COMPARISON BETWEEN DIFFERENT SEISMIC ZONE TO ANALYZE SEISMIC PERFORMANCE OF IRREGULAR SHAPED MULTI-STOREYED R.C.C. BUILDINGS BY USING BNBC 1993

A THESIS BY

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DECLARATION

The thesis titled "COMPARISON BETWEEN DIFFERENT SEISMIC ZONE TO ANALYZE SEISMIC PERFORMANCE OF IRREGULAR SHAPED MULTI-STOREYED R.C.C. BUILDINGS BY USING BNBC 1993" hereby declared that except for the contents where specific reference has been made to the work of others, the studies contained in this thesis is the result of an investigation carried out by the author under the supervision of Arifa Akther, Lecturer, Department of Civil Engineering, Daffodil International University, Dhaka. No part of this thesis has been submitted to any other University or other educational establishments for a Degree, Diploma or other qualification (Except for publication).

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DEDICATION

This thesis (COMPARISON BETWEEN DIFFERENT SEISMIC ZONE TO ANALYZE SEISMIC PERFORMANCE OF IRREGULAR SHAPED MULTI-STOREYED R.C.C. BUILDINGS BY USING BNBC 1993) is dedicated to all of our parents and our supervisor.

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ABSTRACT

The most destructive and unpredictable natural event is the earthquake that causes tremendous damage of both human lives and structures. Seismic stresses triggered by earthquakes lead to significant damage to structural parts and often to structural collapse. Analysis and construction of the buildings taking into account the influence of lateral forces is also a very significant feature. Buildings in Bangladesh are BNBC-designed. This section examines a structure designed to evaluate its performance for gravity load and earthquake loads. The design was followed by an earthquake load as BNBC-1993. For serviceability, design and maximum earthquake, the structure's performance point is analyzed by ETABS software. Performance point of any structure, is required it has been generated with ETABS. But several parameters are required to generate the different figure. In this section, those parameters are defined and the design is plotted by ETABS. A high-rise building with standard columns and at various locations is considered for study in this work. This analysis was done in this article and was also compared according to the findings of the analysis. The results of the Base Shear study, Overall earthquake load deflection, Storey drift and Rebar percentage are compared. In bar chart and graphical type, the results are displayed.

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CHAPTER-01

INTRODUCTION

1.1 GENERAL

Bangladesh located in a seismically active territory in the world, due to geological and tectonic structures. Sylhet and Mymensingh are part of the country in the high seismic zone, while Dhaka and Chattogram are in the moderate seismic zone, and Barishal and Khulna are in the low seismic zone under the Bangladesh National Building Code (BNBC) 1993. Due to inadequate design and construction of structures, the major metropolitan cities of our country are under heavy pressure. Perfunctory urbanization in major cities such as Dhaka, Chattogram, Bogura etc. generates a large demand for the human harbour. In multi-storey buildings, frame structures are used repeatedly, mostly in conjunction with the comfort of construction and rapid work progress.

Bangladesh has a long tradition of sustainable practices in engineering. But, sadly, no written code of standard civil engineering procedure existed until 1993. Building and Housing Research published the Bangladesh National Building Code (BNBC) in 1993. Institute that is generally referred to as BNBC. BNBC's seismic engineering requirements are based on the United States of America's Uniform Building Code-1991. A more realistic simulation of structural behaviour has been made possible, especially by the wide availability of technological innovations.

1.2 SIGNIFICANCE

In the last few decades, Bangladesh has experienced many demolishing earthquakes. The occurrence of earthquakes is not evenly distributed in Bangladesh. Earthquakes occur irregularly in Bangladesh, though there are frequent earthquakes in the northeastern region of Bangladesh.

During an earthquake, at weak points, structure collapse begins. Based on the discontinuity of mass and stiffness of the system, the vulnerability develops. It is entitled to discontinuity as abnormal structures. Depending on their mass, strength and stiffness, the irregularity in the construction systems can be irregular distributions along with the height of the house. Irregularity is one of the key causes of structure collapses during earthquakes today. The plan irregularity is characterized by the position of the resistant elements such as walls, columns, floor structures, mass etc. and geometric structure. There are two categories of irregularities: plan irregularity and vertical irregularity. In the distribution of mass, rigidity and power, vertical irregularities are denoted by vertical discontinuities.

1.3 RESEARCH OBJECTIVES

This study aim is to analyze on earthquake response of R.C.C multi-storeyed building frames according to BNBC-1993. The specific objectives of the introduced study are as follows:

- To conduct a comparative seismic research study in various zones with a view to studying the usefulness of the seismic analysis.
- To assess the base shear for the construction of a building by the multiple seismic zones by using ETABS software.
- To research the change in various parameters of seismic response due to Different Seismic Zone of buildings.
- To evaluate-base shear and storey drift of buildings in different seismic zone.
- To evaluate maximum deflection and column rebar percentage for Different Seismic Zone of buildings.
- In order to determine the level of seismic performance, the performance of selected frame structure buildings construction in compliance with the code requirements will be analyzed.
- To compare the charts and graphs in order to draw a conclusion regarding various building areas.

1.4 OUTLINE OF METHODOLOGY

The thesis dissertation was induced by the analysis of seismic provisions of the Bangladesh National Building Code 1993 in the methodology of the thesis to achieve the above-selected objectives. The concept has been completed with ETABS software and variations have been listed below.

- ❖ Frame section are categorised by beam and column.
- ❖ Buildings have varying features, such as 8 and 12 storey buildings using f'c value is 3.5 ksi, 14 and 16 storey buildings using f'c value is 4 ksi.
- ❖ The slab has various features, such as a membrane thickness of 150 mm and a bending thickness of 125 mm.

- ❖ As the beam used 87.5 mm and the column used 62.5 mm, the building frame properties of the transparent cover differ.
- ❖ The height of the beams is the same as a section in each storey.
- ❖ The soil site factor is same in each building in every zone.
- ❖ The same plan area in each building. And the slab thickness is also the same.
- ❖ The height of typical storey is the same in every building.
- ❖ The Structure Importance Coefficients is same in each building.
- ❖ The structural system is Intermediate moment resisting frames (IMRF), concrete. And the Response Modification Factor is the same of each building in every zone.
- ❖ The Seismic Zone Coefficient will vary in Different Seismic Zone for analysis.

CHAPTER-02

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 BACKGROUND STUDY

The BNBC-1993 work for common and unique buildings in multi-storey residential buildings was carried out by Sabbir Siddique (2006). The scope behind the work was to learn how the National Building Code of Bangladesh is used for the design of various building components. Surwase et al. (2018) conducted the work for normal and unusual buildings in G+4 multi-storey residential buildings in line with IS 1893-2002 and IS 1893-2016 seismic load guidelines in Zone III & IV. The scope behind the work was to understand how the related Indian Standard codes are used in Etabs for the construction of different building elements.

In order to research the effect of the building sequence, Panigrahi et al. (2019) conducted an experimental study on a functional structure. In order to research the effect of beam and column with different structural specifications, construction of three different heights was considered. The proportion of wind and seismic forces developed at each floor level due to changes in vertically irregular structures was investigated by Rahman and Salik (2018). In order to calculate the structural response in the form of storey response, such as shear, displacement and drift, static analysis and dynamic analysis were used.

2.3 EARTHQUAKE LOAD PARAMETERS DUE TO BNBC 1993

The real earthquake displacement of the individual construction site is more complex than the simple motion waveform. Earthquake refers to an equally dynamic way of vibrating the earth when waves of varying frequencies and intensity interconnect with each other.

The earthquake movement's seismic waves were not always of a single type. These waves travel through the fault to the construction site and are changed by the media by which they pass through the soil and rock. They experience more changes as the seismic waves hit the construction site, based on the properties of the soil and soil in the lower part of the building. The key element alluded to is the cause, direction and local side effects.

2.3.1 EARTHQUAKE LOAD

In 1993, the Housing and Construction Research Institute released the Bangladesh National Building Code. The Code specifies a basic procedure for static analysis by Equivalent Static Force Method to describe earthquake-induced inertia forces.

The load from the earthquake is a complex load. A building vibrates and loads on the building for the earthquake load, and its strength and position have depended on the model's form. For the measurement of seismic forces, this approach could be used and the static earthquake effect is represented.

2.3.2 SEISMIC ZONE FACTOR

Based on the magnitude of the probable strength of seismic ground motion and damage, the seismic zoning map of Bangladesh has been subdivided into three seismic zones, such as Zone 1, Zone 2 and Zone 3. The most extreme one is Zone 3.

Based on the location of the site on the Seismic Zoning Map, the seismic zone for the construction site has been determined. A Seismic Zone Coefficient, Z, has been assigned to each building or structure. The values of this coefficient are assumed to reflect the effective apex ground acceleration manifested as a fraction of the acceleration due to gravity. The table below displays the values of Bangladesh's zone coefficients.

