CHAPTER - 1

INTRODUCTION

1.1 General

An earthquake is a shaking of the ground caused by the sudden breaking and movement of large sections (tectonic plates) of the earth's rocky outermost crust. The edges of the tectonic plates are marked by faults (or fractures). Most earthquakes occur along the fault lines when the plates slide past each other or collide against each other. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. Hence, structure in such locations need to be suitably designed and detailed ensure stability, strength and serviceability with acceptable levels of safety under seismic effect.

Civil engineers are trained for linear analysis but for seismic resistant building design seismic evaluation and design process are needed. Seismic analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. So to observe the behavior of the structure seismic analyses are important. Structural detailing depends on different loads which subjected on structural elements such as lateral and axial loads. The building should be planned in such way that complete analysis of each component is possible. It is possible to design and construct an earthquake resistant building with small additional cost.

1.2 Background and Present State of the Problems

Bangladesh is an earthquake prone country. So all building must be earthquake resistant with proper planning and structural design. According to probable magnitudes of earthquake, Bangladesh has been divided into four seismic zones, namely major damage zone, moderate zone, minor zone and negligible zone (BNBC, 2015). But based on the severity of the probable intensity of the seismic ground motion and damages, Bangladesh has divided into four seismic zones i.e. Zone - 1, Zone - 2, Zone - 3 and Zone - 4. There are different types of structural system but it is considered based on height and seismic zones. Structural systems have gradually evolved for residential and office building, reflecting their differing functional requirements. For this research intermediate moment resisting frames (dual system) has considered for four seismic zones in Bangladesh. Estimate of construction materials and probable cost of various items of works are absolutely necessary.

Several studies have been carried out on seismic action in various aspects by different researches. But very few studies have been carried out on cost estimation of building materials due to seismic load in Bangladesh. The seismic risk and construction cost of a same building analyzed and designed for different zones in Bangladesh followed by BNBC,1993 (**Rahman, 2010**). Upcoming BNBC - 2015 is going to be published very soon. Bangladesh has divided into four seismic zones according to BNBC- 2015 which was only three zones in previous BNBC. Present study will be carried out for a comparative study on construction cost of same structural system for four seismic zones in Bangladesh will be followed by BNBC - 2015. Very limited of studies have been done on this aspect. It needs to be explored to design earthquake resistant building and find out the required quantity of materials for four seismic zones in Bangladesh.

1.3 Objectives with Specific Aims and Possible Outcome

The objective of the study is to compare the construction cost for a same building in four seismic zones of Bangladesh.

It may give an idea to the users and designers about the difference of construction cost among four seismic zones in Bangladesh.

1.4 Outline of Methodology / Experimental Design

This study has been conducted by considering two different heights (80feet and 150 feet) of intermediate dual framing concrete structures. For structural analysis and design of this building under seismic considerations frame will consider as an intermediate reinforced concrete structure (dual system). Plan length, width and elevation of the selected (150 feet height) building are 100ft, 58 ft and 150 ft, respectively. Length to width, length to height and width to height ratio of this (150 feet height) building are 1.72, 1.5 and 1.72, respectively. On the other hand, selected other building’s (80 feet height) plan length, width and elevation height are 100 feet, 58 feet and 80 feet, respectively. Ratios of plan length to plan width, plan width to building height, plan length to building height are 1.72, 0.8 and 1.37, respectively. Architectural drawing and detailing also will prepare by Auto CAD. Structural analysis and design of this structural will be carried out by ETABS - 2016 software. Structural drawing and seismic detailing also will be prepared by Auto CAD. MS Excel will be used to find out the total required materials according to analysis results. Comparative study will be carried on required materials cost for major structural frames such as beams and columns, shear walls among four seismic zones. All of this comparison will be presented graphically.

