 comparing zone-1, zone-2 and zone-3

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION:

Bangladesh is a disaster prone country. Disaster management needs to be considered as prime issue for overall development of the country. Bangladesh and adjoining areas is at high seismic risk. Recently a series of earthquakes has been experienced throughout the country. Earthquake is a cataclysmic event that needs to be addressed in a more concerted way. Earthquake induced large destruction occurs due to vast majority of properties not meeting the earthquake resistant standards in building design. When the vast majority of properties do not meet the earthquake resistance standards in building design, it exposes the occupants the risk of injury or death arising from the building collapse in the event of a major earthquake. One of the reasons for high level of destruction is the poor building quality particularly of residential in nature [2].

As part of earthquake preparedness, it is essential to undertake a structural vulnerability assessment of properties to determine its resistance level in earthquake and advice necessary steps, such as retrofitting, to rectify any deficiencies. Bangladesh has been classified into Four seismic zones such as Zone-I (0.12), Zone-II (0.20), Zone-III (0.28) and Zone-IV (0.36) as per Bangladesh National Building Code, BNBC-2020 [2].

Design processes currently in use include demand estimation, seismic analysis, and design according to the code. This plan does not ensure that the designed building will satisfy the initial aims. A preliminary assessment of the design is done to see if it fulfills the desired performance objectives, and if necessary, the design is reworked and reassessed until it does. Nonlinear static pushover analysis or nonlinear dynamic analysis can be used to assess or evaluate something. The structural engineering community has been employing nonlinear static procedure (NSP) or pushover analysis because of its simplicity. Pushover analysis is performed using the FEMA-356 and ATC 40 criteria for both the default and user-defined hinge parameters in both the default and user-defined hinge parameters [3].

By involving BNBC-2020 the present research examines a multi-story building employing response spectrum analysis as well as the non-linear pushover analysis. The process would be carried out by using ETABS v-16 that can help the existing building's future outcomes. The mathematical outcome would enhance the information of properties of beams and columns for concrete and reinforcement according to BNBC-2020. Also, the estimated safety factors would be useful to understand different earthquake loading criteria with response analysis. Additionally, it was discovered that such systems, 6th International Conference on Civil Engineering for Sustainable Development (ICCESD 2022), Bangladesh ICCESD-2022-4809-3 when it undergoes through various performance levels such as immediate occupancy, Life-safety and collapse prevention [3].

1.2 OBJECTIVES

The main objectives of this study are:

- to compare the seismic behavior of structures with shear wall and without shear wall buildings for four different seismic zones.
- to analyze and compare the base shear, base moment and storey drift for different seismic zones.
- to prepare seismic loading models through ETABS software.
- to observe how comparatively vulnerable the structures are in each zone.

1.3 METHODOLOGY OF THE PRESENT STUDY

- Two identical 10 storied models are made by ETABS software for with shear wall and without shear wall where dimensions of all respective members are same.
- The applied dead loads and live loads were same accept the earthquake loading as it is different in three different zones of Bangladesh.
- Base shear, base moment and drift values are obtained by linear static analysis.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION:

Most buildings in our country are still specifically designed for loads of gravity. Among Bangladesh's structural designers, the understanding and application of seismic details are very limited. This is quite unexpected, especially since a chapter on detailing reinforced concrete structures is included in the Bangladesh National Building Code BNBC (PART 6, Chapter 8). The Earthquake Resistant Structure Design Criteria are used as a code of practice to analyze and design earthquake-resistant buildings.

2.2 SCOPE OF THE STUDY:

Based on project, study was undertaken with a view to determine the extent of possible changes in the seismic behavior of multi-storey Building Model. The study highlights the effect of seismic zone factor in different zones that is in Zone I, II, III, and IV which is considered in the seismic performance evaluation of buildings. The study emphasis and discusses the effect of seismic zone factor on the seismic performance of G+9 storied residential building structure. The entire process of modelling, analysis and design of all the primary elements for all the models are carried by using ETABS 17 version software. [4]

2.3 REVIEW OF SOME EXISTING LITERATURE:

There are some references to literature on comparative research of existing codes in Bangladesh and throughout the world.

Faysal R. M., (2014) studied the comparative study of wind force analysis provided by BNBC 1993 and BNBC 2010. The wind provision recommended in BNBC 2010 is upgraded by the authority taking in consideration of the influence of surrounding structures and building height. As a consequence, wind load in metropolitan regions (Exposure A) is discovered to be significantly greater (7-12%) compared to BNBC 1993. Meanwhile, wind load computed from this new code for obstructed and unobstructed plain territory region (Exposure B and C) is significantly lower than BNBC 1993. [5]

Imam F. S. et. al, (2014) investigate the comparative evaluation of wind and seismic analysis presented in the BNBC 1993 with the BNBC 2012 suggested. They analyzed a typical multistoried residential building with intermediate moment resisting frame system resting on medium dense soil situated in Dhaka to find the differences in structural analysis between BNBC 2012 and BNBC 1993. Base shear of the residential structure obtained by this new draft code varies significantly and the maximum lateral displacement and inter story drift w.r.t number of stories is less in BNBC 2012 than in BNBC- 1993 for wind load only. They include that the design of RC building for lateral load in BNBC-2012 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2012 although this is applicable for Dhaka city only. [6]

Bari M. S. and Das T., (2013) illustrate the similarities among specific requirements in BNBC 1993, BNBC 2010, NBC 2005 and ASCE 7-05 regarding tectonic assessment of building codes. In this study, BNBC 1993 is shown to have the minimal base shear among the guidelines. Base shear values factorized for BNBC 2010 have improved considerably compared with BNBC 1993 in lower elevated structures (B $\leqslant$ 20 m) over the state across its antecedent. This enhancement of the earthquake safety factor established by the proposed BNBC 2010 code, which recommends greater base shear values, is noteworthy. [7]

1. Base shear, 2. Importance of structure, 3. Seismic factor, 4. Structural System factor, 5. Time period of structure, 6. Effective weight of structure, 7. Soil factor Finally, a typical residential building situated in Dhaka is selected for the case study to identify the changes in analysis and design with BNBC 2012 as compared to BNBC 1993. The analyses are conducted for base shear, maximum lateral displacement with respect to variable number of stories (from 2 to 18). A basic difference in maximum reinforcement requirement and inter storey drift for 6, 12, and 18 storied buildings is also presented. For earthquake load base shear, maximum lateral displacement and inter storey drift is higher in BNBC 2012 than BNBC1993.But for wind load maximum lateral displacement and inter storey drift is less in BNBC-1993 than BNBC-2012 than BNBC-1993. Design of reinforced concrete buildings for lateral load in BNBC-2012 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2012. [8]

CHAPTER 3

METHODOLOGY

3.1 GENERAL:

Many earthquakes originate from accelerated displacement within the earth's crust along the plane of faults. This sudden shifting of the fault releases a great deal of energy which, in the form of seismic waves, then spreads through the earth. Before eventually loosing much of their steam, seismic waves travel long distances.

These seismic waves hit the earth's surface at some point after their generation and set it in motion, which we refer to as earthquake ground motion. When this earthquake ground motion happens under a building and when it is intense enough, it sets the building in motion, beginning from the base of the building, and eventually moves the motion in a very complicated manner across the rest of the building. In turn, these motions cause forces that can produce damage.