Table 2.1: Seismic Zone Coefficient

Seismic Zone	Zone Coefficient, Z
1	0.075
2	0.15
3	0.25

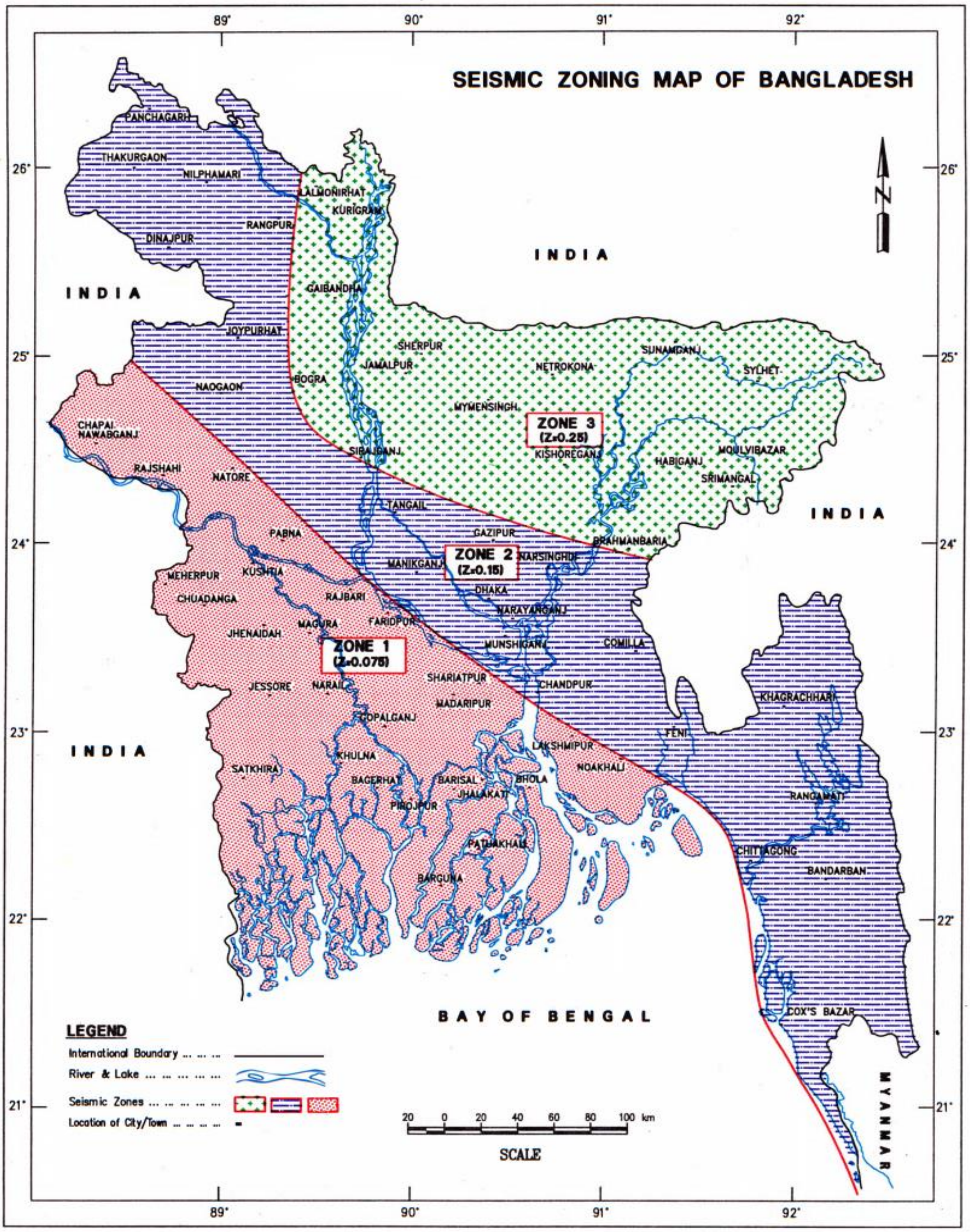

Figure 2.1: Seismic Zoning Map of Bangladesh Due to BNBC-1993

2.3.3 BASE SHEAR

The total design base shear in a given direction has determined from the following relation-

$$V = \frac{ZIC}{R} W$$

Where,

Z	=	Seismic zone coefficient
I	=	Structure importance coefficient
R	=	Response modification coefficient
W	=	The total seismic dead load
C	=	Numerical coefficient

2.3.4 NUMERICAL COEFFICIENT

This coefficient refers to the elementary period of the building and soil property of the building site.

C is calculated by the relation of

$$C = \frac{1.25S}{T^{2/3}}$$

Where,

S is the site coefficient for soil characteristics as provided at Table 6.2.25 in BNBC-1993. T is the fundamental period of the building.

2.3.5 TIME PERIOD

The core structure time period is just the reverse of the recurrence of the structure at which it has to vibrate as a form of alarming effect in building architecture gets underway, typically a seismic potential depending on the mass and firmness characteristics of the system. As the code-based architecture spectrum shows greater rising speeds at shorter intervals, systems with shorter main periods draw in higher seismic forces. The fundamental period the building buildings the value of T may be approximated by the following relation-

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

Where,

- C_t = 0.083 for steel moment-resisting frames
- C_t = 0.073 for reinforced concrete moment resisting frames, and eccentrically braced steel frames
- C_t = 0.049 for all other structural systems
- h_n = Height in metres above the base to level n.

2.3.6 STRUCTURAL IMPORTANCE FACTOR

The lateral force of the earthquake is compounded by a metric called the Building Significance Coefficient which is built for a higher force level such that after an earthquake, the probability of those buildings being undamaged remains higher. This is a significant coefficient that takes the value of the building into account for post-earthquake events. It is labelled I. From the experience of previous earthquakes, this coefficient is applied as a major installation is overthrown.

Table 2.2: Structure Importance Categories

Structure Importance Category	**Occupancy Type or Functions of Structure**	
	General	**Particular**
I	Essential Facilities	1) Hospital and other medical facilities having surgery and facilities emergency treatment area. 2) Fire and police stations. 3) Tanks or other structures containing housing or supporting water or other fire-suppression materials or equipment required for the protection of essential or hazardous facilities, or special occupancy structures. 4) Emergency vehicle shelters and garages.

		5) Structures and equipment in emergency preparedness centres, including cyclone and flood shelters. 6) Standby power-generating equipment for essential facilities. 7) Structures and equipment in government communication centres and other facilities required for emergency response.
II	Hazardous Facilities	Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released.
III	Special Occupancy Structures	1) Covered structures whose primary occupancy is public assembly with capacity > 300 persons. 2) Buildings for schools through secondary or day care centres with capacity > 250 students. 3) Buildings for colleges or adult education schools with capacity > 500 students. 4) Medical facilities with 50 or more resident incapacitated patients, not included above. 5) Jails and detention facilities. 6) All structures with occupancy> 5,000 persons. 7) Structures and equipment in power- generating stations and other public utility facilities not included above, and required for continued operation.
IV	Standard Occupancy Structures	All structures having occupancies or functions not listed above.
V	Low risk Structures	Buildings and Structures that exhibit a low risk to human life and property in the event of failure, such as agricultural.

Table 2.3: Structure Importance Coefficients l & l' Due to BNBC 1993

Structure Importance Category Coefficient	**Structure Importance Coefficient I**	**Structure Importance Coefficient I'**
• Essential facilities	1.25	1.50
• Hazardous facilities	1.25	1.50
• Special occupancy structures	1.00	1.00
• Standard occupancy structures	1.00	1.00
• Low-risk Structures	1.00	1.00

2.3.7 RESPONSE REDUCTION FACTOR

This aspect relies on the form of structure, properties and ductility. It is essentially dependent on the success in former earthquakes of comparable structures. This element is denoted by R and helps to reduce and separate the earthquake energy. It is responsible for the potential of the building during the earthquake to withstand inelastic deformation.

Table 2.4: Response Modification Factor

Basic Structural System	**Description of Lateral Force Resisting System**	**R**
Bearing Wall System	❖ Light framed walls with shear panels • Plywood walls for structures, 3 storeys or less • All other light framed walls	 8 6
	❖ Shear walls • Concrete • Masonry	 6 6

	❖ Light steel framed bearing walls with tension only bracing	4
	❖ Braced frames where bracing carries gravity loads • Steel • Concrete • Heavv timber	 6 4 4
Building Frame System	❖ Light framed walls with shear panels • Plywood walls for structures, 3 storeys or less • All other light framed walls	 10 9
	❖ Shear walls • Concrete • Masonry	 7 8
	❖ Light steel framed bearing walls with tension only bracing	8
	❖ Braced frames where bracing carries gravity loads • Steel • Concrete • Heavv timber	 8 8 8
Moment Resisting Frame System	❖ Special moment resisting frames (SMRF) • Steel • Concrete	 12 12
	❖ Intermediate moment resisting frames (IMRF), concrete	8
	❖ Ordinary moment resisting frames (OMRF) • Steel • Concrete	 6 5

Dual System	❖ Shear walls • Concrete with steel or concrete SMRF • Concrete with steel OMRF • Concrete with concrete IMRF • Masonry with steel or concrete SMRF • Masonry with steel OMRF • Masonry with concrete IMRF ❖ Steel EBF • With steel SMRF • With steel OMRF	12 6 9 8 6 7 12 6
	❖ Concentric braced frame (CBF) • Steel with steel SMRF • Steel with steel OMRF • Concrete with concrete SMRF • Concrete with concrete IMRF	10 6 9 6

2.3.8 SOIL FACTOR

Described in BNBC 1993 as the site coefficient. The measure of intensification of ground motion relies on soil wave proliferation characteristics, which can be evaluated from shear wave velocity estimates. Delicate soils with slower and broader shear wave velocities yield more notable intensification than firm soils with higher shear wave velocities.

Table 2.5: Site Soil Characters & Soil Factor Due to BNBC 1993

Site Soil Characteristics		
Type	**Description**	**Coefficient S**
S1	A soil profile that requires either: (a) A rock-like material characterized by a shear wave velocity greater than 762 m/s or by other suitable means of classification. (b) Stiff or dense soil condition where the soil depth is less than 61 metres.	1.0
S2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 61 metres.	1.2
S3	A soil profile 21 metres or more in-depth and containing more than 6 metres of soft to medium stiff clay but not more than 12 metres of soft clay.	1.5
S4	A soil profile containing more than 12 metres of soft clay characterized by a shear wave velocity less than 152 m/s.	2.0
Note: The site coefficient is calculated on the basis of duly substantiated geotechnical evidence. Soil profile S3 can be used in areas where the soil properties are not defined in adequate depth to establish the form of the soil profile. It is not appropriate to presume the S4 soil profile until the building officer decides that the S4 soil profile might be present at the site or whether the S4 soil profile is calculated by geotechnical data.		

2.4 SEISMIC WEIGHT

This is the building's seismic weight that is shared in the building's earthquake response. This is the overall dead load of the building or structure, including the permanent partitions, and the applicable parts of other loads, such as the storage and factory buses, have been subject to a minimum of 25% of the floor living load. In compliance with the floor plan, the load is included in the partition, all other loads but not less than 0.6 KN/m^2 have been added, and the complete weight of the permanent equipment has been included.

2.5 LOAD COMBINATION

The building's reaction to ground motion is as complicated as the ground motion itself, but usually very separate. The movements of the house, however, prefer to centre around one unique frequency, which is known as its normal frequency. The normal frequency is a function of the system's mass and stiffness.

Building materials facilitating their use in proportioning structural members by the permitted stress design & strength design have been protected by the provisions of this section. All loads listed herein have been assumed to function in the following combinations when this approach is used in designing structural members. In the design, the mixture that creates the most unfavourable result was used.