1.5 Layout of Thesis Paper

The research is organized into five chapters. The general background, objective of the study and methodology of the work are presented in Chapter 1 to give fundamental idea of the work being done under the study. Chapter 2 deals with the literature review which includes few previous studies, earthquake and its causes, preparation of seismic includes and zoning map of Bangladesh. This Chapter also discusses about various structural systems and response modification coefficient, seismic effect and force on structure, seismic detailing for various structural elements and requirement of estimating of a structure before starting any project. These all are very much related with the subject of study. Chapter 3 discuss about analysis parameters, model and software used in this study are reported. Chapter 4 is composed of results and discussion of the research work. Chapter 5 draws conclusions by summarizing the outcome of the research new directions for further research and developments.

CHAPTER - 2

LITERATURE REVIEW

2.1 General

Bangladesh is a moderately seismic region. It is a known fact that earthquakes do not occur just anywhere. It tends to cluster around defined areas or lines. Bangladesh and its adjoining areas are situated in the northeast part of the Indian subcontinent where earthquakes frequently occur. This region lies along the border of Eurasian and Indo- Australian plates. The Plate Tectonic theory states that the earth's crust is composed of plates which move relative to one another because of natural forces acting on these plates. Ninety percent earthquakes occur along the boundary of these tectonic plates. Earthquake also occurs due to volcanic eruption, manmade activities such as reservoir induced, excavation; mining etc. This chapter reviews the seismic environment prevailing in Bangladesh as a part of the evaluation of seismic risk. Important tectonic features of Bangladesh and evolution of seismic zoning maps are also discussed. Short description of some historical earthquakes and some recent earthquake are also presented. Structural system, seismic design philosophy, seismic detailing and seismic effect reduction technology are also discussed here.

2.2 Previous Study

Several studies have been carried out on seismic action in various aspects by different researches. But very few studies have been carried out on cost estimation of building materials due to seismic load in Bangladesh. The seismic risk and construction cost of a same building analyzed and designed (Rahman, 2010) for different zones in Bangladesh followed by Bangladesh National Building Code (BNBC, 1993). BNBC - 2015 is going to be published very soon. Bangladesh has divided into four seismic zones according to BNBC - 2015 which was only three zones in previous BNBC. Present study will be carried out for a comparative study on construction cost of same structural system for four seismic zones in Bangladesh will be followed by BNBC - 2015. Very limited of studies have been done on this aspect. It is helpful to an engineer to know the cost difference for a same structure in different seismic zones. Various researches carried out on seismic action are given below:

Islam (2005) carried out a research for seismic loss estimation for Syhlet city. Objective of the study was improving our understanding of seismic risk and supporting enforcement of seismic provisions of building codes.

S.Sabri (2002), carried out a relationship between earthquake intensity and attenuation for Bangladesh and its surrounding area. The objective of this study was to find out re-estimate the earthquake intensity of major historical earthquake of Bangladesh on EMS and develop a relationship between intensity - attenuation for Bangladesh and its surrounding area.

Sharfuddin (2004), conducted research work on Earthquake hazards analysis for Bangladesh. The objective of the research work was to develop a homogeneous and complete earthquake catalogue and seismic hazard map.

Mohammad Yeasin (2008) conducted a research work on seismic performance assessments for concrete frame structure. The objectives of the research were to develop a probabilistic hazard curve and make a contour map of PGA for Bangladesh.

Rahman (2011), conducted a comparative study on construction cost for the same structural system in three seismic zones in Bangladesh, considering different height with different response modification coefficient.

2.3 Major Seismic Sources

Bolt (1987) analyzed different seismic sources in and around Bangladesh and arrived at conclusions related to maximum likely earthquake magnitude. Bolt identified the following four major sources which are Assam fault zone, Tripura fault zone, Sub - Dauki fault zone and Bogra fault zone. A brief description of geology, tectonics of the individual fault zone is given below:

2.3.1 Assam fault zone

The east-west fault separates the Assam fault zone separates the Assam fault zone from sub-Dauki fault zone. This zone consists of Archaean Proterozoic basement complex and characterized by the maximum concentration earthquake events. The hypocenter beneath the Shillong plateau is shallow focus in origin and are scattered. Only a few epicenters appear on or close to Dauki fault indicate that this fault is relatively seismically inactive during the recent time. But it was active since the Jurassic and was the main architect for the evolution of Shillong plateau. The great earthquake of 1897 originated in the Asam fault zone.