3.2 MODEL DETAILS

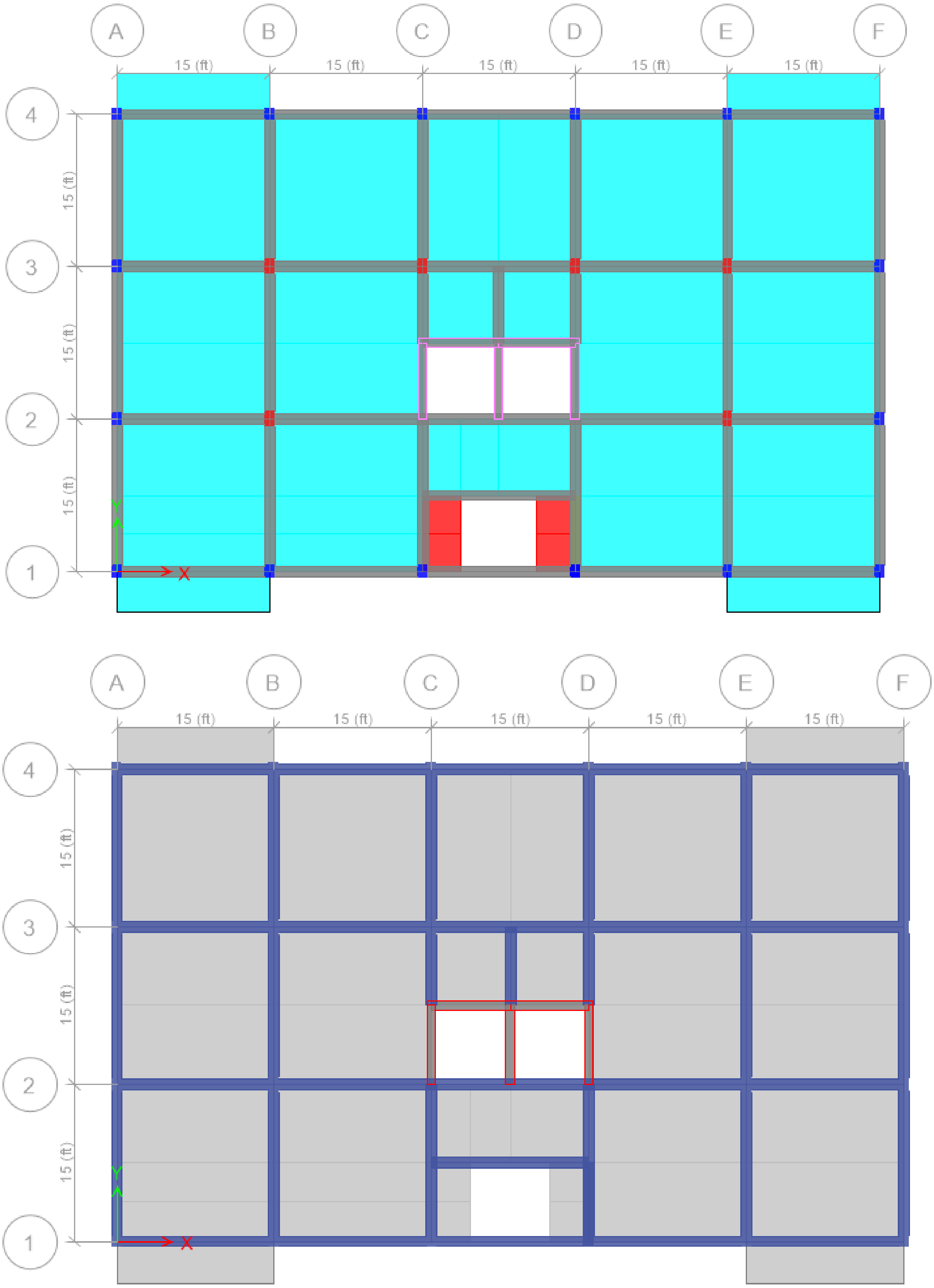

Figure 3.1: Plan of ten storied Residential building with shear wall

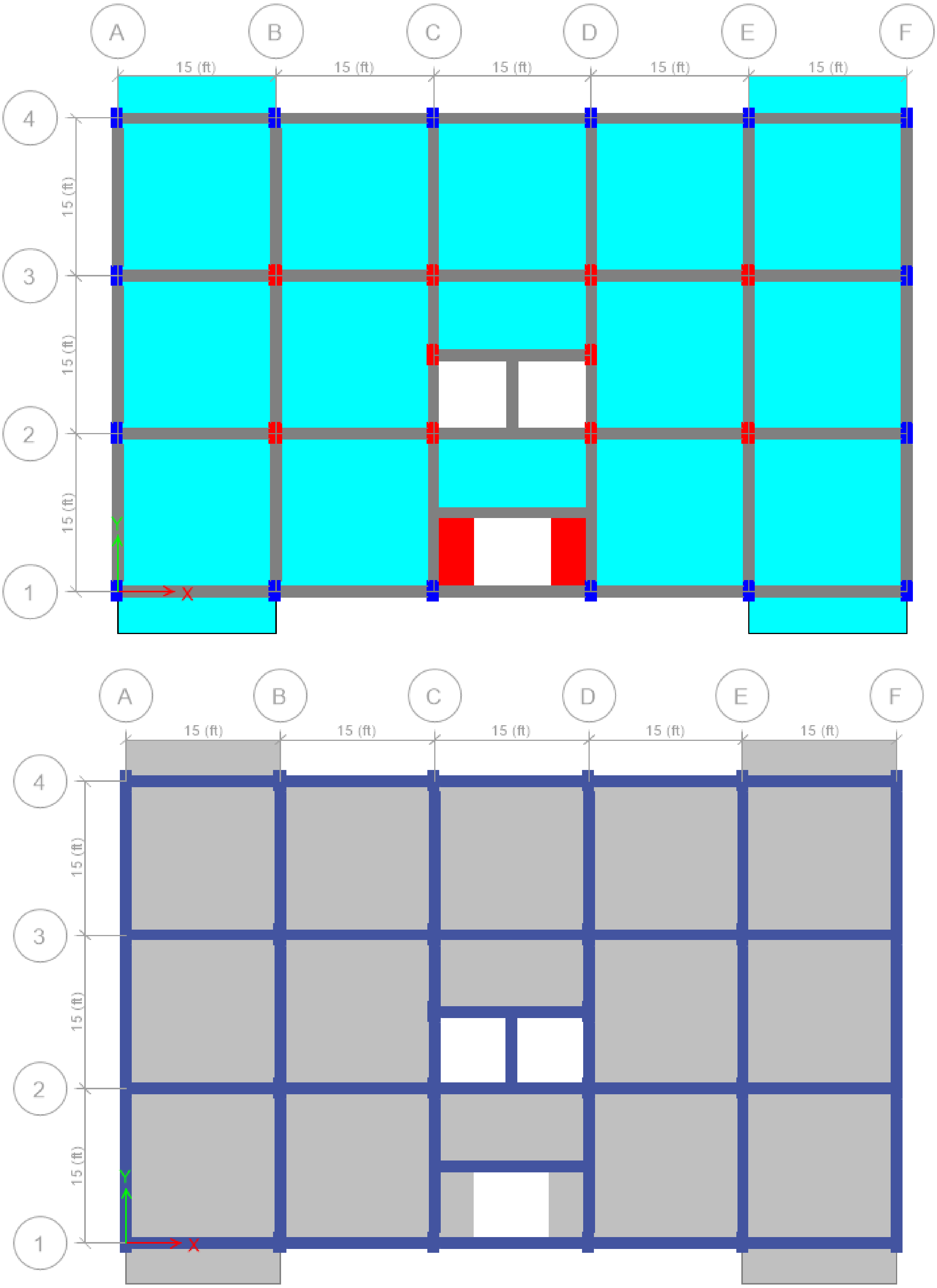

Figure 3.2: **Plan of ten storied Residential building without shear wall**

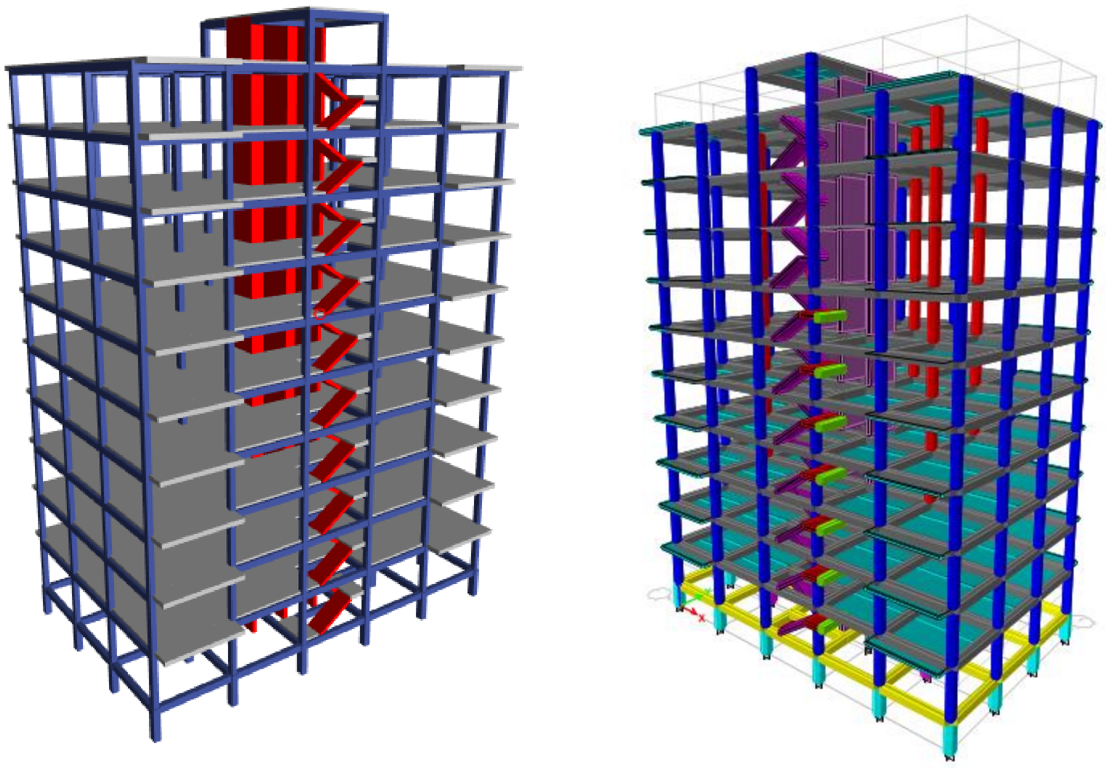

Figure 3.3: 3D Model of 10 storied Residential building with shear wall

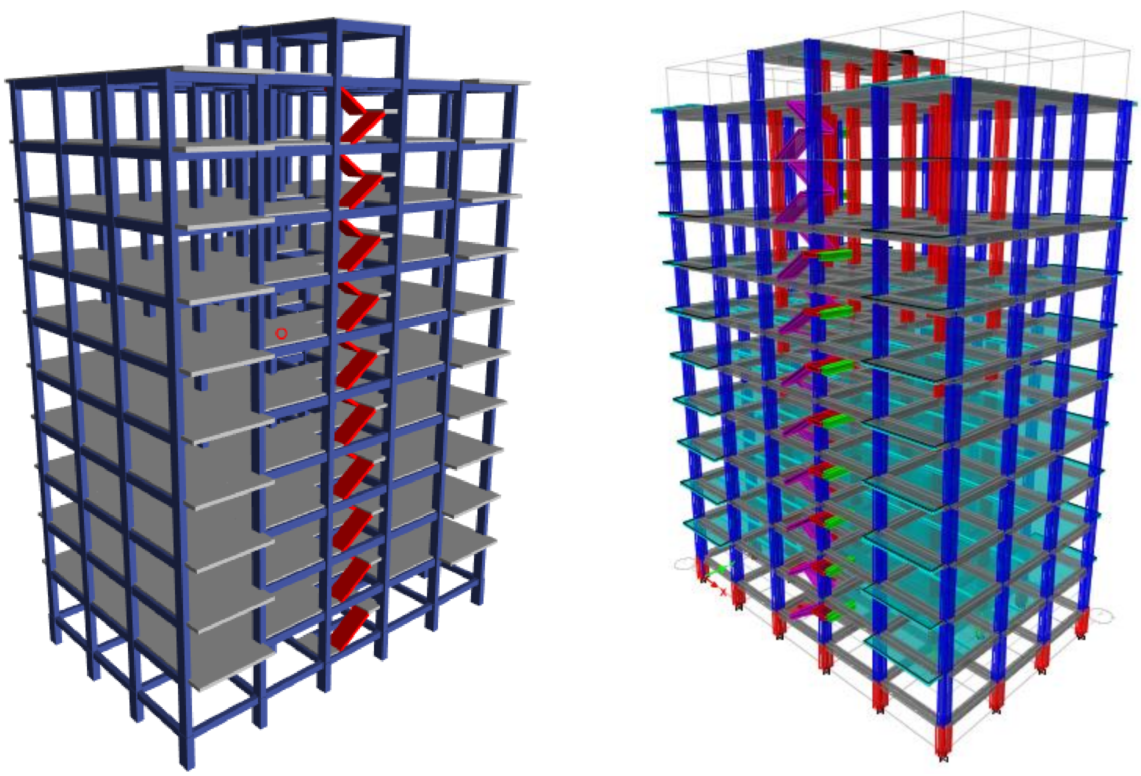

Figure 3.4: 3D Model of 10 storied Residential building without shear wall

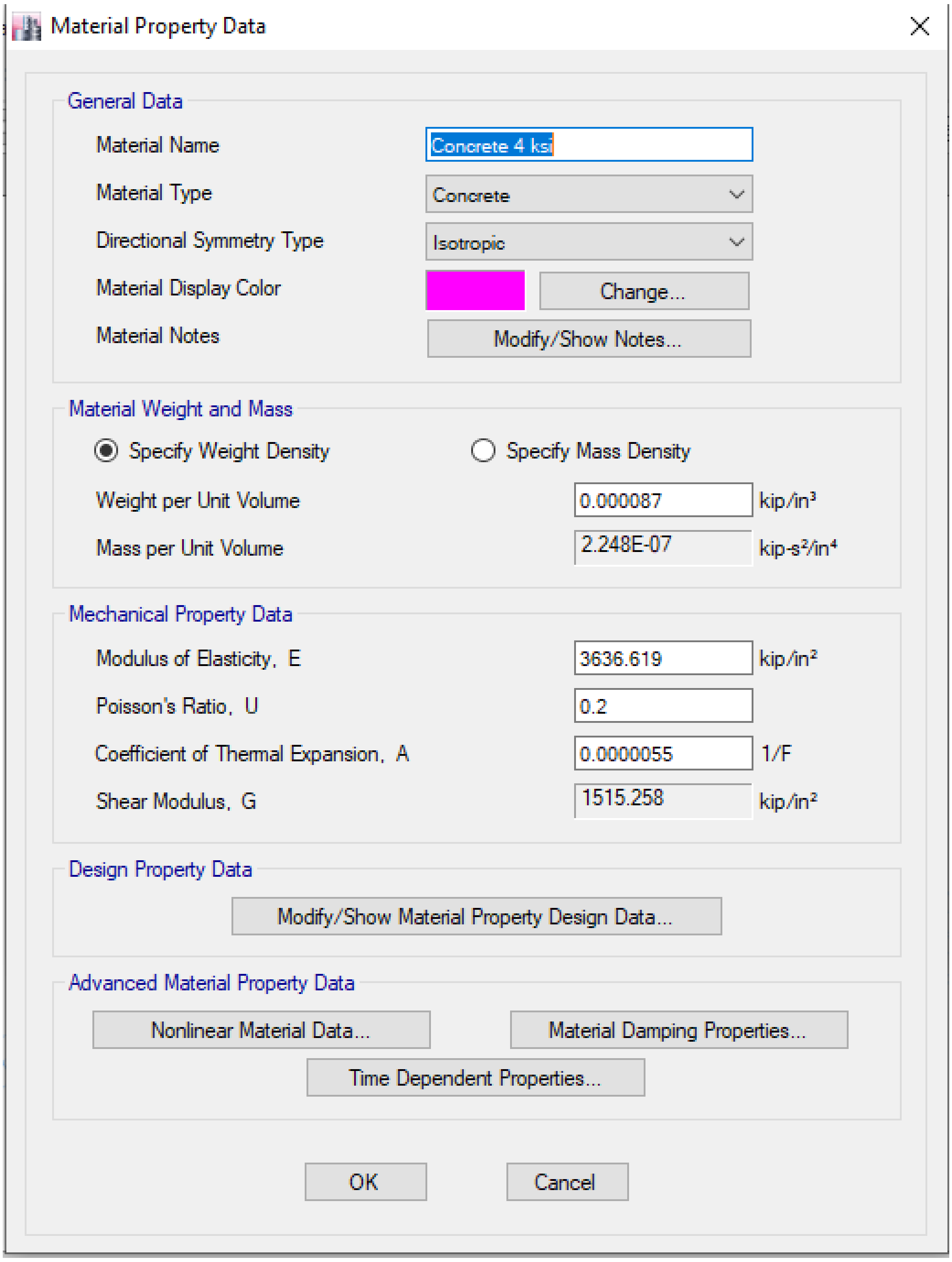

Figure 3.5: Material Property data of 10 storied Residential building