Table 2.6: Load Combinations

Combinations of Loads for Allowable Stress Design	Combinations of Loads for Strength Design
• D • D + L • D + 5 • D + E • 0.9D + E • D + (H or F) • D + L + (H or F) • D + 5 + L • D + 5 + E • D + L + E • D + L + (H or F) + E • D + 5 + L + (H or F) + E	• 1.4D • 1.4D + 1.7L • D + 1.4 [S] • 0.9D + 1.3 (1.1E) • 0.9D + 1.7 (H or F) • 1.4D + 1.7L + 1.7 (H or F) • 0.75 [1.4D + 1.45 + 1.7L] • 0.75 [1.4D + 1.45 + 1.7 (1.1E)] • 0.75 [1.4D + 1.7L] • 0.75 [1.4D + 1.7L + 1.7 (H or F) + 1.7 (1.1E)] • 0.75 [1.4D + 1.45 + 1.7L + 1.7 (H or F) + 1.7 (1.1E)] • 1.4 (D+L+E)

Where,

D = Dead Load

(a) the weight of the members themselves,

(b) weight of all building materials

Integrated into the house, with built-in partitions, to be permanently sponsored by the member,

(c) the permanent apparatus weight.

E = Earthquake Load

F = Loads due to fluids with well-defined pressures and maximum heights, including loads due to water pressure during the flood and surge.

H = Loads due to weight and lateral pressure of soil and water in the soil.

$L = L_f + (L_r \text{ or } P)$

L_f = Live loads due to intended use and occupancy, including loads due to movable objects and movable partitions and loads temporarily supported by the structure during maintenance. It includes any permissible reduction. If resistance to impact loads is taken into account in the design, such effects have been included with the live loads L_f.

L_r = Roof live loads

P = Loads due to initial rainwater ponding.

R = Seismic coefficient.

S = Self-straining forces and effects arising from contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential the settlement, or combinations thereof.

CHAPTER-03

MODELLING AND ANALYSIS

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 PLAN AREA

There are tens panel on each floor, dimensions of each span 8 m by 5 m. i.e. 8 m along the X direction and 5 m along the Y direction. Therefore, in this study, the building models analyzed usually have floor areas in this range.

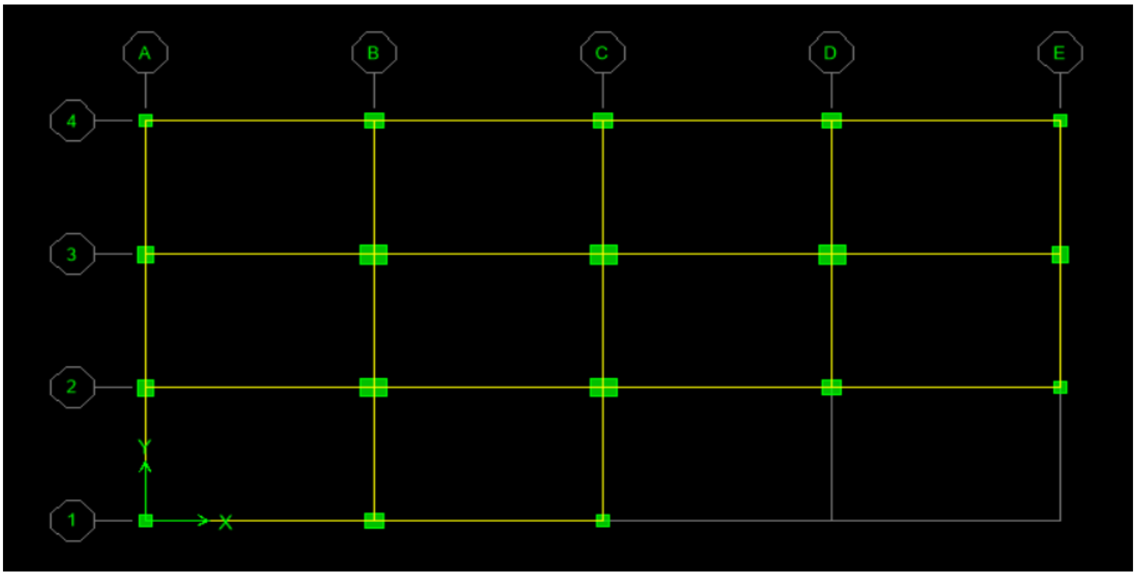

Figure 3.1: Plan Layout

3.3 FLOOR SYSTEM

As the concrete building will be analyzed, the slab is concrete and is considered by 150 mm for membrane and 125 mm bending for each building. In the plane of the intersection, the concrete slab profiled has meshed manually to a suitable rectangular form.

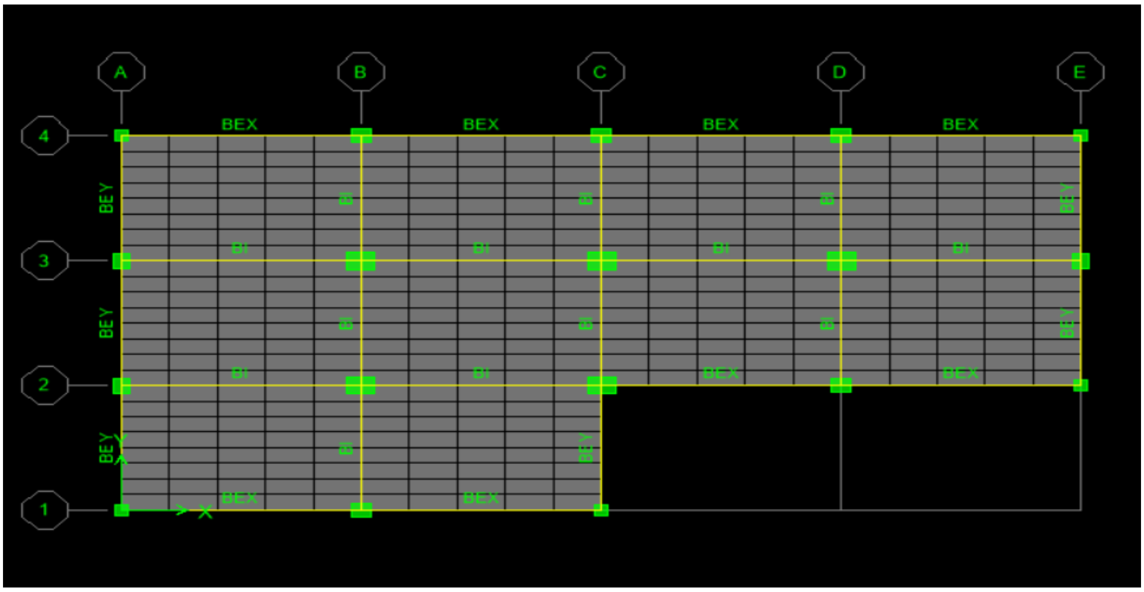

Figure 3.2: Concrete profile and mesh for the Slab

3.4 NUMBER OF STOREY AND FLOOR HEIGHT

Buildings of 8, 12, 14 and 16 floors have been considered in three seismic areas in the latest report. For each span of 8 m by 5 m, gross (8 m x 5 m) x 10 = 400 m^2, the plan area of each floor was used for all twelve building heights in the three seismic areas of the building. With the usual plumbing and vent specifications for air conditioning, etc., the floor-to-floor height was assumed to be 3.60 m. The approximate heights of the 8, 12, 14 and 16-storey buildings of each building are 32.4 m, 46.8 m, 54 m and 61.2 m from base to top, respectively.

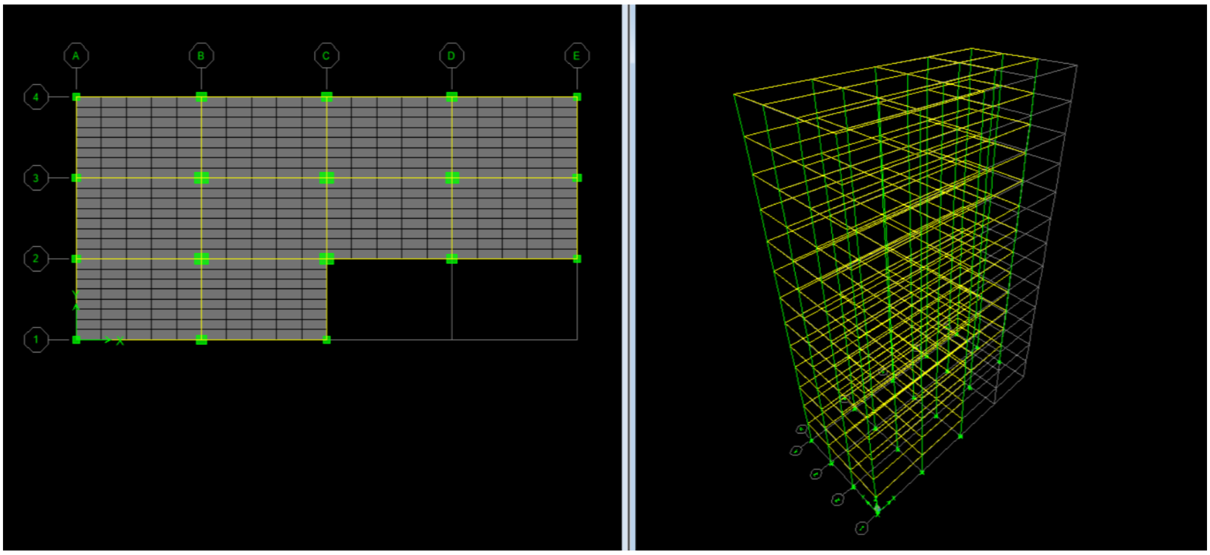

Figure 3.3: 3D view of the ETABS 12-storey RCC building

3.5 STRUCTURAL SYSTEM

The basic casing applies to the heap against a building or structure sub arrangement. The fundamental structure transfers elements or entities in interconnected stacks. In order to recognize the BNBC 1993, the three-zone includes the IMRF for R.C.C structures which we considered for this analysis. The Design Modification Factors are listed in Table 2.4 in this paper.

3.6 MATERIAL PROPERTY

Concrete and rebar are the primary building materials for the reinforced concrete structure. Below are the properties of the substance used for modelling.

Table 3.1: Material Properties of R.C.C Building

Material Properties of R.C.C Building		
Number of Storey	Compressive Strength, **f_c'** (MPa) For Concrete	Yield Strength, **f_y** (MPa) For Steel (Deformed bar)
8	24.13	413.685
12	24.13	413.685
14	27.58	413.685
16	27.58	413.685

3.7 FINITE ELEMENT ANALYSIS

The supplementary review approach profoundly impacts the current building design as far as defence and economy are concerned. Depending on the form of venture, there are several proven approaches, including, perhaps, the general advanced and generally inclusive Finite Element Method (FEM). For this research, unbelievable and well known ETABS (Extended Three Dimensional Analysis of Building System) component programming package was used for the fundamental analysis and design.