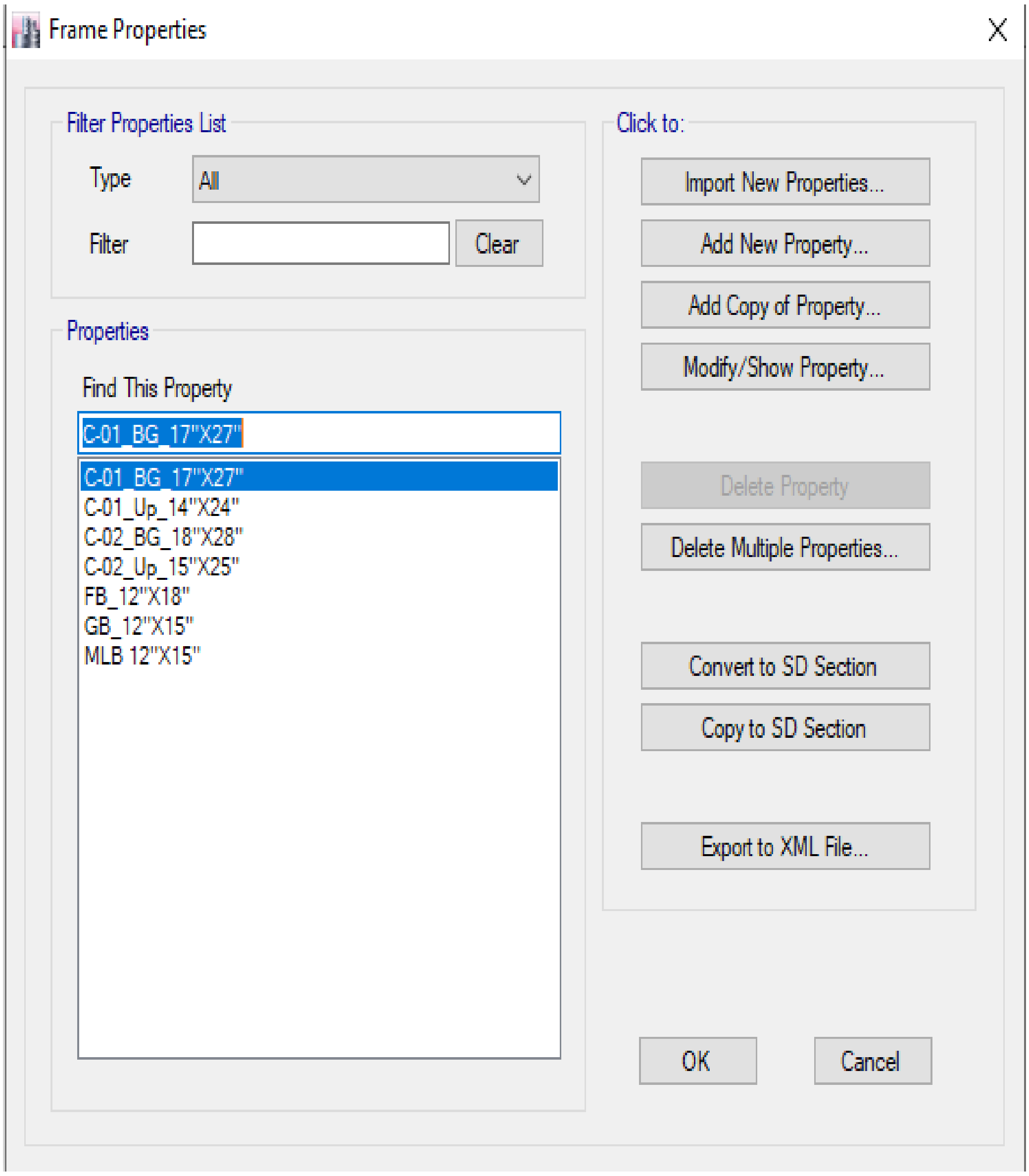

Figure 3.6: Frame Properties of 10 storied Residential building

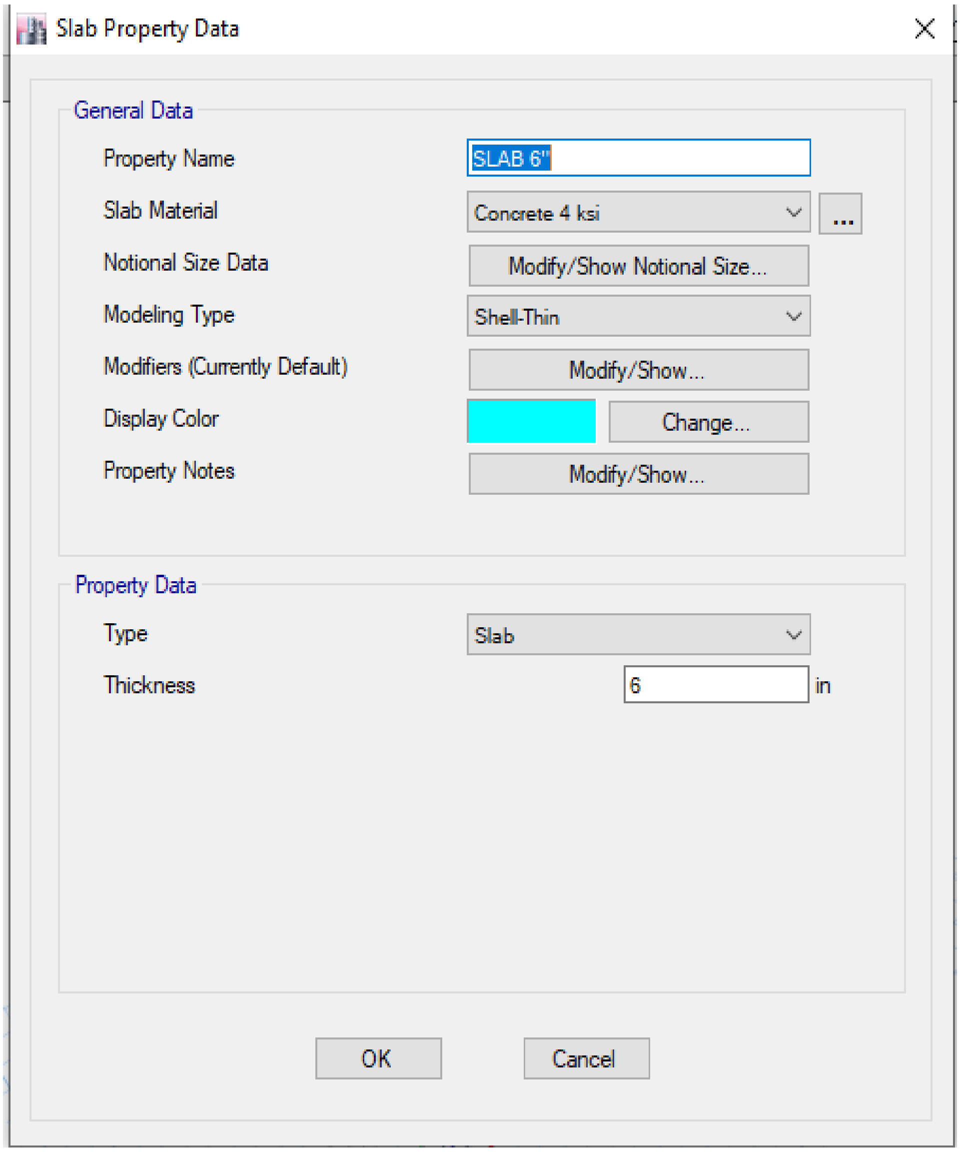

Figure 3.7: Slab property data of 10 storied Residential building

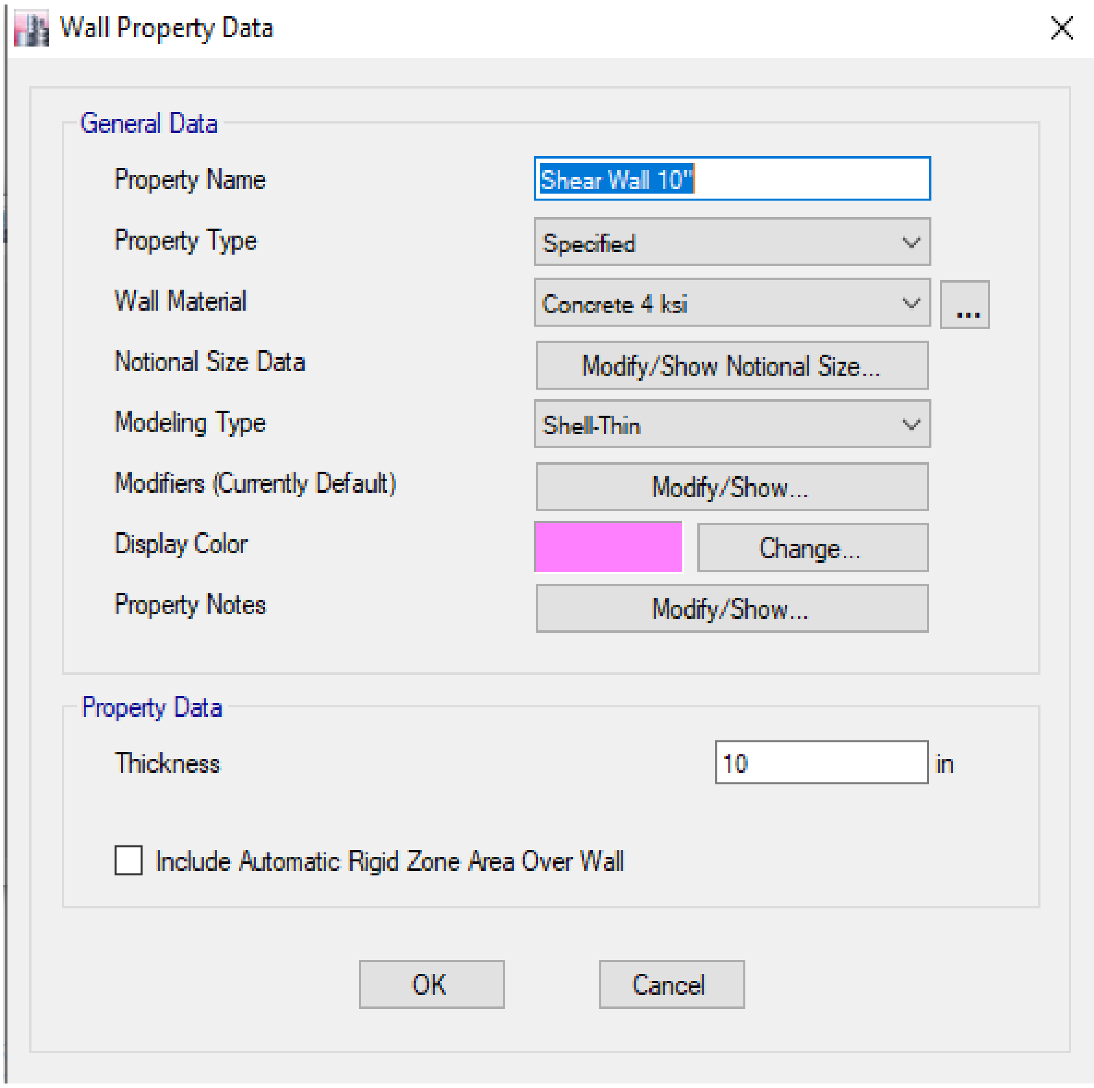

Figure 3.8: Shear wall property data of 10 storied Residential building

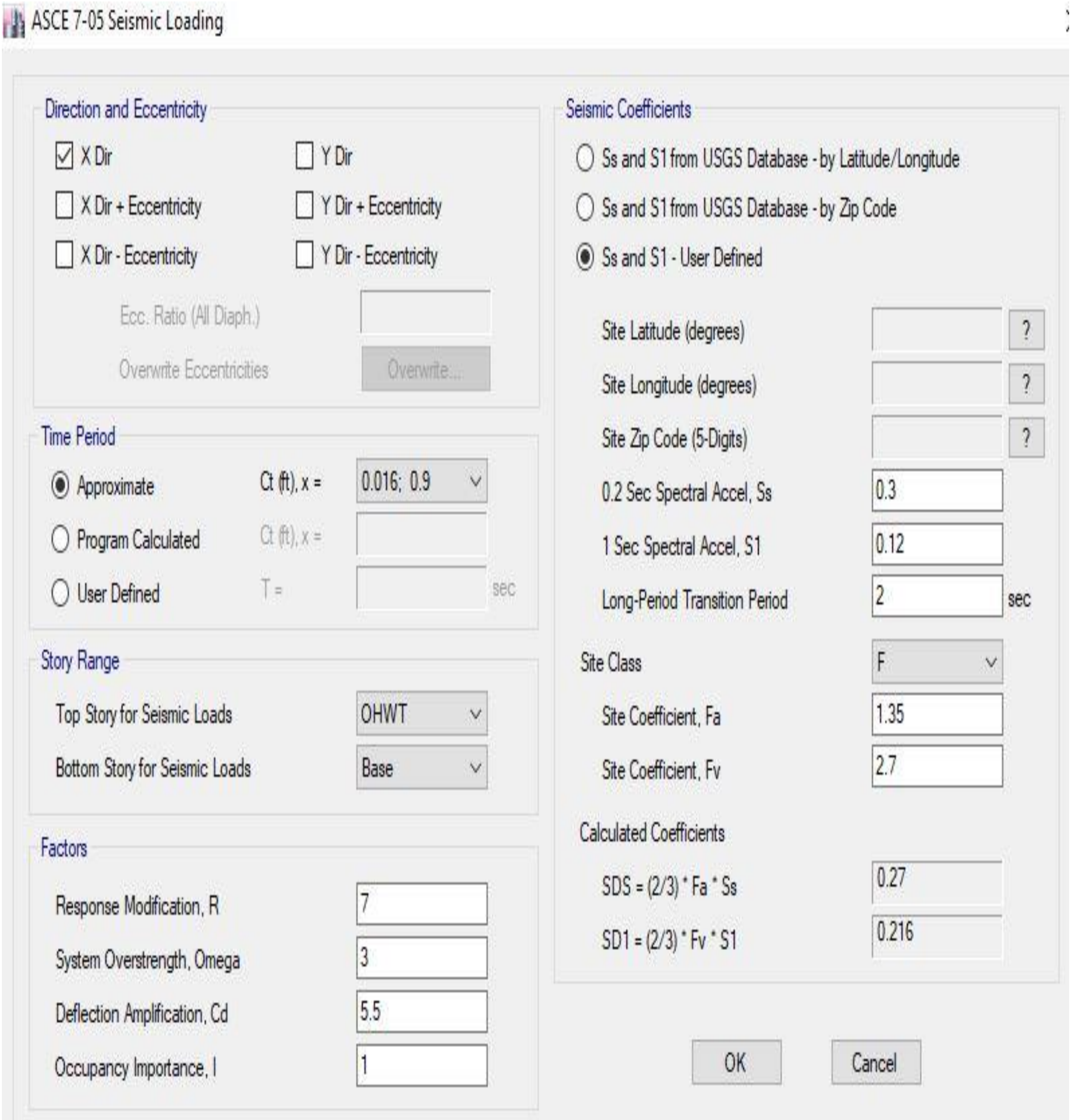

Figure 3.9: Seismic loading input data (Zone 1) for 10 storied Residential building with shear wall

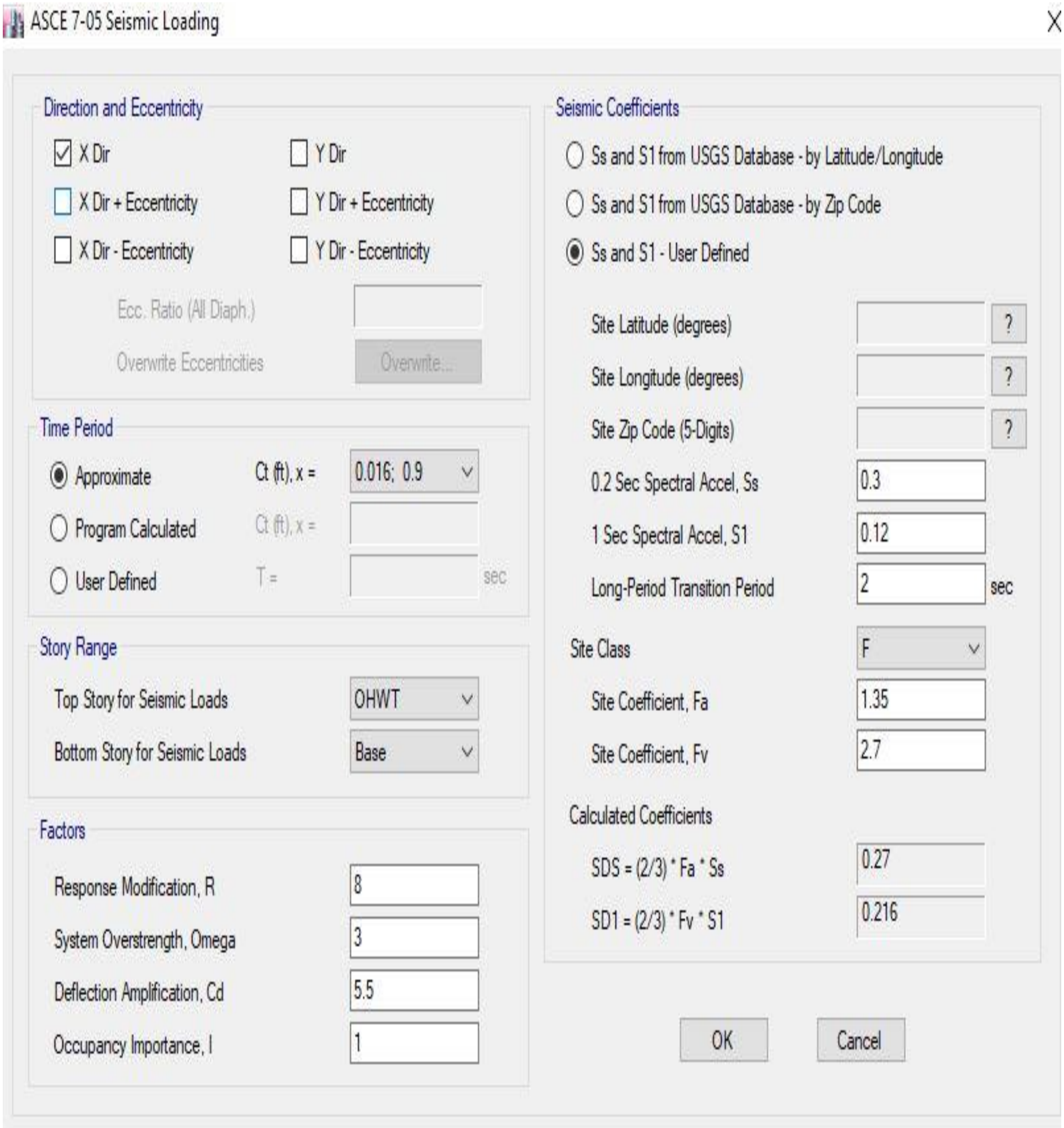

Figure 3.10: Seismic loading input data (Zone 1) for 10 storied Residential building without shear wall

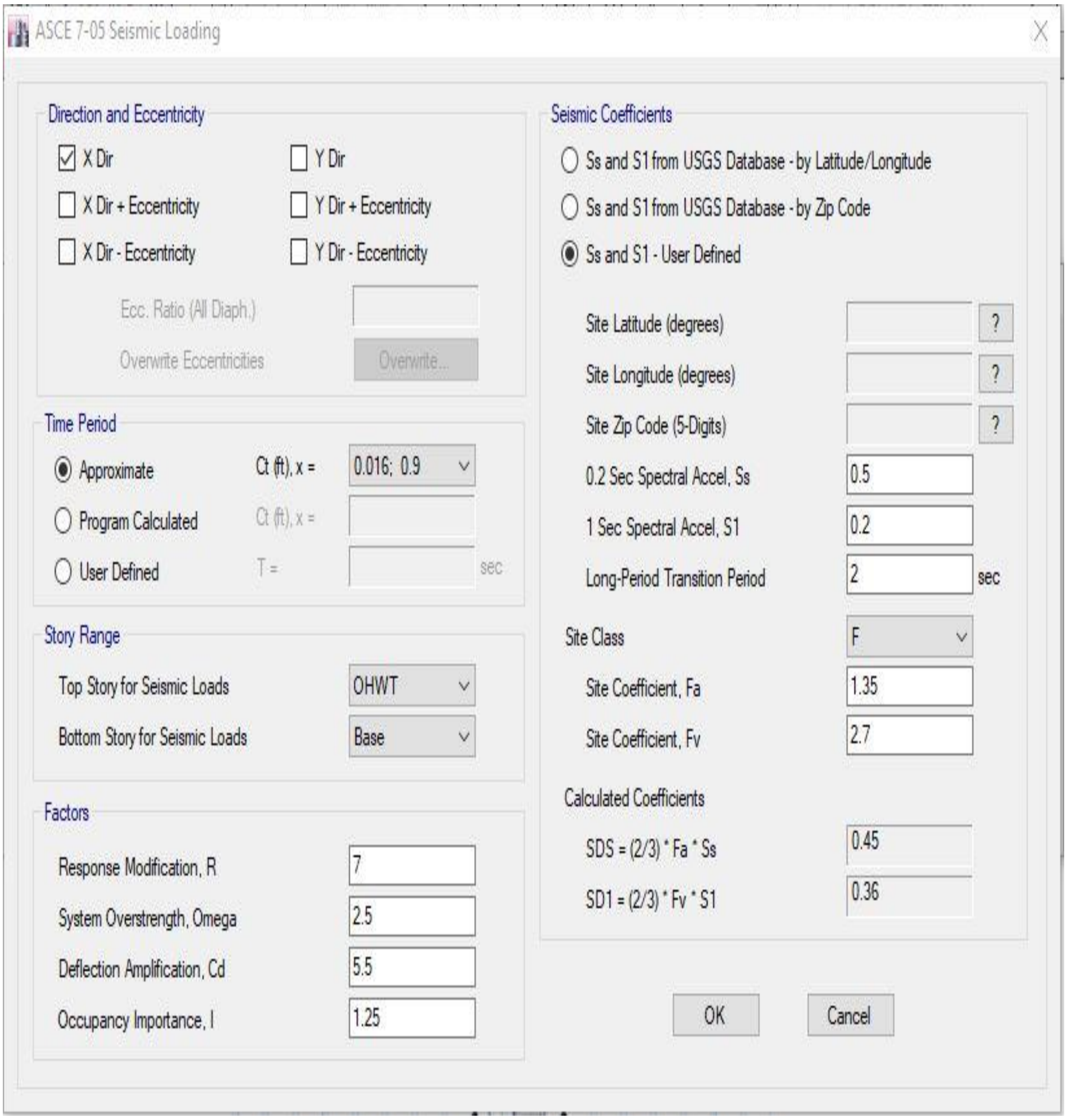

Figure 3.11: Seismic loading input data (Zone 2) for 10 storied Residential building with shear wall

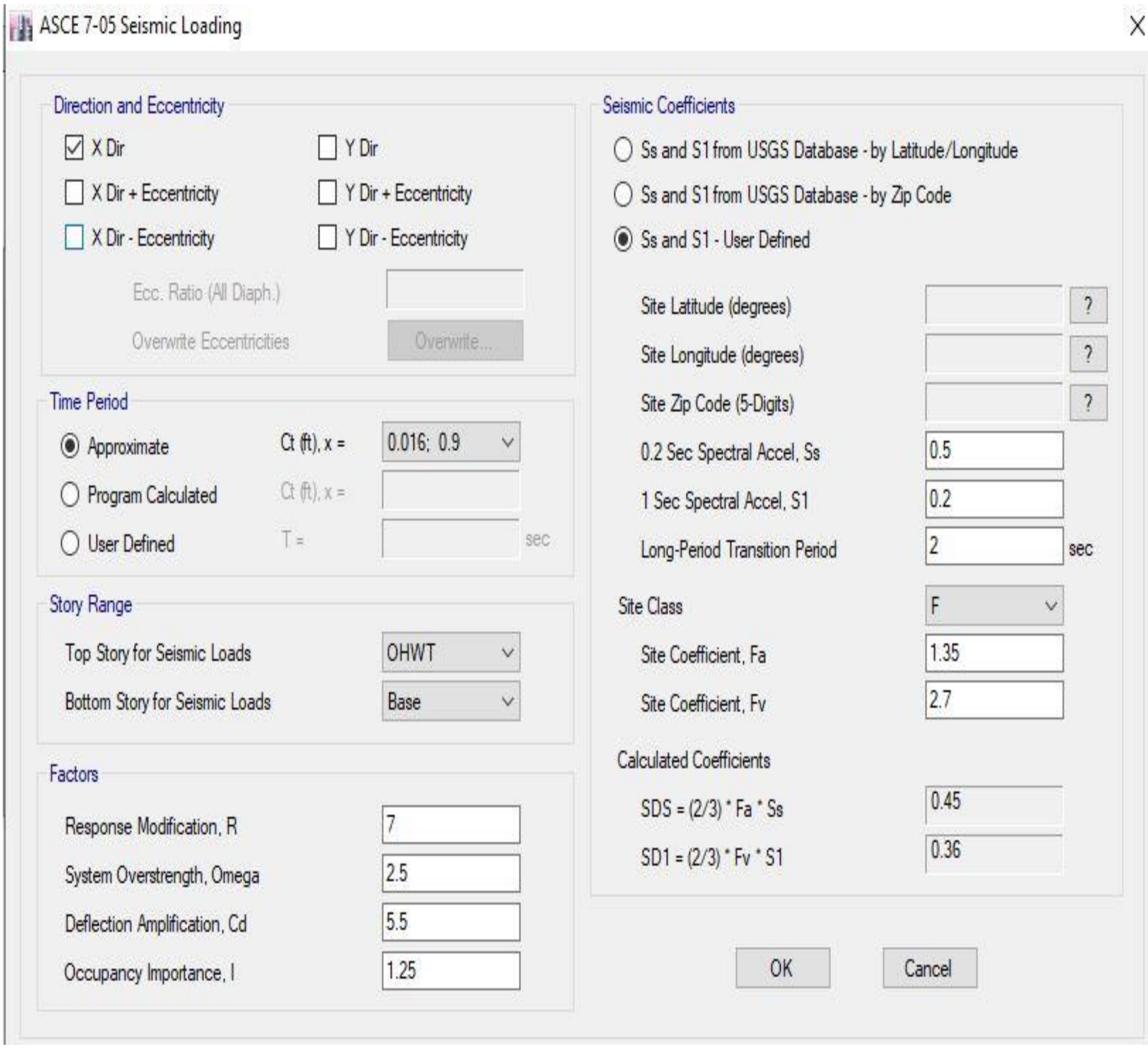

Figure 3.12: Seismic loading input data (Zone 2) for 10 storied Residential building without shear wall

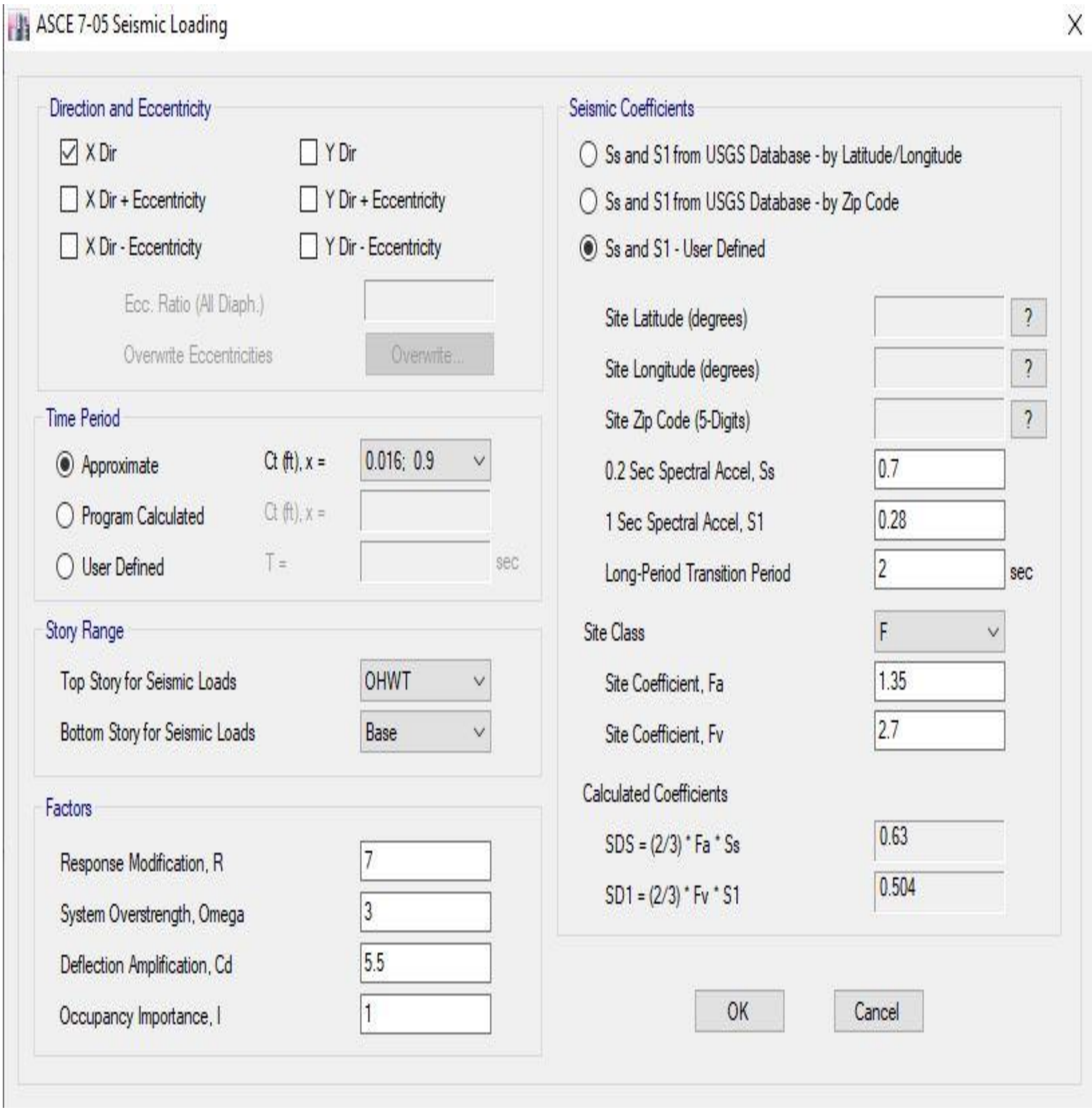

Figure 3.13: Seismic loading input data (Zone 3) for 10 storied Residential building with shear wall

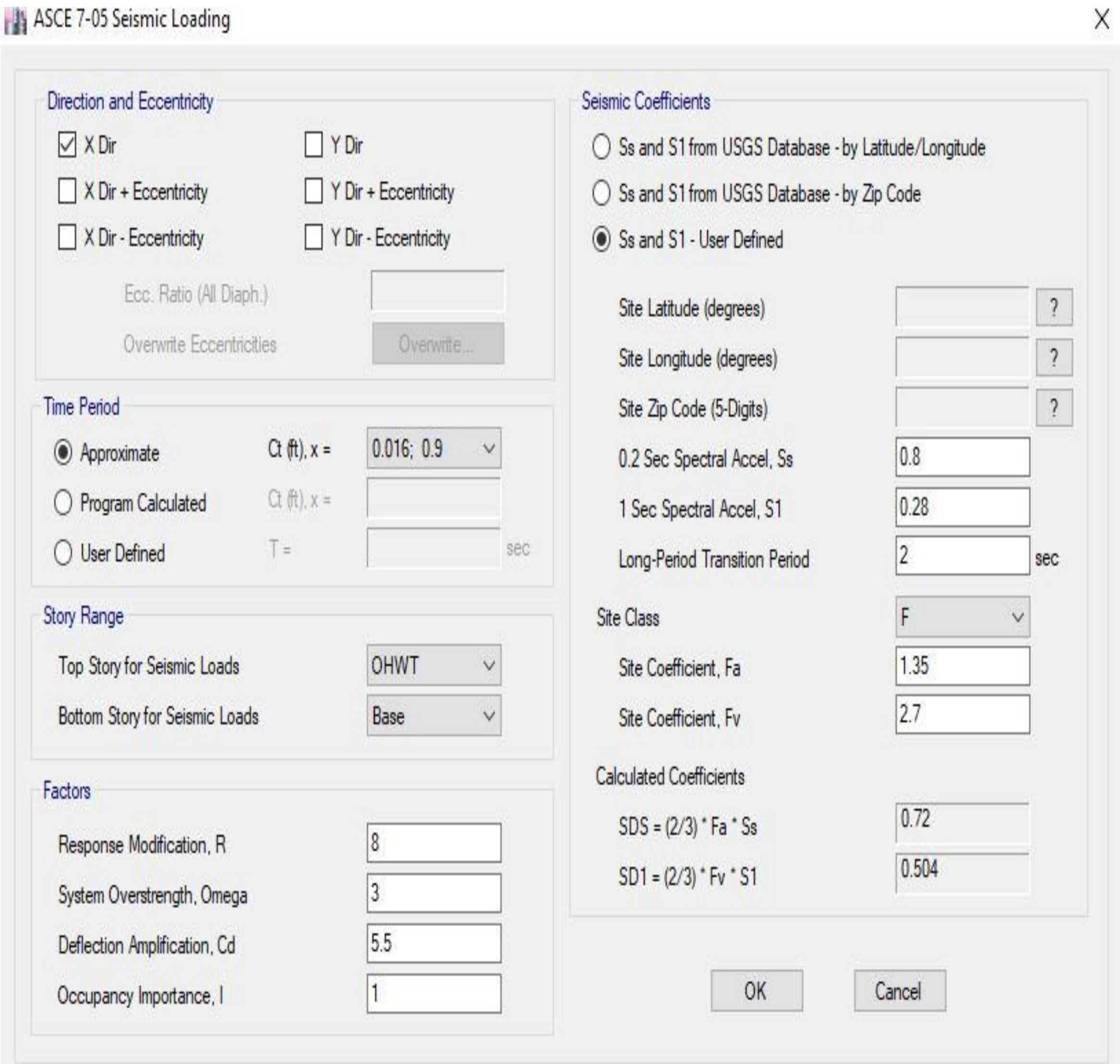

Figure 3.14: Seismic loading input data (Zone 3) for 10 storied Residential building without shear wall