The shafts, parts and support are displayed by edge components while the shell components represent the floorboards, rooftops and parts. Both centre points were limited to interpretation at the base level. A 3D viewpoint has emerged for the 16-storey model for the solid structure.

3.8 STRUCTURAL DIMENSION OF BUILDINGS

There are total twelve residential buildings and four buildings in each zone. The building is the immediate moment-resisting frame. It is fixed at its support at 3.6 m below the existing ground level. Slab thickness of 150 mm for membrane and 125 mm for bending for all floor. Clear cover to re-bar centre of 62.5 mm for column and 87.5 mm for the beam. Typical floor height is 3.6 m at the ground floor for parking. Other structural dimensions are given below

Table 3.2: Structural Dimension of Zone 1

No. of Storey	Column (mm)				Beam (mm)		
	CC	CEX	CEY	CI	BEX	BEY	BI
8	450x450	450x450	450x450	475x650	450x475	350x375	350x375
12	450x450	500x575	475x550	650x825	475x475	375x375	375x400
14	450x450	500x625	500x575	675x825	475x475	350x375	375x375
16	425x425	575x625	600x550	700x925	450x475	350x375	375x375

Table 3.3: Structural Dimension of Zone 2

No. of Storey	Column (mm)				Beam (mm)		
	CC	CEX	CEY	CI	BEX	BEY	BI
8	450x450	475x450	450x450	475x650	450x475	350x375	375x400
12	450x450	525x650	475x550	650x825	475x475	375x375	375x400
14	450x475	525x700	500x575	675x825	475x475	350x375	375x400
16	500x475	575x725	550x575	700x925	450x475	350x375	375x400

Table 3.4: Structural Dimension of Zone 3

No. of Storey	Column (mm)				Beam (mm)		
	CC	CEX	CEY	CI	BEX	BEY	BI
8	450x450	500x550	450x475	550x700	450x475	350x375	400x400
12	500x575	600x775	500x675	700x900	475x475	400x425	425x425
14	525x525	625x850	575x600	725x875	475x475	400x400	425x450
16	525x550	750x850	650x625	750x900	450x475	400x400	450x475

Where,

CC = Corner column

CEX = Exterior column in X-direction

CEY = Exterior column in Y-direction

CI = Interior column

BEX = Exterior beam in X-direction

BEY = Exterior beam in Y-direction

BI = Interior beam

3.9 LOADING ANALYSIS

The seismic complexity of earthquake ground motion is attributed to not every wave generated at the time of the earthquake fault was of a uniform nature, because these waves shift the earth from a fault to the construction site, they change the surface and rock media they migrate through and as the seismically adjacent waves enter the construction site, they undergo additional changes depending on the properties of the soil.

3.10 GRAVITY LOAD ANALYSIS

Structures are examined for gravity loads and planned such as dead loads and live loads. Dead loads include building frame and shell part self-weight, floor finish, section divider and other very forced loads. Live loads comprise all transitory burdens added during building construction. The following are very coerced deaths and live loads used for the test.

Live Load = 3 KN/m^2

Floor Finish = 1.5 KN/m^2

Partition Wall = 2.5 KN/m^2

3.11 BNBC 1993 EARTHQUAKE LOAD PROVISION

There are separate provisions in the Bangladesh National Building Code (BNBC) for the measurement of earthquake loading and the theoretical methods for earthquake structures. In BNBC, the preferable methods for seismic lateral forces determination in primary framing systems are available.

The total design Base Shear in a given direction has determined from the following relation-

$$\mathbf{V} = \frac{ZIC}{R}\mathbf{W}$$

Where,

Z	=	Seismic zone coefficient
I	=	Structure importance coefficient
R	=	Response modification coefficient
W	=	The total seismic dead load
C	=	Numerical coefficient

This coefficient refers to the elementary period of the building and soil property of the building site. C is calculated by the relation of

$$\mathbf{C} = \frac{1.25S}{T^{2/3}}$$

Where,

S is the site coefficient for soil characteristics as provided at Table 6.2.25 in BNBC-1993. T is the fundamental period of the building.

$$\mathbf{T = C_t (h_n)^{3/4}}$$

Where,

C_t = 0.083 for steel moment-resisting frames

C_t = 0.073 for reinforced concrete moment resisting frames, and eccentrically braced steel frames

C_t = 0.049 for all other structural systems

h_n = Height in metres above the base to level n.

3.12 EARTHQUAKE LOAD ANALYSIS

This study offers a strong indicator of the structure's reaction, but it does not forecast processes of failure and account for the allocation of forces for earthquake excitation during progressive yield. The final value is needed and the demand curve with ETABS has been generated as a performance point of any structure and got below output.

Output of base shear of storey in different seismic zone by ETABS

Table 3.5: Base Shear of Storey in Different Seismic Zone

No. of Storey	Base Shear, V (KN) Zone 1	Base Shear, V (KN) Zone 2	Base Shear, V (KN) Zone 3
8	631.23	1274.51	2161.51
12	795.61	1598.75	2794.64
14	851.93	1727.40	3028.75
16	919.37	1863.42	3298.77

The output of maximum deflection of storey in different seismic seismic zone are found by ETABS

Table 3.6: Maximum Deflection within Different Seismic Zone

No. of Storey	Zone 1		Zone 2		Zone 3	
	X-Direction (mm)	Y-Direction (mm)	X-Direction (mm)	Y-Direction (mm)	X-Direction (mm)	Y-Direction (mm)
8	41.247674	52.025043	77.261494	92.640176	116.773131	141.107601
12	62.104065	78.573264	121.093676	155.125530	174.513618	189.797356
14	82.444913	115.183964	151.449748	200.959984	212.985654	232.217658
16	103.479402	138.361553	188.687375	244.526470	250.701668	254.327122

The output of storey drift for Earthquake Load in X and Y-Direction are found by ETABS

Table 3.7: Storey Drift (8 Storey) for Earthquake Load of Different Seismic Zone

Storey Drift	Zone 1		Zone 2		Zone 3	
	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
S1	0.000935	0.001166	0.001798	0.002103	0.002518	0.002994
S2	0.00165	0.002057	0.003102	0.003665	0.004563	0.00547
S3	0.001765	0.0022	0.0033	0.003909	0.004983	0.005956
S4	0.001703	0.002134	0.003192	0.003782	0.004874	0.00581
S5	0.001559	0.001955	0.002922	0.003484	0.004468	0.005373
S6	0.001362	0.001716	0.002536	0.00306	0.003886	0.00471
S7	0.001122	0.001429	0.002095	0.00255	0.003209	0.0039
S8	0.000844	0.001088	0.001583	0.001923	0.002424	0.002994
S9	0.000571	0.000723	0.001043	0.001296	0.001652	0.002055

Table 3.8: Storey Drift (12 Storey) for Earthquake Load of Different Seismic Zone

Storey Drift	Zone 1		Zone 2		Zone 3	
	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
S1	0.000773	0.000972	0.001447	0.001926	0.001923	0.002245
S2	0.001496	0.001882	0.002884	0.003705	0.003943	0.004461
S3	0.001785	0.002215	0.003457	0.004339	0.004862	0.005294
S4	0.001835	0.002264	0.003564	0.004485	0.005137	0.005494
S5	0.00181	0.002239	0.003534	0.004424	0.005127	0.005428
S6	0.00173	0.002147	0.003379	0.004253	0.00496	0.005219
S7	0.001621	0.00203	0.003156	0.004022	0.004653	0.004907
S8	0.001481	0.00187	0.002903	0.003705	0.004235	0.004535
S9	0.001321	0.001679	0.002593	0.003339	0.00379	0.004089
S10	0.001147	0.001483	0.002243	0.002925	0.003288	0.003599
S11	0.000952	0.001255	0.001864	0.002474	0.002759	0.003019
S12	0.000753	0.001003	0.001466	0.001962	0.002187	0.002468
S13	0.000569	0.000763	0.001107	0.001499	0.0017	0.001829

Table 3.9: Storey Drift (14 Storey) for Earthquake Load of Different Seismic Zone

Storey Drift	Zone 1		Zone 2		Zone 3	
	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
S1	0.000785	0.001103	0.001537	0.001976	0.001919	0.002133
S2	0.00165	0.002245	0.003032	0.004019	0.004089	0.004531
S3	0.001986	0.002719	0.00367	0.004763	0.005063	0.005434
S4	0.002094	0.002859	0.003848	0.00498	0.005403	0.005729
S5	0.002095	0.00286	0.003838	0.00498	0.005432	0.00573
S6	0.002055	0.002805	0.003764	0.004885	0.005344	0.005667
S7	0.001963	0.002712	0.003618	0.004722	0.005137	0.005434
S8	0.001855	0.002572	0.003398	0.004479	0.004842	0.005169
S9	0.001713	0.002401	0.003158	0.004195	0.004473	0.004858
S10	0.001576	0.002215	0.002886	0.003856	0.004104	0.004468
S11	0.001406	0.001997	0.002572	0.003491	0.003661	0.004048
S12	0.001229	0.001756	0.002248	0.003058	0.003189	0.003581
S13	0.00103	0.0015	0.001903	0.002626	0.002701	0.003083
S14	0.000825	0.001243	0.001516	0.002124	0.002155	0.002522
S15	0.000637	0.000979	0.001161	0.001678	0.001683	0.001977

Table 3.10: Storey Drift (16 Storey) for Earthquake Load of Different Seismic Zone

Storey Drift	Zone 1		Zone 2		Zone 3	
	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
S1	0.00083	0.001122	0.001505	0.001878	0.001975	0.001972
S2	0.001697	0.00222	0.00308	0.004002	0.004117	0.004106
S3	0.002112	0.00274	0.003826	0.004898	0.005128	0.005025
S4	0.002275	0.002935	0.004148	0.005244	0.005541	0.005367
S5	0.002313	0.002992	0.004229	0.005317	0.005633	0.005456
S6	0.002301	0.002992	0.004206	0.005288	0.005602	0.00544
S7	0.00225	0.002919	0.004114	0.005173	0.005464	0.005351
S8	0.002156	0.002846	0.003941	0.005013	0.005265	0.005174
S9	0.002061	0.002707	0.003734	0.004782	0.004975	0.004952
S10	0.001936	0.002577	0.003505	0.004522	0.004684	0.004699
S11	0.001785	0.002398	0.003263	0.004248	0.004347	0.004418
S12	0.001634	0.00222	0.002965	0.003901	0.003934	0.004092
S13	0.001464	0.002024	0.002666	0.003554	0.003551	0.003736
S14	0.001295	0.001805	0.002333	0.00315	0.003077	0.003335
S15	0.0011	0.001585	0.001988	0.002731	0.002633	0.002935
S16	0.000911	0.001333	0.001643	0.002297	0.002143	0.002476
S17	0.000735	0.001065	0.001287	0.001835	0.001699	0.002016