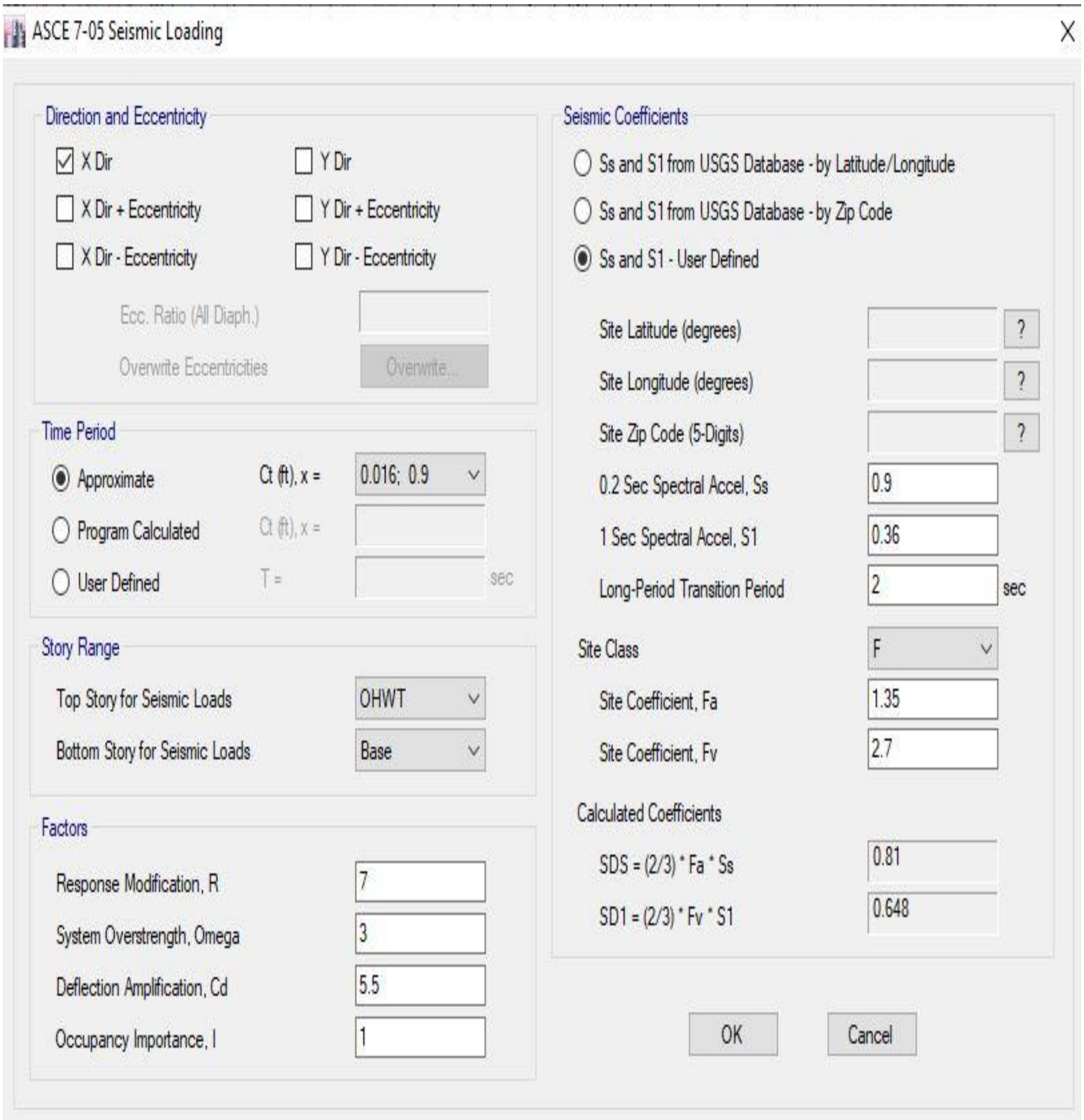

Figure 3.15: Seismic loading input data (Zone 4) for 10 storied Residential building with shear wall

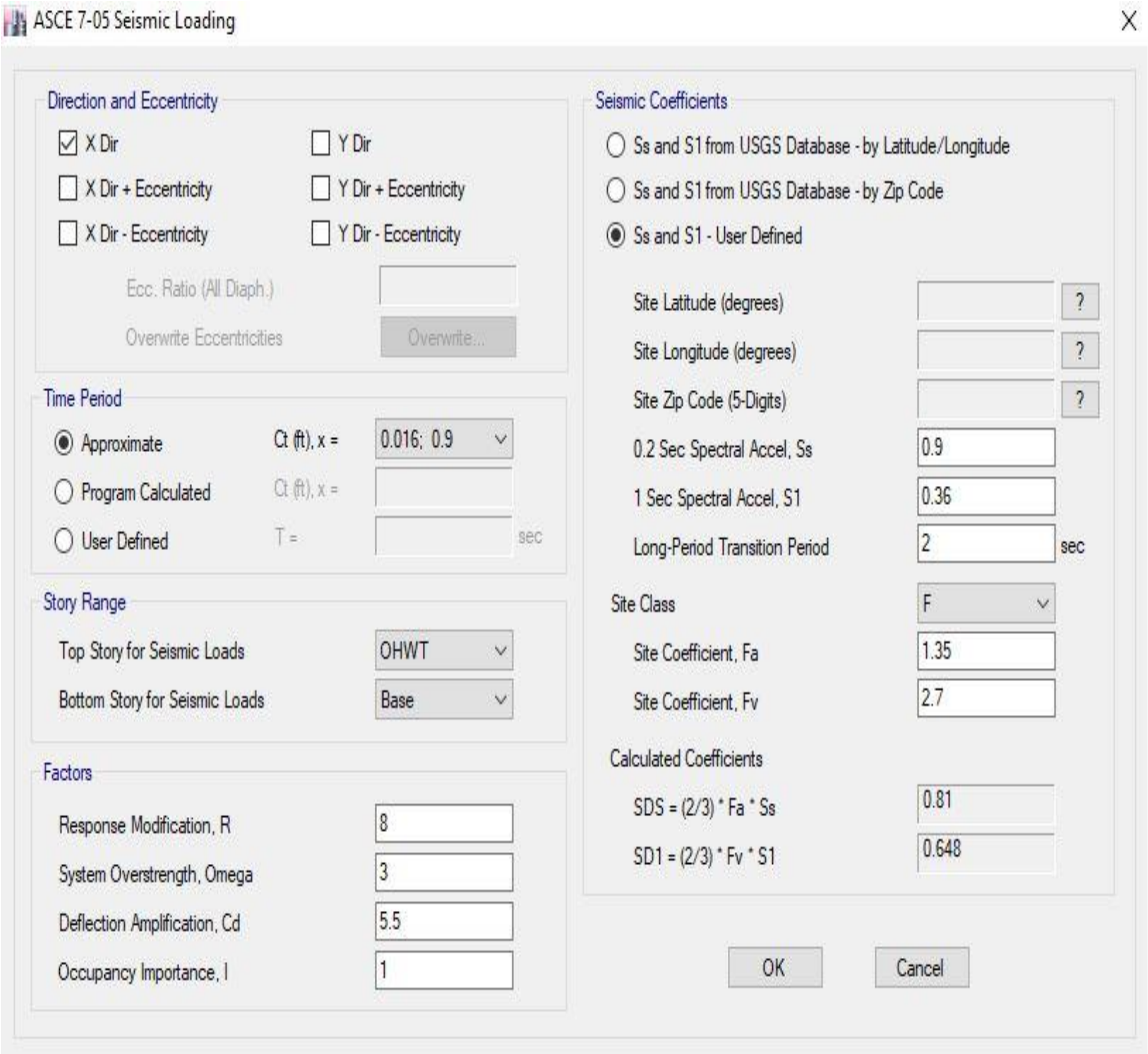

Figure 3.16: Seismic loading input data (Zone 4) for 10 storied Residential building without shear wall

Table 3.1 Design data

Sr. No	Building Parameters	Description
1	Type of frame	MRF
2	Seismic zone	Zone 1 : 0.12, Zone 2 : 0.20, Zone 3 : 0.28 & Zone 4 : 0.36 (as per BNBC 2020)
3	Importance Factor (I)	1
4	Response modification	7 (with shear wall), 8 (without shear wall)
5	Site Coefficient	1.35
6	Loadings	
	i) Dead Load	Self-weight of structural elements
	ii) Floor Finishes	25 psf
	iii) Partition Wall	50 psf
	iv) Live Loads	42 psf
7	Floor to floor height	10 ft.
8	Specific Weight of RCC	150 pcf
9	USD Load Combination	1.4D 1.2D + l .6L + 0.5rL l.2 D+1.6Lr+ L l.2 D+l.6Lr + 0.8 W l.2D+L+0.5rL + 1.6 W l.2D+L+E 0.9D+l.6W 0.9D+E
10	Seismic Load Combination	1.0DL + 1.5LL + 1.0FF + 1.0PW 1.29DL + 4.0LL + 1.29FF + 1.29PW + 1.0EX 1.29DL + 4.0LL + 1.29FF + 1.29PW - 1.0EX 1.29DL + 4.0LL + 1.29FF + 1.29PW + 1.0EY 1.29DL + 4.0LL + 1.29FF + 1.29PW - 1.0EY 0.81DL + 0.81FF + 0.81PW + 1.0EX 0.81DL + 0.81FF + 0.81PW - 1.0EX 0.81DL + 0.81FF + 0.81PW + 1.0EY 0.81DL + 0.81FF + 0.81PW – 1.0EY
11	Size of Beam	12” x 18”

12	Size of Column	14” x 24” & 15”x25”
13	Thickness of Slab	6”
14	Thickness of Shear Walls	10”
15	Modulus of Elasticity of Concrete	3636.62 ksi
16	Zone coefficient value	Zone 1 : 0.12 Zone 2 : 0.20 Zone 3 : 0.28 Zone 3 : 0.36

3.3 SEISMIC WEIGHT (2.5.7.3 BNBC 2020) [1]

Seismic weight, W, is the total dead load of a building or a structure, including partition walls, and applicable portions of other imposed loads listed below:

- For live load up to and including 3 kN/m^2, a minimum of 25 percent of the live load shall be applicable.
- For live load above 3 kN/m^2, a minimum of 50 percent of the live load shall be applicable.
- Total weight (100 percent) of permanent heavy equipment or retained liquid or any imposed load sustained in nature shall be included.

Where the probable imposed loads (mass) at the time of earthquake are more correctly assessed, the designer may go for higher percentage of live load.

Table 3.2: Description of Seismic Zones (Table 6.2.14 BNBC 2020) [1]

Seismic Zone	Location	Seismic Intensity	Seismic Zone Coefficient, Z
1	Southwestern part including Barisal, Khulna, Jessore, Rajshahi	Low	0.12
2	Lower Central and Northwestern part including Noakhali, Dhaka, Pabna, Dinajpur, as well as Southwestern corner including Sundarbans	Moderate	0.20
3	Upper Central and Northwestern part including Brahmanbaria, Sirajganj, Rangpur	Severe	0.28
4	Northeastern part including Sylhet, Mymensingh, Kurigram	Very Severe	0.36

Table 3.3: Seismic Zone Coefficient Z for Some Important Towns of Bangladesh
(Table 6.2.15 BNBC 2020) [1]

Bagerhat	0.12	Jessore	0.12	Comilla	0.20	Madaripur	0.20
Gaibandha	0.28	Mymensingh	0.36	Kishoreganj	0.36	Panchagarh	0.20
Magura	0.12	Satkhira	0.12	Naogaon	0.20	Feni	0.20
Patuakhali	0.12	Chandpur	0.20	Sunamganj	0.36	Munshiganj	0.20
Bandarban	0.28	Jhalokati	0.12	Cox's Bazar	0.28	Rangpur	0.28
Gazipur	0.20	Narail	0.12	Kurigram	0.36	Brahmanbaria	0.28
Manikganj	0.20	Shariatpur	0.20	Netrakona	0.36	Khulna	0.12
Pirojpur	0.12	Chapainababganj	0.12	Sylhet	0.36	Natore	0.20
Barguna	0.12	Jhenaidah	0.12	Dhaka	0.20	Srimangal	0.36
Gopalganj	0.12	Narayanganj	0.20	Kushtia	0.20	Faridpur	0.20
Maulvibazar	0.36	Sherpur	0.36	Nilphamari	0.12	Lalmanirhat	0.28
Rajbari	0.20	Chittagong	0.28	Tangail	0.28	Pabna	0.20
Barisal	0.12	Khagrachari	0.28	Dinajpur	0.20	Rajshahi	0.12
Habiganj	0.36	Narsingdi	0.28	Lakshmipur	0.20	Meherpur	0.12
Bogra	0.28	Sirajganj	0.28	Noakhali	0.20	Bhola	0.12
Jamalpur	0.36	Chuadanga	0.12	Thakurgaon	0.20	Jaipurhat	0.20

Table 3.4: Seismic Design Category of Building (Table 6.2.18 BNBC 2020) [1]

Site Class	Occupancy Category I, II and III				Occupancy Category IV			
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
SA	B	C	C	D	C	D	D	D
SB	B	C	D	D	C	D	D	D
SC	B	C	D	D	C	D	D	D
SD	C	D	D	D	D	D	D	D
SE, S1, S2	D	D	D	D	D	D	D	D

Table 3.5: Importance Factor (Table 6.2.17 BNBC 2020) [1]

Occupancy Category	Importance factor I
I, II	1.00
III	1.25
IV	1.50

Table 3.6: Response Reduction Factor, Deflection Amplification Factor and Height Limitations for Different Structural Systems(Table 6.2.19 BNBC 2020) [1]

Seismic Force–Resisting System	Response Reduction Factor, R	System Over strength Factor, Ω_0	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limits (m)		
A. BEARING WALL SYSTEM (no frame)						
1. Special reinforced concrete shear walls	5	2.5	5	NL	NL	50
2. Ordinary reinforced concrete shear walls	4	2.5	4	NL	NL	NP
3. Ordinary reinforced masonry shear walls	2	2.5	1.75	NL	50	NP
4. Ordinary plain masonry shear walls	1.5	2.5	1.25	18	NP	NP
B. BEARING WALL SYSTEM (with bracing or shear wall)						
1. Steel eccentrically braced frames, moment resisting connections at columns away from links	8	2	4	NL	NL	50
2. Steel eccentrically braced frames, non-moment resisting, connections at columns away from links	7	2	4	NL	NL	50
3. Special steel concentrically braced frames	6	2	5	NL	NL	50
4. Ordinary steel concentrically braced frames	3.25	2	3.25	NL	NL	11
5. Special reinforced concrete shear walls	6	2.5	5	NL	NL	50

Seismic Force–Resisting System	Response Reduction Factor, R	System Over strength Factor, Ω_0	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limits (m)		
6. Ordinary reinforced concrete shear walls	5	2.5	4.25	NL	NL	NP
7. Ordinary reinforced masonry shear walls	2	2.5	2	NL	50	NP
8. Ordinary plain masonry shear walls	1.5	2.5	1.5	18	NP	NP
C. MOMENT RESISTING FRAME SYSTEMS (no shear wall)						
1. Special steel moment frames	8	3	5.5	NL	NL	NL
2. Intermediate steel moment frames	4.5	3	4	NL	NL	35
3. Ordinary steel moment frames	3.5	3	3	NL	NL	NP
4. Special reinforced concrete moment frames	8	3	5.5	NL	NL	NL
5. Intermediate reinforced concrete moment frames	5	3	4.5	NL	NL	NP
6. Ordinary reinforced concrete moment frames	3	3	2.5	NL	NP	NP

D. DUAL SYSTEMS: SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1. Steel eccentrically braced frames	8	2.5	4	NL	NL	NL
2. Special steel concentrically braced frames	7	2.5	5.5	NL	NL	NL
3. Special reinforced concrete shear walls	7	2.5	5.5	NL	NL	NL
4. Ordinary reinforced concrete shear walls	6	2.5	5	NL	NL	NP

3.4 WIND LOAD

3.4.1 General

Scope: Buildings and other structures, including the Main Wind-Force Resisting System (MWFRS) and all components and cladding thereof, shall be designed and constructed to resist wind loads as specified herein [1].

3.4.2 Design for wind load:

Design of buildings and their components to resist wind induced forces shall comply with the following requirements:

3.4.2.1 Direction of wind

Structural design for wind forces shall be based on assumption that wind may blow from any horizontal direction [1].

3.4.2.2 Design considerations

Design wind load on the primary framing systems and components of a building or structure shall be determined on the basis of the procedures provided in Sec 2.4 Chapter 2 Part 6 considering the basic wind speed, shape and size of the building, and the terrain exposure condition of the site. For slender buildings and structures, dynamic response characteristics, such as fundamental natural frequency, shall be determined to estimate gust response coefficient. Load effects, such as forces, moments, and deflections etc. on various components of building due to wind shall be determined from static analysis of the structure as specified in Sec 1.2.7.1 of this Chapter [1].

Table 3.7: Importance Factor, I (Wind Loads) (Table 6.2.9 BNBC 2020) [1]

Occupancy Category1 or Importance Class	Non-Cyclone Prone Regions and Cyclone Prone Regions with V= 38-44 m/s	Cyclone Prone Regions with V > 44 m/s
I	0.87	0.77
II	1.0	1.00
III	1.15	1.15
IV	1.15	1.15

3.5 Topographic factor [1]

The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}:

$$Kzt = (1 + K_1 + K_2 + K_3)^2$$

Where, K_1, K_2 and K_3 are given in Figure 6.2.4. If site conditions and locations of structures do not meet all the conditions specified in Sec 2.4.7.1 then $K_{zt} = 1.0$.

Table 3.8: Wind Directionality Factor, Kd (Table 6.2.12 BNBC 2020) [1]

Structure Type	Directionality Factor Kd	Structure Type	Directionality Factor Kd
Buildings		Solid Signs	0.85
Main Wind Force Resisting System	0.85	Open Signs and Lattice Framework	0.85
Components and Cladding	0.85	Trussed Towers	
Arched Roofs	0.85	Triangular, square, rectangular	0.85
Chimneys, Tanks, and Similar Structures		All other cross section	0.95
Square	0.90		
Hexagonal	0.95		
Round	0.95		

Table 3.9: Wall Pressure Coefficients, Cp [1]

Surface	*L/B*	C_P	Use With
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥4	-0.3	
Side Wall	All values	-0.7	q_z

CHAPTER 4

RESULT & ANALYSIS

4.1 DESIGN BASE SHARE:

The seismic design base shear force in a given direction shall be determined from the following relation:

$$V = S_a W$$

Where,

S_a = Lateral seismic force coefficient calculated using Eq. 6.2.34 (Sec 2.5.4.3). It is the design spectral acceleration (in units of g) corresponding to the building period T (computed as per Sec 2.5.7.2).

W =Total seismic weight of the building defined in Sec 2.5.7.

4.2 Seismic Design Parameters for Alternative Method of Base Shear Calculation:

Table 4.1: Spectral Response Acceleration Parameter s_s and s_1 for Different Seismic Zone (Table 6.C.1 BNBC 2020) [1]

Parameters	Zone-1	Zone-2	Zone-3	Zone-4
SS	0.3	0.5	0.7	0.9
S1	0.12	0.2	0.28	0.36

Table 4.2: Site Coefficient $\boldsymbol{F_a}$ for Different Seismic Zone and Soil Type (Table 6.C.2 BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.2	1.2	1.2	1.2
SC	1.15	1.15	1.15	1.15
SD	1.35	1.35	1.35	1.35
SE	1.4	1.4	1.4	1.4

Table 4.3: Site Coefficient F_v for Different Seismic Zone and Soil Type
(Table 6.C.3 BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.2	1.2	1.2	1.2
SC	1.725	1.725	1.725	1.725
SD	2.7	2.7	2.7	2.7
SE	1.75	1.75	1.75	1.75

Table 4.4: Spectral Response Acceleration Parameter S_{DS} for Different Seismic Zone and Soil Type (Table 6.C.4 BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	0.2	0.333	0.466	0.6
SB	0.24	0.4	0.56	0.72
SC	0.23	0.383	0.536	0.69
SD	0.27	0.45	0.63	0.81
SE	0.28	0.466	0.653	0.84

Table 4.5: Spectral Response Acceleration Parameter S_{D1} for Different Seismic Zone and Soil Type (Table 6.C.5 BNBC 2020)

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	0.08	0.133	0.186	0.24
SB	0.12	0.2	0.28	0.36
SC	0.138	0.23	0.322	0.414
SD	0.216	0.36	0.504	0.648
SE	0.14	0.233	0.326	0.42

Table 4.6: Base shear for different structural systems in different seismic zones.

Zone identity	Presence of Shear Wall	Base shear(kip)
Zone 1	With shear wall	267.28
Zone 1	Without shear wall	243.94
Zone 2	With shear wall	556.85
Zone 2	Without shear wall	580.81
Zone 3	With shear wall	623,67
Zone 3	Without shear wall	569.19
Zone 4	With shear wall	801.86
Zone 4	Without shear wall	731.82

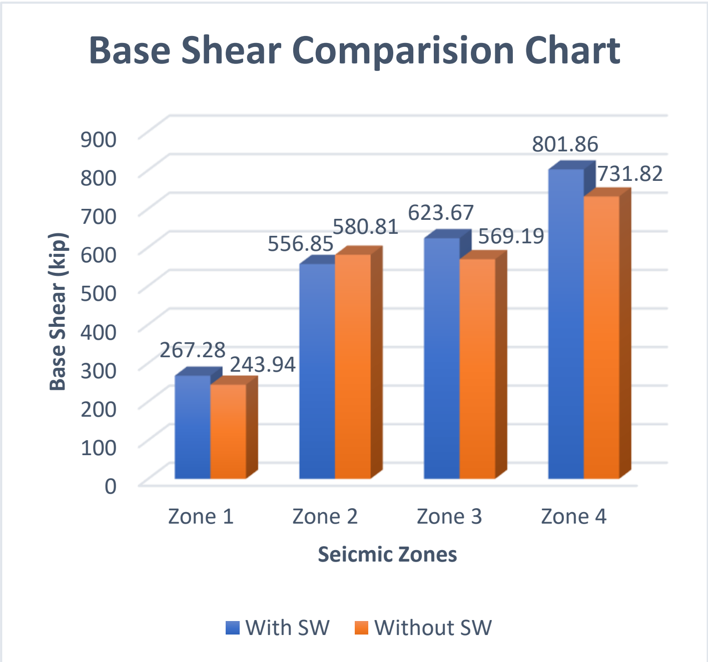

Figure 4.1: Base shear comparison chart in different seismic zones.

From the results of the analytical investigation of this study presented in table 4.6 and figure 4.1, it is seen that the Base shear are higher for shear wall buildings comparing to without shear wall buildings at Zone 1, Zone 2 and Zone 4 but for Zone 4 Base shear are higher for without shear wall buildings comparing to shear wall buildings.

4.1 ANALYSIS RESULTS AND FINDINGS OF BASE MOMENT

Table 4.7: Base moment for different structural systems in different seismic zones

Zone identity	Presence of Shear wall	Base moment(kip-ft.)
Zone 1	With shear wall	10515.47
Zone 1	Without shear wall	9616.99
Zone 2	With shear wall	21907.22
Zone 2	Without shear wall	22897.59
Zone 3	With shear wall	24536.09
Zone 3	Without shear wall	22439.64
Zone 4	With shear wall	31546.39
Zone 4	Without shear wall	28850.97

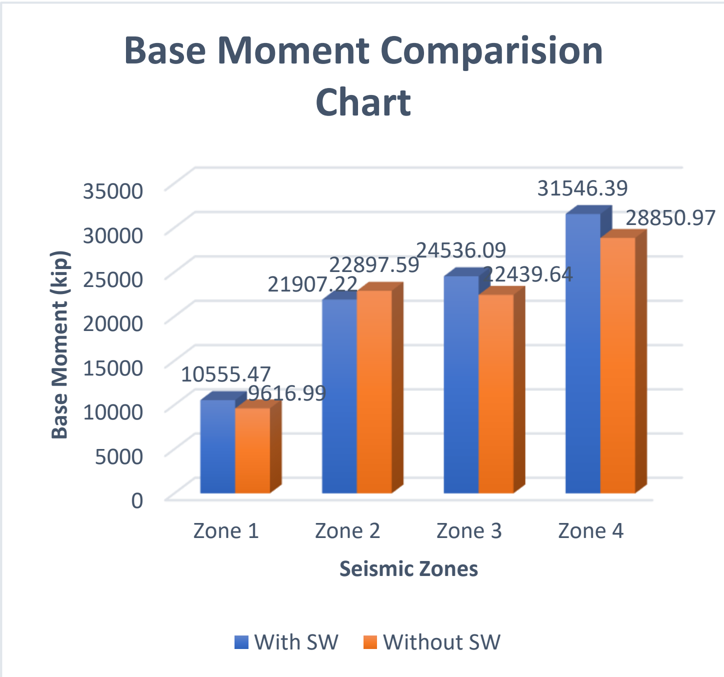

Figure 4.2: Base moment comparison chart in different seismic zones

From the results of the analytical investigation of this study presented in table 4.7 and figure 4.2, it is seen that the Base moment are higher for shear wall buildings comparing to without shear wall buildings at Zone 1, Zone 2 and Zone 4 but for Zone 4 Base moment are higher for without shear wall buildings comparing to shear wall building.

4.2 STOREY DRIFT

4.2.1 Storey drift:

Maximum story drift corresponding to the design lateral force including displacement due to vertical deformation of the isolation system shall not exceed the following limits:

1) The maximum story drift of the structure above the isolation system calculated by response spectrum analysis shall not exceed 0.015.
2) The maximum story drift of the structure above the isolation system calculated by nonlinear time history analysis shall not exceed 0.020 h_{sx}.

The storey drift shall be calculated as in Sec 2.5.7.7 except that C_d for the isolated structure shall be taken equal to R_I and importance factor equal to 1.0 [1].

4.2.2 Deflection and storey drift

The deflections (δ_x) of level x at the center of the mass shall be determined in accordance with the following equation:

$$\delta_I = \frac{C_d\,\delta_{xe}}{I}$$

Where,

$F_i =$ Portion of the seismic base shear, V induced at level i

$h_{i,}, h_i$ Height from the base to level i or x

The foundations of structures, except inverted pendulum-type structures, shall be permitted to be designed for three-fourths of the foundation overturning design moment, M_0 determined using above equation [1].

$$\Delta_x = \delta_x - \delta_{x-1}$$

4.2.3 Storey drift limitation

Storey drift is the horizontal displacement of one level of a building or structure relative to the level above or below due to the design gravity (dead and live loads) or lateral forces (e.g. wind and earthquake loads). Calculated storey drift shall include both translational and torsional deflections and conform to the following requirements:

(a) Storey drift, Δ, for loads other than earthquake loads, shall be limited as follows:

$\Delta \leq 0.005\hbar$ for T < 0.7 second

$\Delta \leq 0.004\hbar$ for T ≥ 0.7 second

$\leq 0.0025\hbar$ for unreinforced masonry structures [1].

Table 4.8: Allowable Storey Drift Limit (Δ_a) (Table 6.2.21 BNBC 2020 [1])

Structure	Occupancy Category		
	I and II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

4.3 STOREY DRIFT ANALYSIS

Drift obtained from analysis for four different seismic zones are given below respectively.

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	5.314	4.968	1.07
9F	EX1	X	5.564	5.378	1.035
8F	EX1	X	5.566	5.542	1.004
7F	EX1	X	5.947	5.736	1.037
6F	EX1	X	5.989	5.636	1.062
5F	EX1	X	5.98	5.467	1.094
4F	EX1	X	5.759	5.088	1.132
3F	EX1	X	5.286	4.458	1.186
2F	EX1	X	4.48	3.533	1.268
1F	EX1	X	2.996	2.325	1.288
GF	EX1	X	0.624	0.444	1.406

Figure 4.3: Analysis output data of story drift for 10 storied building with shear wall (zone 1)

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	1.976	1.957	1.01
9F	EX1	X	3.332	3.275	1.017
8F	EX1	X	4.651	4.555	1.021
7F	EX1	X	5.8	5.663	1.024
6F	EX1	X	6.749	6.581	1.026
5F	EX1	X	7.509	7.313	1.027
4F	EX1	X	8.079	7.863	1.028
3F	EX1	X	8.446	8.22	1.027
2F	EX1	X	8.496	8.287	1.025
1F	EX1	X	7.867	7.077	1.112
GF	EX1	X	3.095	2.363	1.31

Figure 4.4: Analysis output data of story drift for 10 storied building without shear wall (zone 1)

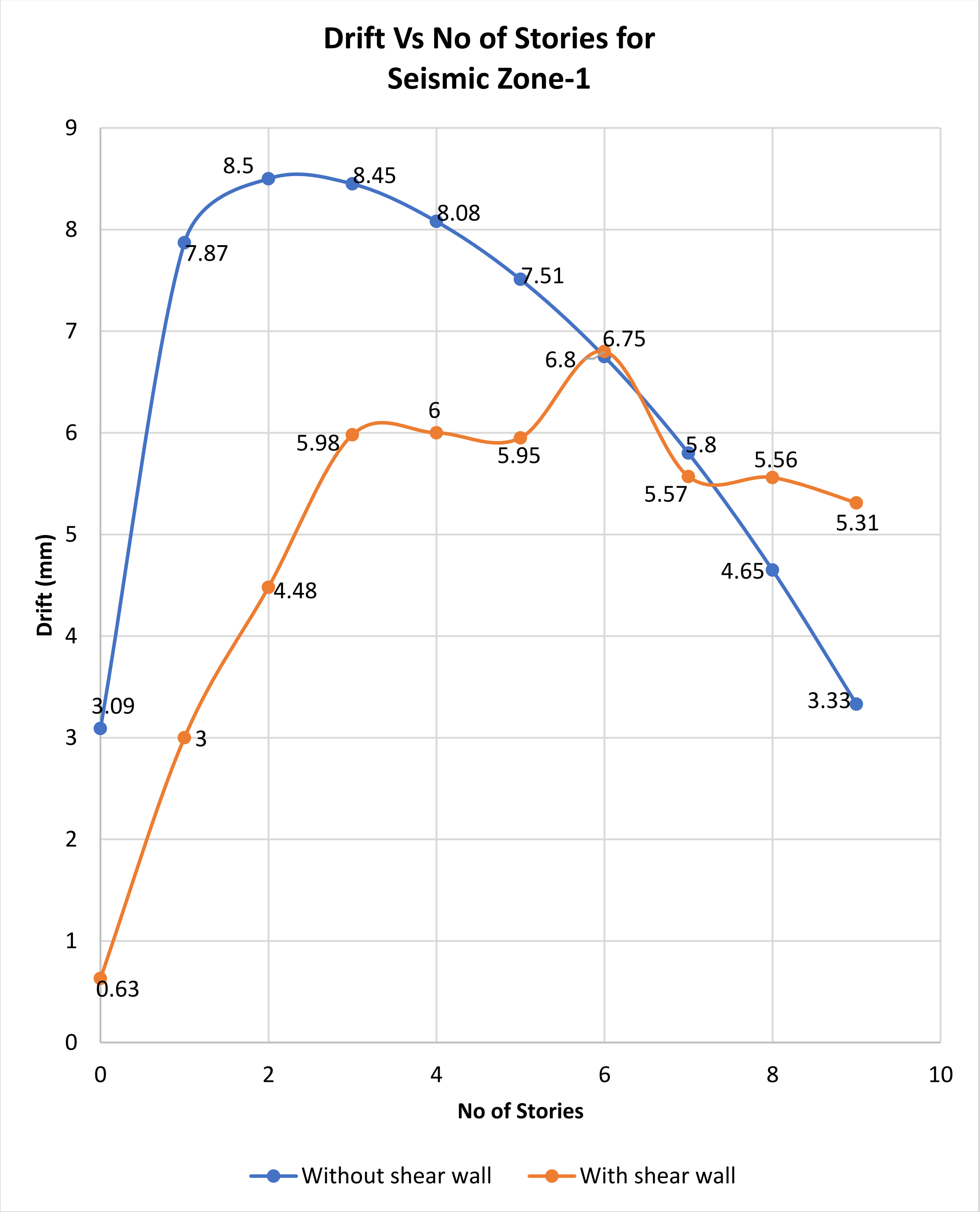

Figure 4.5: Storey drift Comparison for both shear wall and without shear wall buildings (Zone-1)

From the results of the analytical investigation of this study presented in Table: 4.3, Table: 4.4 and Figure: 4.5, it is seen that the drift values, it can be said that due to presence of shear wall building oscillate comparatively low.