The output of rebar percentage (%) of column in different seismic zone are found by ETABS

Table 3.11: Rebar Percentage (%) of Column in Different Seismic Zone

No. of Storey	Zone 1 (%)				Zone 2 (%)				Zone 3 (%)			
	CC	CEX	CEY	CI	CC	CEX	CEY	CI	CC	CEX	CEY	CI
8	1	2.74	2.25	3.91	1.31	3.93	2.94	3.96	2.71	4	3.72	3.91
12	1.76	3.94	3.96	3.84	3.74	3.98	3.94	3.68	3.89	4	3.77	3.84
14	2.03	3.82	3.64	3.93	3.72	3.94	3.63	3.90	3.93	3.88	3.78	3.89
16	3.58	3.94	3.96	3.86	4	3.99	3.96	3.77	3.88	3.95	3.94	3.77

CHAPTER-04

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The work is studied the effectiveness of earthquake load analysis in comparison to different seismic zone with Equivalent Static Force Method. The primary goal of the analysis is to assess the seismic quality of the different conventionally constructed seismic zone intermediate moment-resistant frames (IMRF) completely in-filled, storey condition of earthquake-loading buildings. Another purpose of this research is to define, by using ETABS software, the maximum deflection, storey drift, base shear and column rebar percentage in the different seismic performance of the building analysis. Finally, it will discuss the output of this analysis.

4.2 BASE SHEAR FOR EARTHQUAKE LOAD

Base shear is an estimate due to the seismic activity of the maximum expected earthquake force on the base of the structure. The seismic zone, earthquake force equations of the building code are calculated using.

In the figure we can see, base shear is increased when the seismic zone coefficient factor increased. In the same time base shear is proportional to the height of the building.

The Figure below displays the values in Table 3.5.

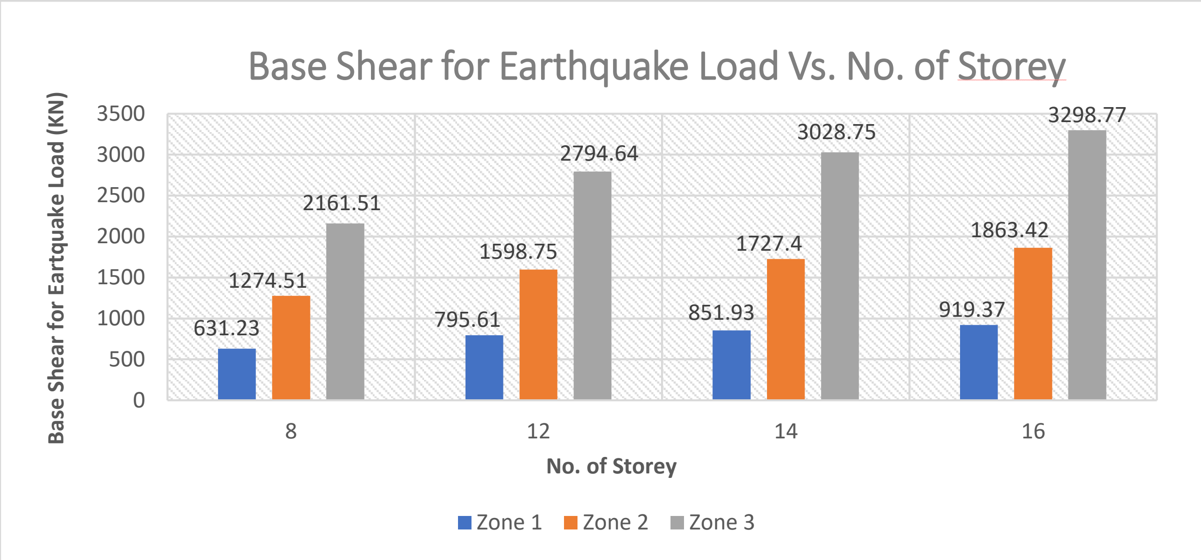

Figure 4.1: Base Shear for Earthquake Load Vs. No. of Storey

4.3 MAXIMUM DEFLECTION FOR EARTHQUAKE LOAD (X-DIRECTION)

Due to the seismic activity of the overall predicted earthquake intensity of the system, maximum deflection in the X-direction is evaluated by ETABS software. The seismic zone is measured using the building code's earthquake force equations.

We can see in the figure that, Maximum deflection is proportional to the increase of Storey No., while maximum deflection is proportional to the growth of the Seismic Zone Coefficient. When the value of the seismic zone coefficient is an increase, as for the shaking increases. Then, when the shaking is created as a result the building deflection starts automatically.

The values in Table 3.6 are shown in the figure below.

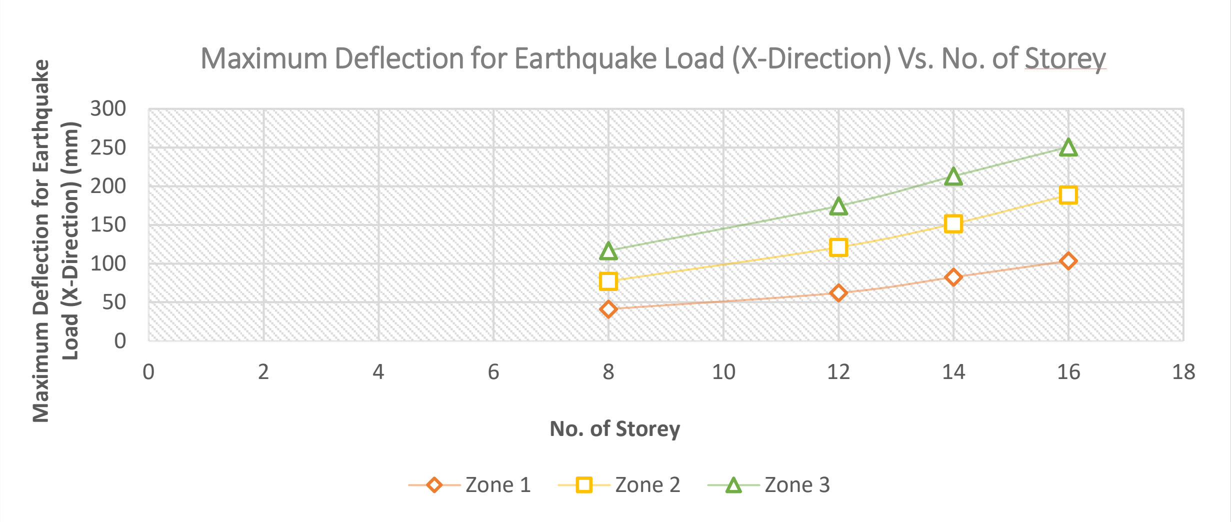

Figure 4.2: Maximum Deflection for Earthquake Load (X-Direction) Vs. No. of Storey

4.4 MAXIMUM DEFLECTION FOR EARTHQUAKE LOAD (Y-DIRECTION)

Maximum deflection in the Y-direction is evaluated by ETABS software due to the seismic activity of the generally expected earthquake strength of the system. The seismic zone is measured using the earthquake force equations of the building code.

When the seismic zone coefficient value increases as the shaking increases. The building deflection begins automatically when the shaking is produced as a result. So, in the figure, we can see, the deflection is increasing when No. of storey and seismic zone factor increases.

The following figure indicates the values in Table 3.6

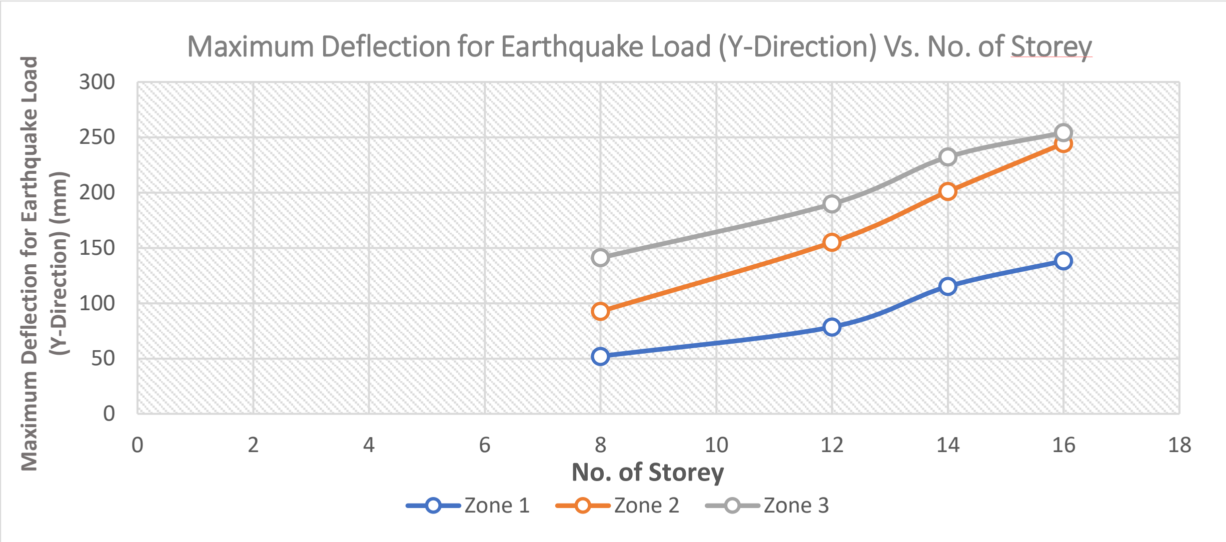

Figure 4.3: Maximum Deflection for Earthquake Load (Y-Direction) Vs. No of Storey

4.5 STOREY DRIFT

Storey drift is the displacement between two levels of storey. In this paper, storey drift is the critical part, because of the increase of seismic zone factor within storey drift. But it goes to a point to grow, then start to go down again. Each figure, we can see is the same condition of storey drift.