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	11.071	10.349	1.07
9F	EX1	X	11.593	11.204	1.035
8F	EX1	X	11.595	11.547	1.004
7F	EX1	X	12.389	11.949	1.037
6F	EX1	X	12.476	11.743	1.062
5F	EX1	X	12.459	11.39	1.094
4F	EX1	X	11.999	10.6	1.132
3F	EX1	X	11.012	9.286	1.186
2F	EX1	X	9.334	7.36	1.268
1F	EX1	X	6.241	4.845	1.288
GF	EX1	X	1.3	0.925	1.406

Figure 4.6: Analysis output data of story drift for 10 storied building with shear wall (zone 2)

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	4.706	4.659	1.01
9F	EX1	X	7.933	7.797	1.017
8F	EX1	X	11.073	10.844	1.021
7F	EX1	X	13.81	13.484	1.024
6F	EX1	X	16.068	15.668	1.026
5F	EX1	X	17.878	17.412	1.027
4F	EX1	X	19.236	18.721	1.028
3F	EX1	X	20.109	19.572	1.027
2F	EX1	X	20.228	19.731	1.025
1F	EX1	X	18.732	16.851	1.112
GF	EX1	X	7.368	5.625	1.31

Figure 4.7: Analysis output data of story drift for 10 storied building without shear wall (zone 2)

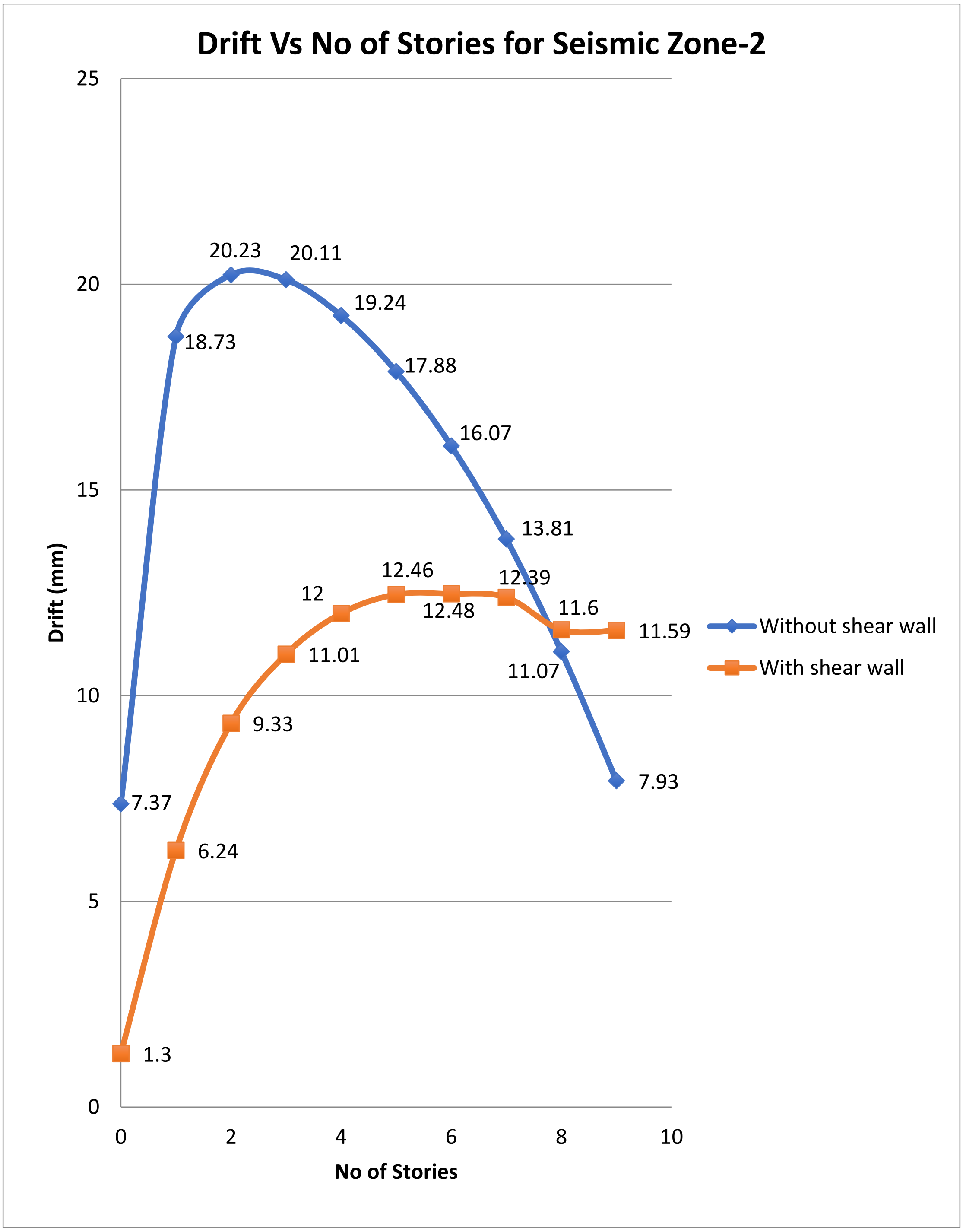

Figure 4.8: Storey drift Comparison for both shear wall and without shear wall buildings (Zone-2)

From the results of the analytical investigation of this study presented in Table: 4.6, Table: 4.7 and Figure: 4.8, it is seen that the drift values, it can be said that due to presence of shear wall building oscillate comparatively low.

Story Max/Avg Drifts

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	12.4	11.591	1.07
9F	EX1	X	12.984	12.548	1.035
8F	EX1	X	12.987	12.932	1.004
7F	EX1	X	13.875	13.383	1.037
6F	EX1	X	13.973	13.152	1.062
5F	EX1	X	13.954	12.757	1.094
4F	EX1	X	13.439	11.872	1.132
3F	EX1	X	12.334	10.401	1.186
2F	EX1	X	10.454	8.243	1.268
1F	EX1	X	6.99	5.426	1.288
GF	EX1	X	1.456	1.036	1.406

Figure 4.9: Analysis output data of story drift for 10 storied building with shear wall (zone 3)

Story Max/Avg Drifts

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	4.611	4.566	1.01
9F	EX1	X	7.774	7.641	1.017
8F	EX1	X	10.851	10.627	1.021
7F	EX1	X	13.534	13.214	1.024
6F	EX1	X	15.747	15.355	1.026
5F	EX1	X	17.52	17.063	1.027
4F	EX1	X	18.851	18.347	1.028
3F	EX1	X	19.707	19.181	1.027
2F	EX1	X	19.823	19.336	1.025
1F	EX1	X	18.357	16.514	1.112
GF	EX1	X	7.221	5.513	1.31

Figure 4.10: Analysis output data of story drift for 10 storied building without shear wall (zone 3)

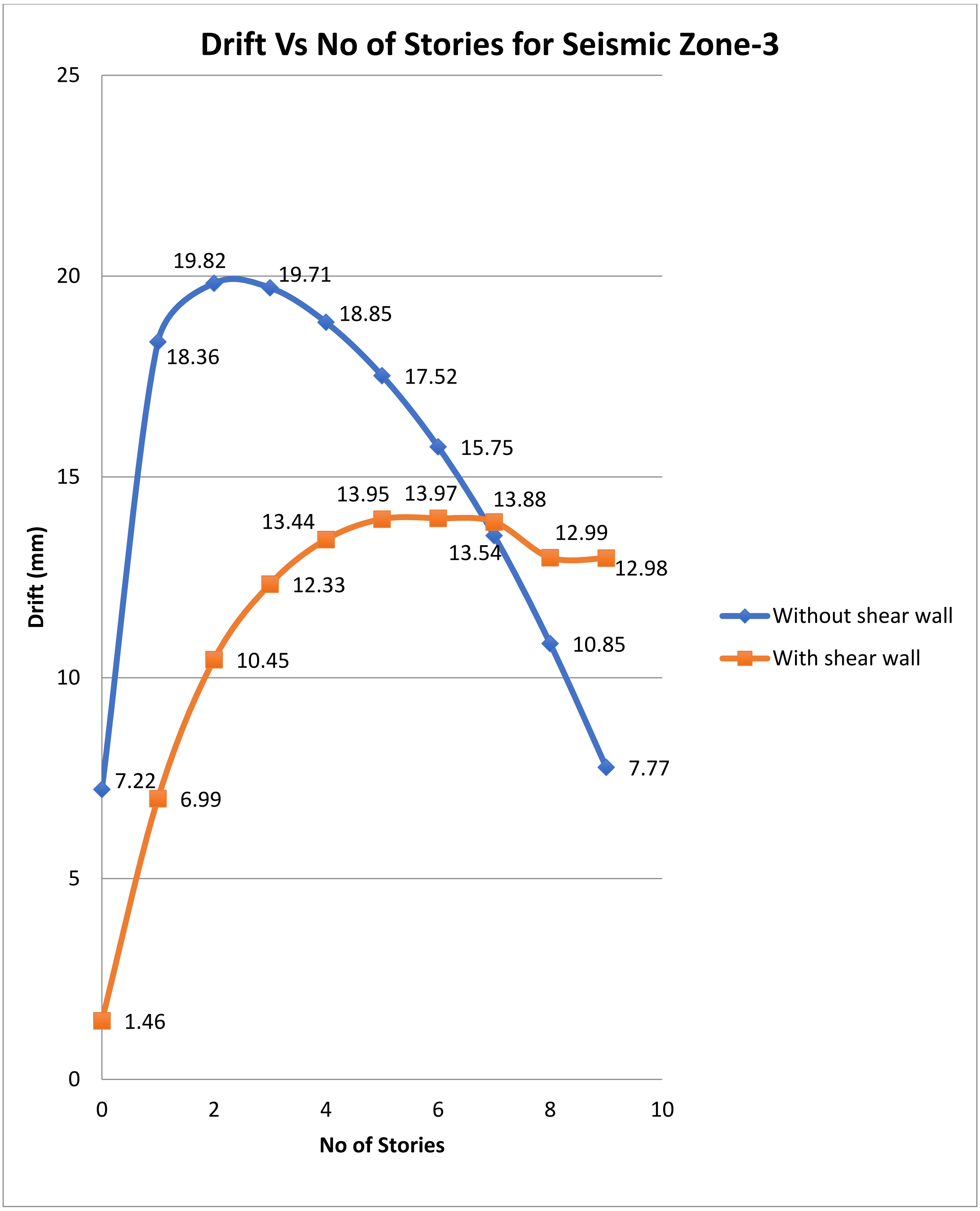

Figure 4.11: Storey drift Comparison for both shear wall and without shear wall buildings (Zone-3)

From the results of the analytical investigation of this study presented in Table: 4.9, Table: 4.10 and Figure: 4.11, it is seen that the drift values, it can be said that due to presence of shear wall building oscillate comparatively low.

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	15.943	14.903	1.07
9F	EX1	X	16.693	16.133	1.035
8F	EX1	X	16.697	16.627	1.004
7F	EX1	X	17.84	17.207	1.037
6F	EX1	X	17.966	16.909	1.062
5F	EX1	X	17.941	16.402	1.094
4F	EX1	X	17.278	15.264	1.132
3F	EX1	X	15.858	13.373	1.186
2F	EX1	X	13.441	10.598	1.268
1F	EX1	X	8.987	6.976	1.288
GF	EX1	X	1.873	1.332	1.406

Figure 4.12: Analysis output data of story drift for 10 storied building with shear wall (zone 4)

Story Max/Avg Drifts

1 of 11 Reload Apply

Story	Load Case/Combo	Direction	Max Drift mm	Avg Drift mm	Ratio
ROOF	EX1	X	5.929	5.87	1.01
9F	EX1	X	9.996	9.824	1.017
8F	EX1	X	13.952	13.664	1.021
7F	EX1	X	17.401	16.99	1.024
6F	EX1	X	20.246	19.742	1.026
5F	EX1	X	22.526	21.939	1.027
4F	EX1	X	24.238	23.589	1.028
3F	EX1	X	25.337	24.661	1.027
2F	EX1	X	25.487	24.861	1.025
1F	EX1	X	23.602	21.232	1.112
GF	EX1	X	9.284	7.088	1.31

Figure 4.13: Analysis output data of story drift for 10 storied building without shear wall (zone 4)

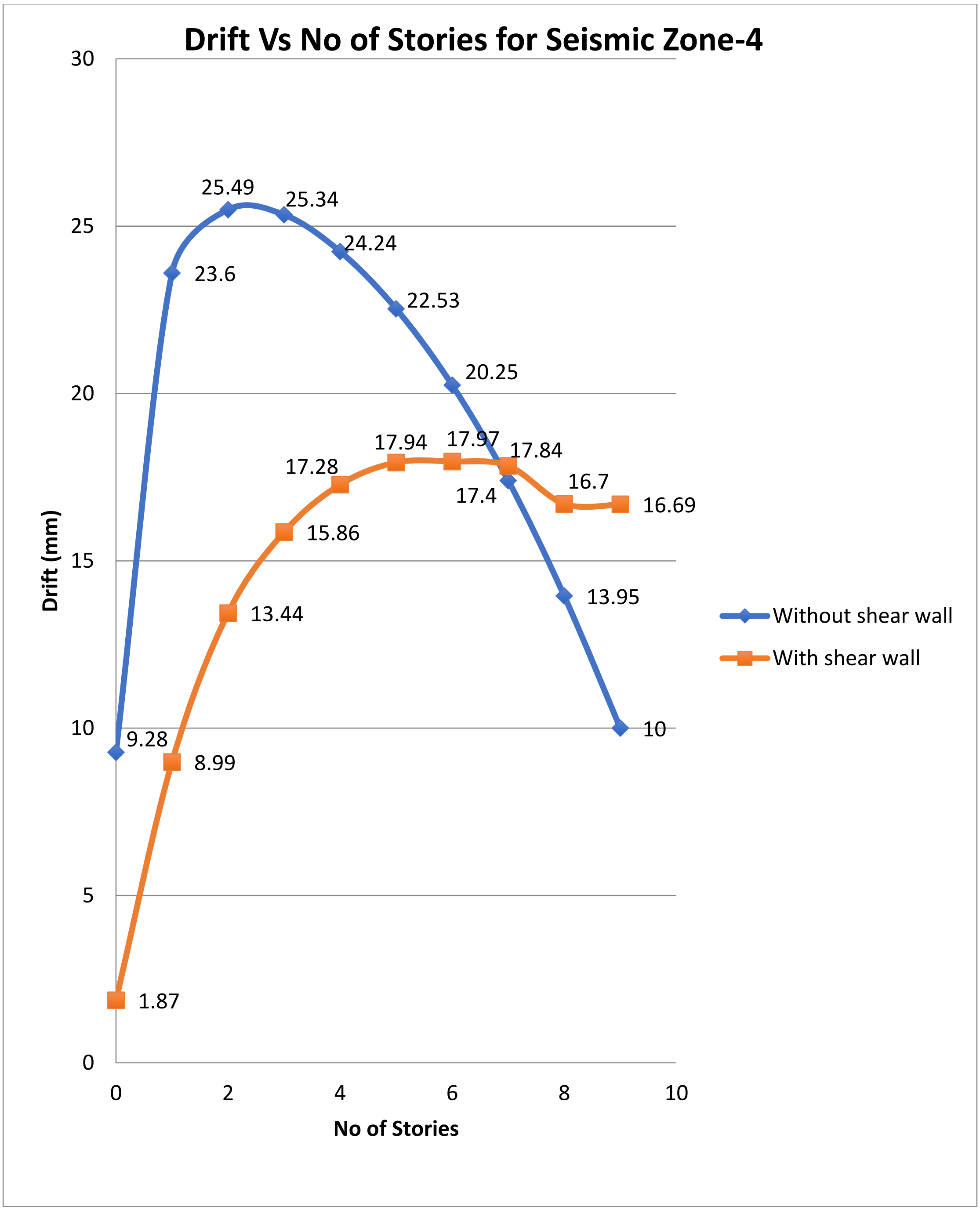

Figure 4.14: Storey drift Comparison for both shear wall and without shear wall buildings (Zone-4).

From the results of the analytical investigation of this study presented in Table: 4.12, Table: 4.13 and Figure: 4.14, it is seen that the drift values, it can be said that due to presence of shear wall building oscillate comparatively low.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION:

The whole study is concentrated on Seismic Performances of RCC Buildings Located in four different Seismic Zones in Bangladesh. Seismic analysis is carried out for 10 storied residential building. The reinforcement provided in building is compared with base shear, Base moment & Storey drift. After all the study the following conclusions are drawn:

- In this study it is clearly understandable that base shear, base moment and storey drifts are higher in seismic zone-4 comparing to other zones.
- Base shear and base moments are higher for shear wall buildings comparing to without shear wall buildings at Zone 1, Zone 2 and Zone 4 but for Zone 4 Base shear and base moments are higher for without shear wall buildings comparing to shear wall buildings.
- By observing the drift values, it can be said that due to presence of shear wall building oscillate comparatively low.
- It can be said that shear wall building performs well in higher seismic zone comparing to without shear wall building.

5.2 LIMITATIONS

- The case study conducted in this research is for Bangladesh only. However the seismic zone coefficient and wind speed varies for different parts of our country. Similar study can be other parts of Bangladesh especially for seismic active zones.
- To find the impact on design only base shear, base moment and storey drifts were considered.
- This study can be extended on a large scale of analysis including shear wall building performs and without shear wall building.
- This study has not considered any adjacent buildings. But pounding effect between adjacent buildings should be checked if there are adjacent buildings.
- Only two identical 10 storied models are made by ETABS software for with shear wall and without shear wall have been studied.

5.3 RECOMMENDATIONS

- Comparison of lateral load in BNBC 2020 can be made with other codes such as Euro code, Indian code, UBC, ACI, Italian code etc.
- This study can be extended on a large scale of analysis including shear wall building performs and without shear wall building.
- Dynamic analysis such as time history analysis and response spectrum analysis can be adopted for further and better analysis process..
- The applied dead loads and live loads were same accept the earthquake loading as it is different in three different zones of Bangladesh.
- Base shear, base moment and drift values are obtained by linear static analysis

REFERENCE

[1] BNBC (2020), *Bangladesh National Building Code*, HBRI-BSTI.

[2] Md. Hasan Imam, Md. Mohiuddin Ahmed, "STUDY OF SEISMIC PERFORMANCES OF RCC BUILDINGS LOCATED IN DIFFERENT SEISMIC ZONES IN BANGLADESH," *Journal of Construction and Building Materials Engineering*, vol. 5, no. 1, pp. 13-18,2019.

[3] Md. Tanjid Mehedi,Md. Montaseer Meraz, and Nusrat jahan Mim, "EVALUATION OF THE SEISMIC PERFORMANCE OF AN EXISTING RC," *Proceedings of the 6 th International Conference on Civil Engineering for Sustainable Development*, p. 10~12, 2022.

[4] B. Reshma, M. Sai krishna. P. Siva nagaraju, K. Venkata sai,P. Siva sai, "SEISMIC ANALYSIS AND DESIGN OF MULTISTOREY BUILDING IN," *International Research Journal of Engineering and Technology (IRJET),* vol. 06, no. 03, pp. 6854-6859, 2019.

[5] R. M. Faysal, "Comparison of Wind Load among BNBC and other Codes in different type of areas," *Basha Res. Corp.*, vol. 03, no. 03, 2014.

[6] F. S. Imam, S. Tahsin, and A. Hassan, "Comparative Study on Lateral Load Analysis by BNBC - 1993 and Proposed BNBC - 2012," *Int. J. Sci. Technol. Res.*, vol. 3, no. 11, pp. 57–61, 2014.

[7] M. S. Bari and T. Das, "A Comparative Study on Seismic Analysis of Bangladesh National Building Code (BNBC) with Other Building Codes*," J. Inst. Eng. Ser. A,* vol. 94, no. 3, pp. 131–137, 2013.

[8] Faria S. Imam, Saimah Tahsin, Asif Hassan, "Comparative Study On Lateral Load Analysis by BNBC - 1993 And Proposed BNBC - 2012," *International Journal of Scientific & Technology Research*, volume 3, issue 11, November 2014

APPENDIX

Appendix A

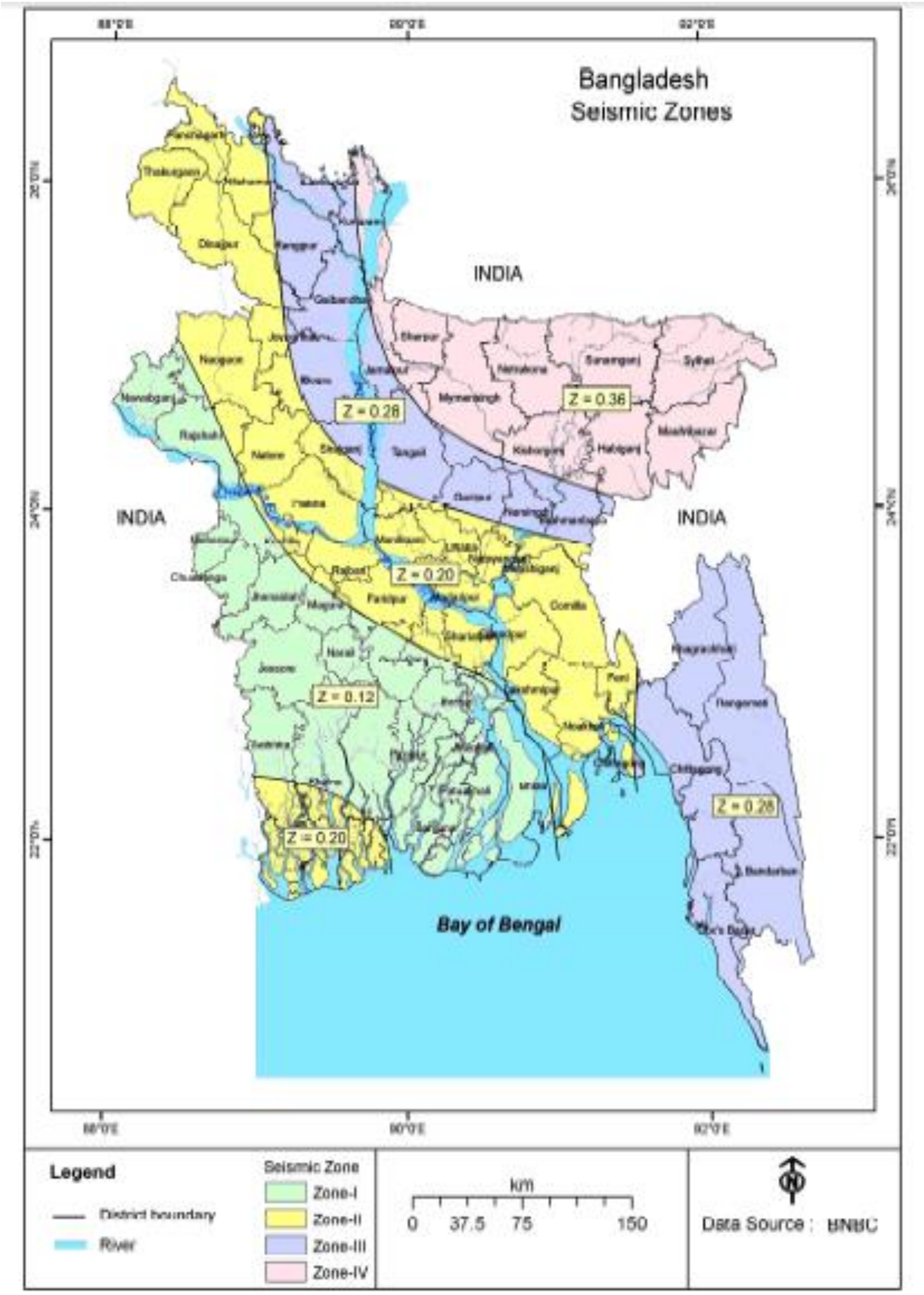

Figure A.1: Seismic Zoning map of Bangladesh (Table 6.2.24 BNBC 2020) [1]

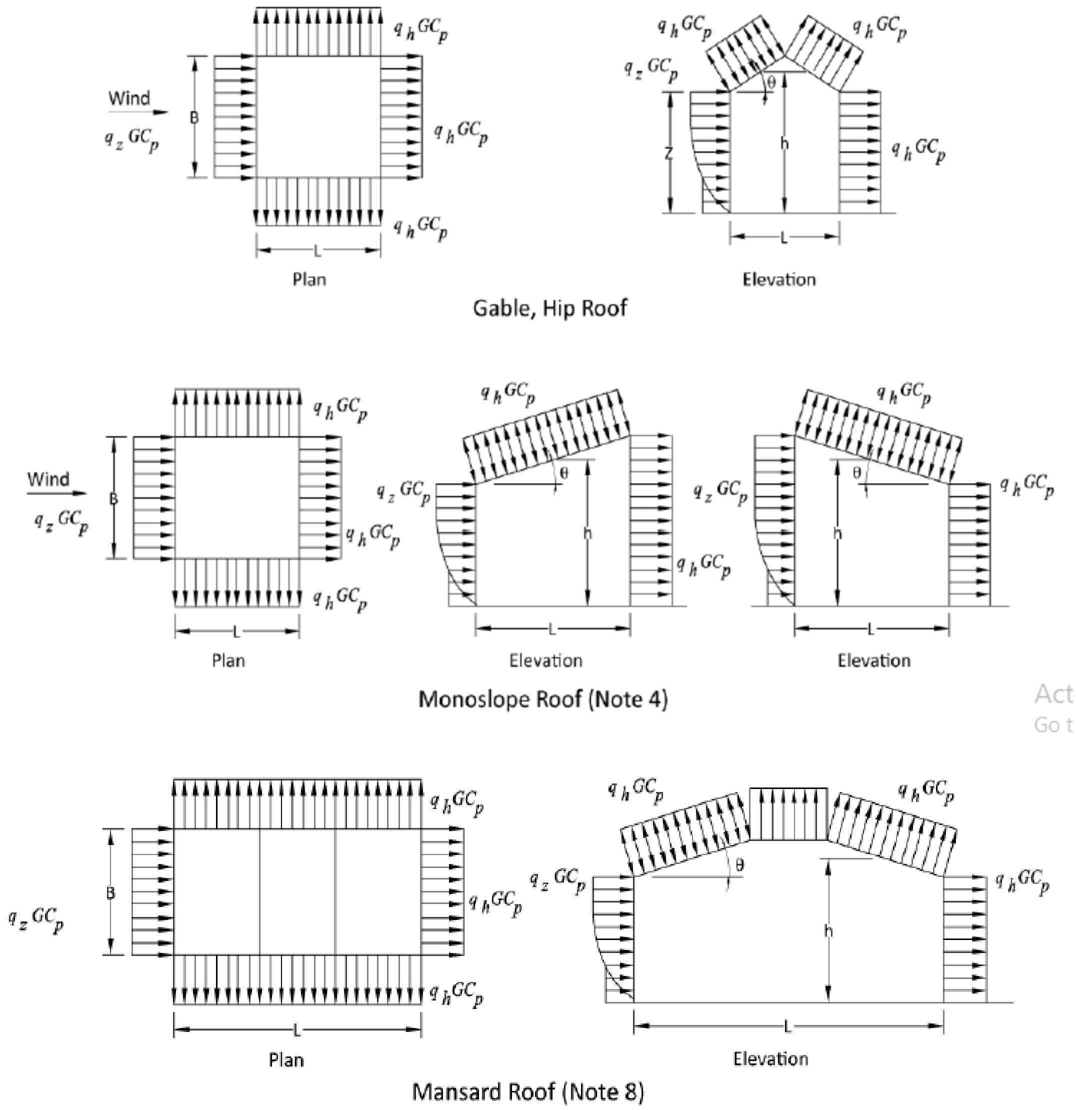

Figure A.2: External Pressure Co-efficient (Wall) (BNBC 2020) [1]