The values in Table 3.7 are seen in the Figure below.

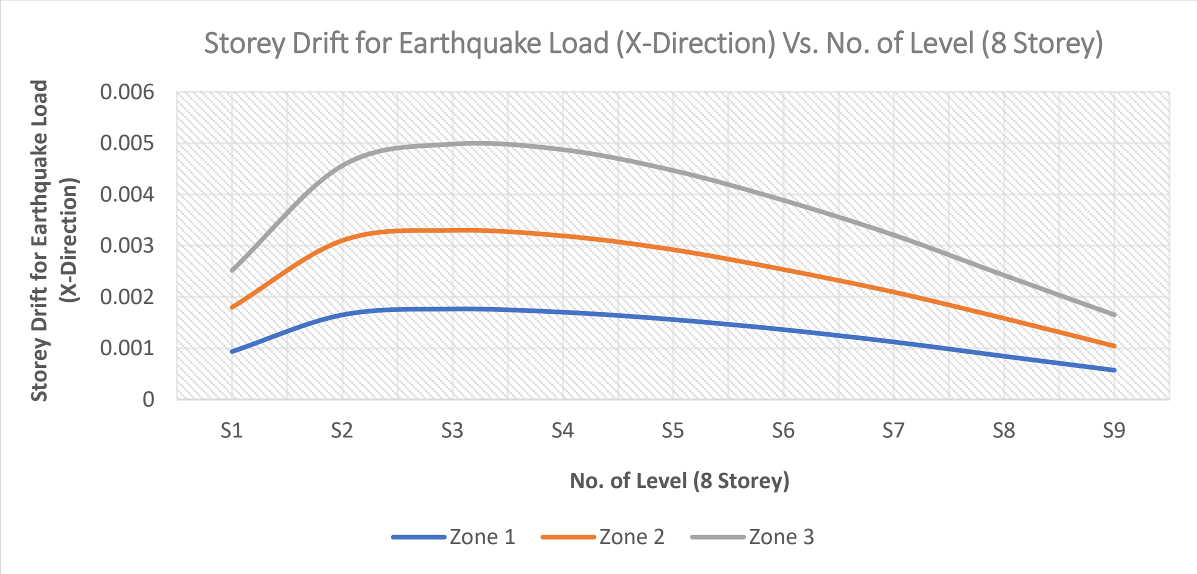

Figure 4.4: Storey Drift for Earthquake Load (X-Direction) Vs. No. of Level (8 Storey)

The following Figure indicates the values in Table 3.7

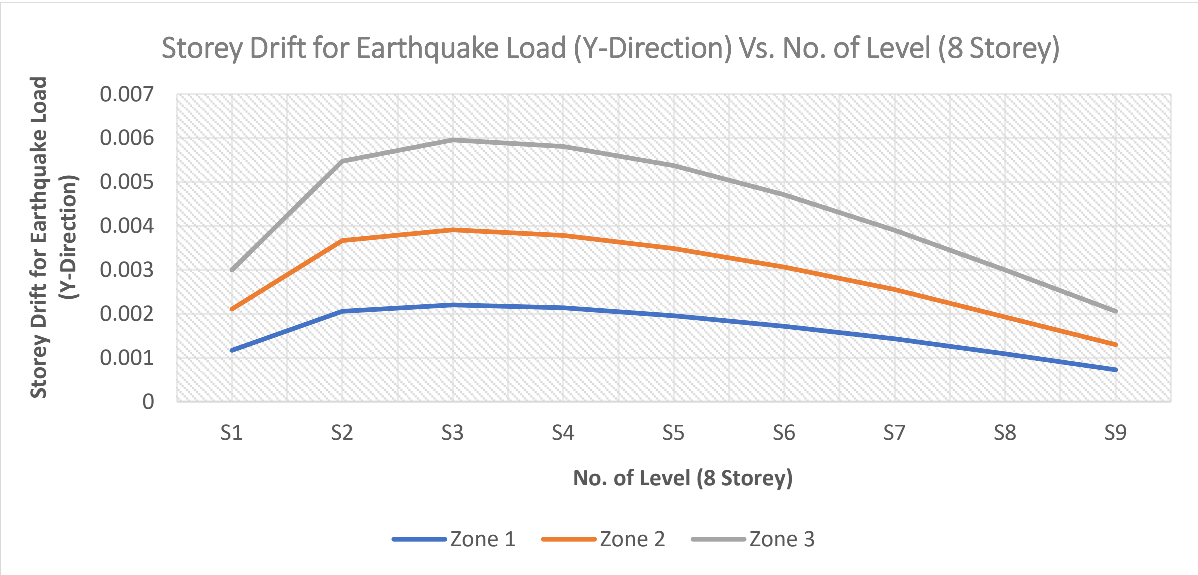

Figure 4.5: Storey Drift for Earthquake Load (Y-Direction) Vs. No. of Level (8 Storey)

The following Figure indicates the values in Table 3.8

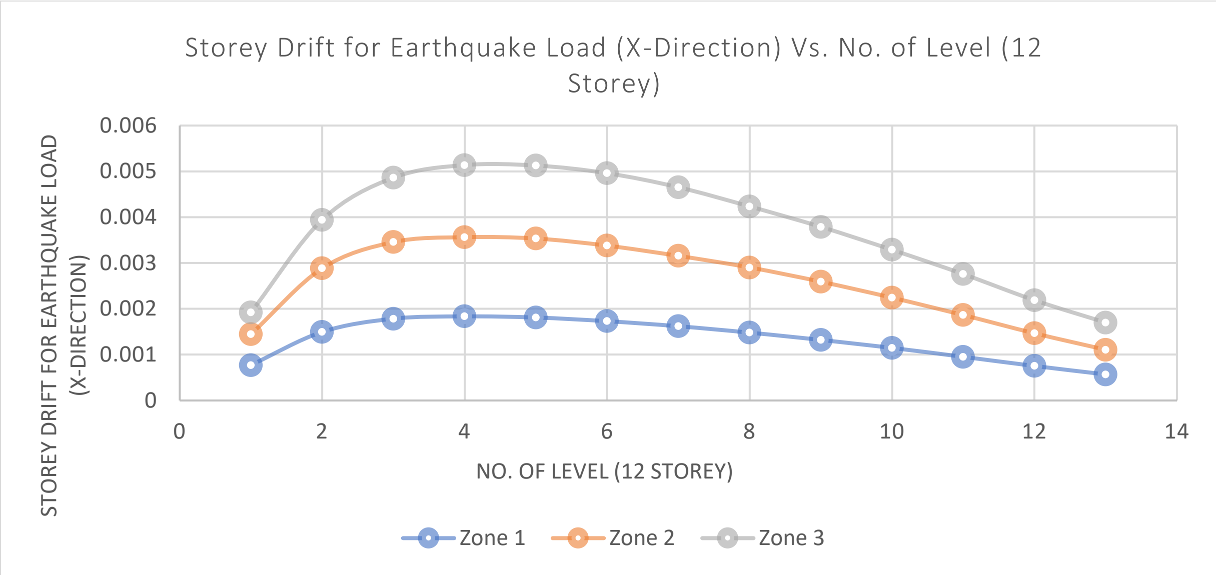

Figure 4.6: Storey Drift for Earthquake Load (X-Direction) Vs. No. of Level (12 Storey)

The following Figure indicates the values in Table 3.8

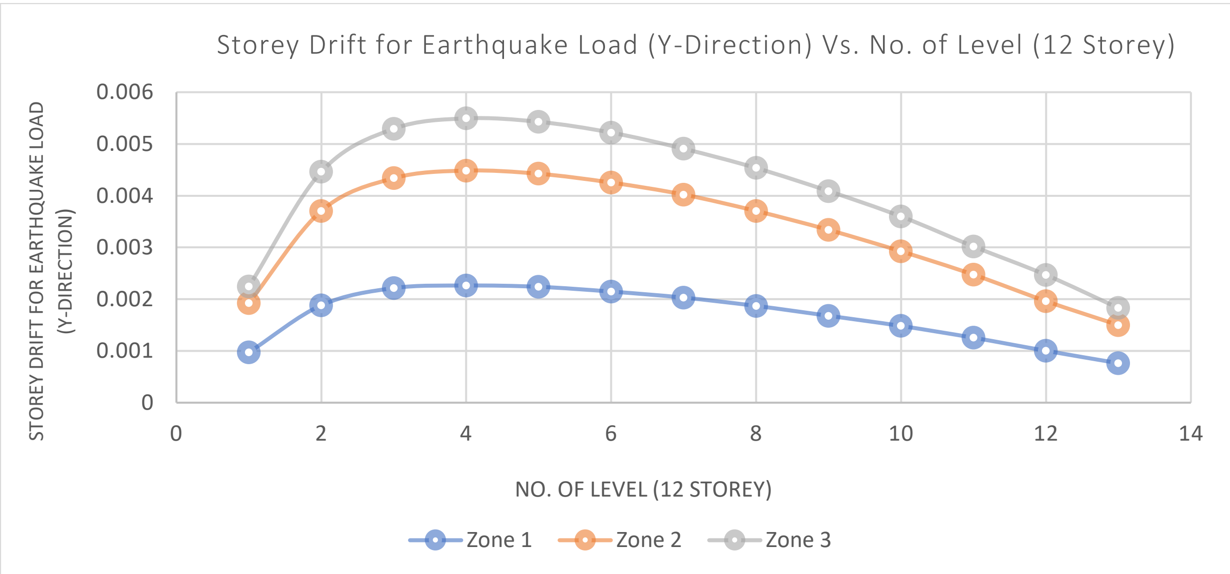

Figure 4.7: Storey Drift for Earthquake Load (Y-Direction) Vs. No. of Level (12 Storey)

The following Figure indicates the values shown in Table 3.9

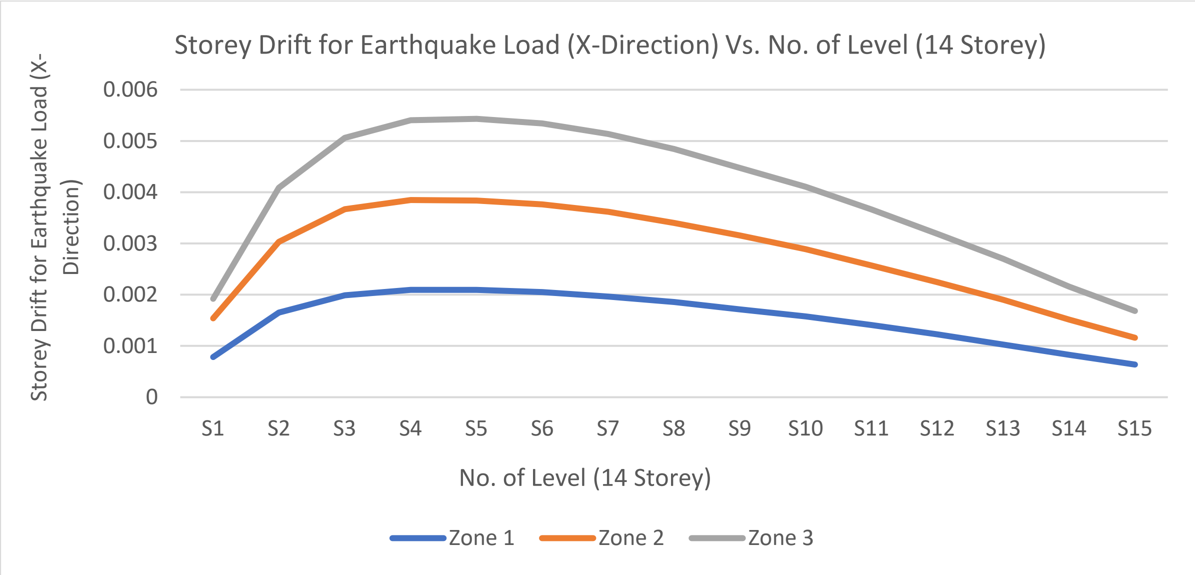

Figure 4.8: Storey Drift for Earthquake Load (X-Direction) Vs. No. of Level (14 Storey)

The following Figure indicates the values in Table 3.9

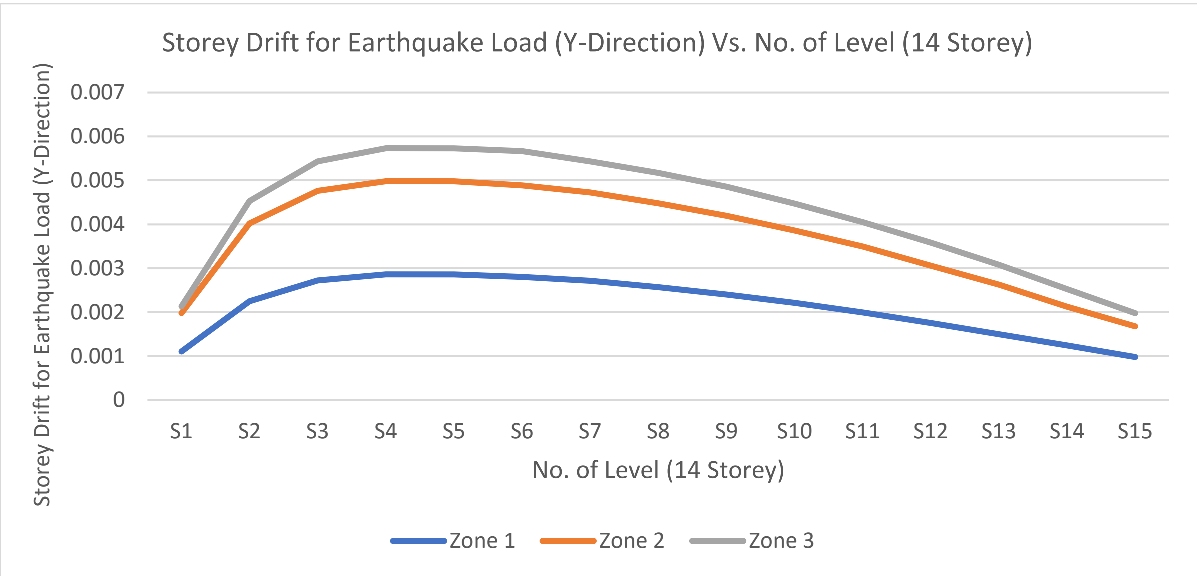

Figure 4.9: Storey Drift for Earthquake Load (Y-Direction) Vs. No. of Level (14 Storey)

The following Figure indicates the values shown in Table 3.10

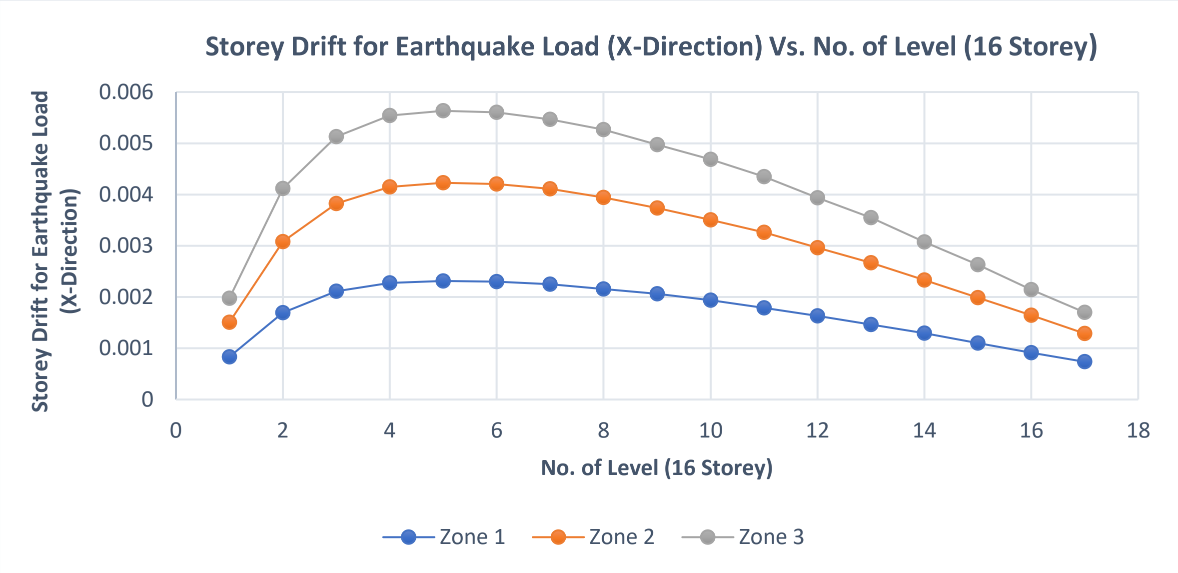

Figure 4.10: Storey Drift for Earthquake Load (Y-Direction) Vs. No. of Level (16 Storey)

The following Figure indicates the values shown in Table 3.10

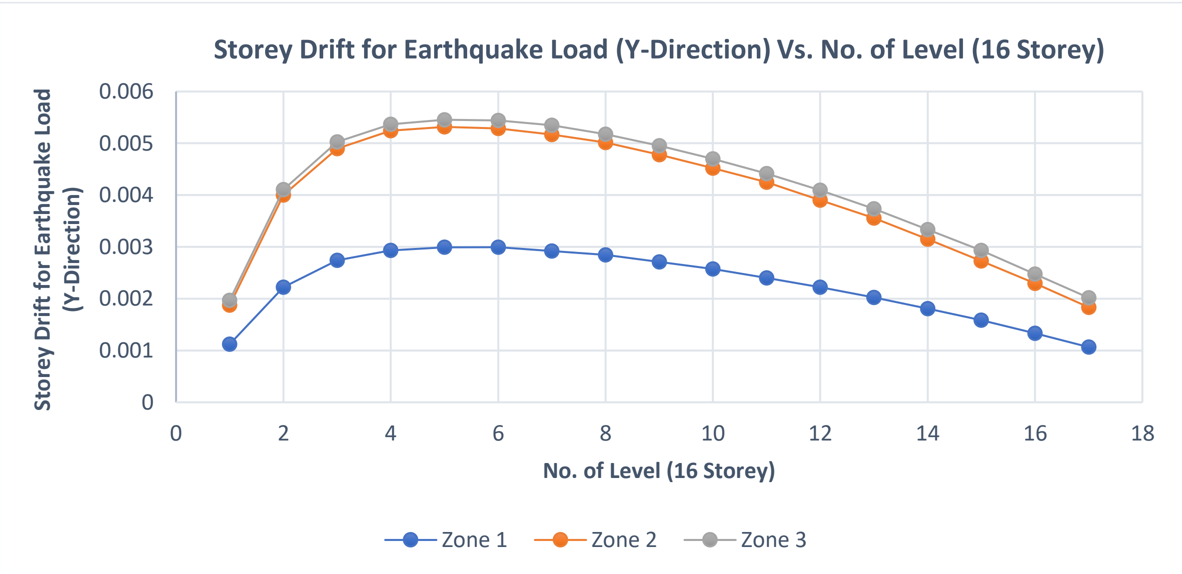

Figure 4.11: Storey Drift for Earthquake Load (Y-Direction) Vs. No. of Level (16 Storey)

4.6 COMPARISON OF REBAR PERCENTAGE (%) IN DIFFERENT TYPES OF COLUMN

Column rebar percentage is the important thing for a building, because of, if column rebar percentage is more, its dimension will less. As a result, the column will be collapse. On the other hand, if the column rebar percentage is less, the design will not good be looked. The rebar percentage is related to economics for a building. The discussion of the figures is below.

The Figure of 4.10, 4.11, 4.12 and 4.13 below displays the values in Table 3.2, 3.3 and 3.4.

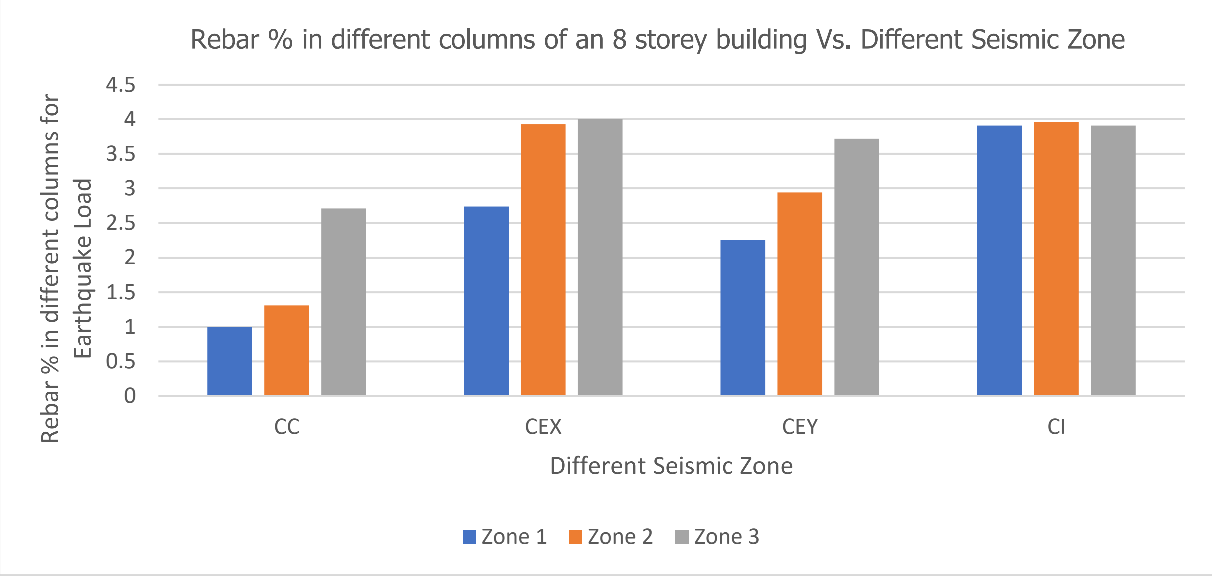

Figure 4.12: Rebar % in different columns of an 8 storey building Vs. Different Seismic Zone

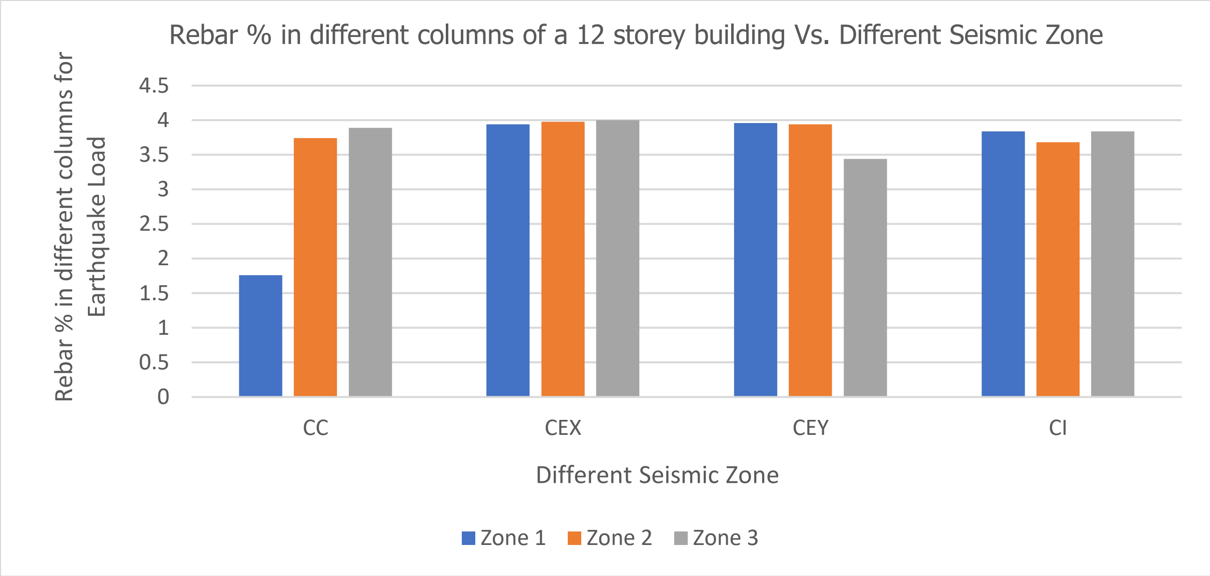

Figure 4.13: Rebar % in different columns of a 12 storey building Vs. Different Seismic Zone

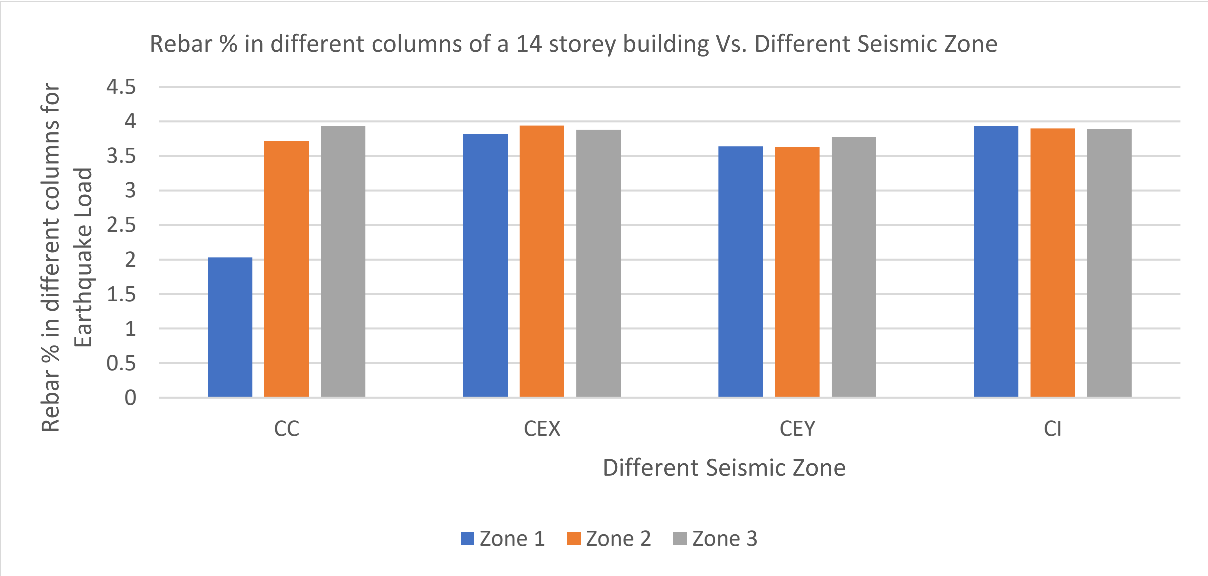

Figure 4.14: Rebar % in different columns of a 14 storey building Vs. Different Seismic Zone

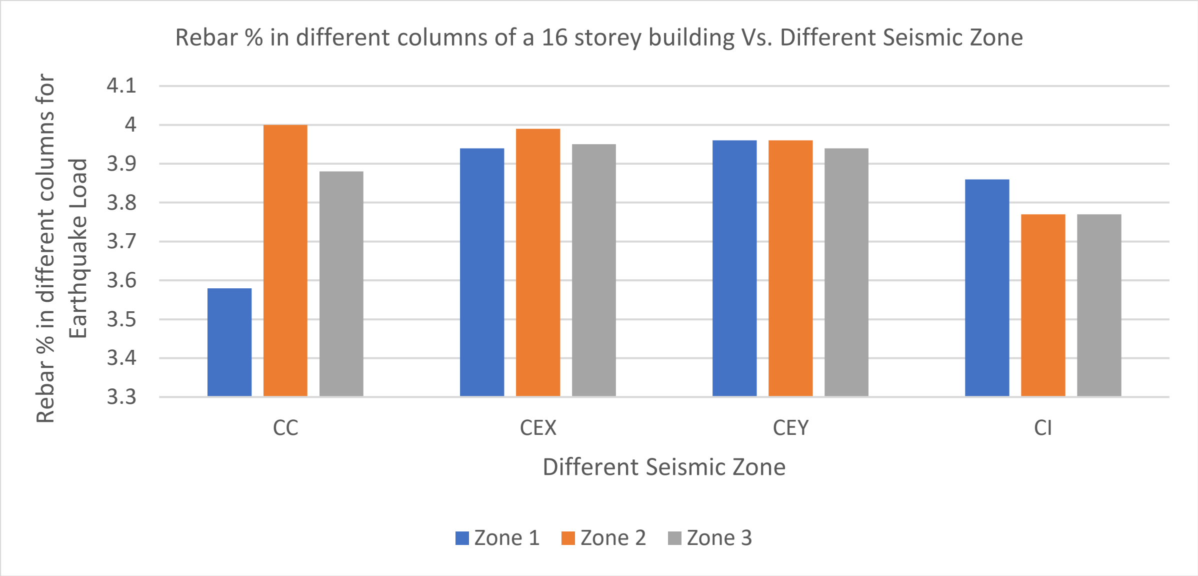

Figure 4.15: Rebar % in different columns of a 16 storey building Vs. Different Seismic Zone

As we can see from the above figure, the rebar percentage has come in a variety of different columns. We can say that, this is due to the live load and dead load of the building the earthquake load of different zones.

CHAPTER-05

CONCLUSION

5.1 GENERAL

In order to lead a similar study, in the event of a refreshing Bangladesh National Construction Law, Bangladesh's high, moderate and low seismic zone was selected. Consideration is provided to four multistoried solid structures of 8, 12, 14 and 16 of a typical configuration. ETABS software is used to dissect the model. To dissect the concept of BNBC-1993 law, all parameters are taken by the concept.

5.2 FINDINGS OF THE STUDY

- ✓ Base shear is proportional to the height of the building.
- ✓ Base shear is proportional to No. of Storey increase, at the same time base shear is proportional to Seismic Zone Coefficient growth.
- ✓ Maximum deflection is proportional to the increase of Storey No., while maximum deflection is proportional to the growth of the Seismic Zone Coefficient.
- ✓ The storey drift increase of seismic zone factor within storey drift. But it goes to a point to grow, then start to go down again.
- ✓ The interior column is always more dimensions than exterior column.
- ✓ Irrespective of the dimension of the interior column is greater than the external column in X and Y direction.
- ✓ And the dimension of the external column in X and Y direction is greater than the corner column.

5.3 RECOMMENDATIONS FOR FURTHER STUDY

A) This irregular shape analysis only by BNBC 1993. Further analysis can be carried out by different BNBC and other code such as BNBC 2017, IS code etc.

B) This paper is analyzed on earthquake load, but further, it can be analyzed on wind load. Also, it can be analyzed on the lateral load that means earthquake load and wind load together.

C) Only very irregular structures with small heights have been studied. Further analysis can be carried out by different religious code for the structures on the basis of clear geometric irregularity.

D) The detailing of the slab has not studied here, further can be analyzed the detailing of the slab.

E) Only Equivalent Static Force Method has been used for this analyzed, further different method can be used for the analyzing.