2.3.2 Tripura fault

This zone is characterized by high concentration of earthquake events. A number of morpho tectonic lineaments have been identified. Among these the Kopili lineament trending NW - SE is remarkable and is geologically recent in origin. Seismic section reveals that this lineament is the surface expression of deep seated sub vertical fault and termed as the Kopili fault, which belongs to the category of high angle reverse fault. At the north of this zone

Halflong - Dissang thrust is present. Morpho tectonic lineaments around the Halflong - Dissang thrust zone trend NE - SW, E - W and NW - SE. Mikir hill is present to the northeast corner of the Halflong - Dissang thrust, which separates the Shillong plateau by Kopili fault.

2.3.3 Sub - Dauki fault zone

This zone covers the southern part of Dauki fault and eastern part of Bogra fault zone and bounded by longitude 900 E. The morpho tectonic lineaments trend NNW- SSE and NW- SE. The Sylhet plain covers the area and comprises the vast alluvial tract and the linear belts of folded Tertiary rocks trending N- S and NNE - SSW. Sylhet lineament of 180 km long trending NESW is the subsurface expression of deep seated high angle reverse fault having a dip of about 70° towards southeast and as named as Sylhet fault.

2.3.4 Bogra fault zone

This is the westernmost area bounded by latitude 200 N and 28° N, and longitude 87° E and 900E. The area is covered with thick deposits of alluvium. The main boundary fault of Himalayan ranges occurs in the north of this fault zone. A number of morph tectonic lineaments have been identified from the study of satellite imagery. These are mostly oriented NWI NNW - SE / SSE. Most of the earthquakes along this fault are shallow in depth. The historical seismic catalogue of the regions covers approximately 250 years of (starting 1762) recent seismicity of the region and such a meager data base does not provide true picture of seismicity of the tectonic provinces. The maximum of earthquake suggested by Bolt is given in table 2.1 are the maximum magnitude generated in these blocks is recorded in the historical seismic catalogue.

Table 2.1 Seismic Sources and Maximum Magnitude

Location	Maximum Likely Earthquake Magnitude
1.Assam fault zone	8.0
2.Tripura fault zone	7.0
3.Sub - Dauki fault zone	7.3
4.Bogra fault zone	7.0

2.4 Structural Vulnerability

Structural vulnerability refers to the susceptibility of those parts of a building that are required for physical support when subjected to an intense earthquake or other hazard. This includes foundations, columns, supporting walls, beams, and floor slabs. Strategies for implementing disaster mitigation measures in hospital facilities will depend on whether the facilities already exist or are yet to be constructed. The structural components are considered during the design and construction phase when dealing with a new building, or during the repair, remodeling, or maintenance phase of an existing structure. Unfortunately, in Bangladesh, earthquake resistant construction standards have not been effectively applied, and special guidelines have not been considered for hospital facilities. For this reason, it is not surprising that each time an earthquake occurs in the region, schools and hospitals among the buildings most affected. The structural vulnerability of schools and hospitals is high, a situation that must be totally or partially corrected in order to avoid enormous economic and social losses, especially in developing countries. Since many schools and hospital facilities are old, and others have neither been designed nor built to seismic resistant standards, there are doubts as to the likelihood of these buildings continuing to function after an earthquake.

2.5 Earthquake Threat for Bangladesh

Bangladesh being located close to the plate margins of Indian and Eurasian plates is susceptible to earthquakes. The collision of the Indian plate moving northward with the Eurasian plate is the cause of frequent earthquakes in the region comprising Bangladesh and neighboring India, Nepal and Myanmar. Historically Bangladesh has been affected by five earthquakes of large magnitude (M) greater than 7.0 (Richter scale) during the 61 year period from 1869 to 1930. Among them, the mighty 8 + magnitude 1897 Great Indian earthquake in Shillong, Assam had an epicentral distance of about 230 km from Dhaka. That earthquake caused extensive damages to masonry buildings in many parts of (M = 7.0, 170 km from Dhaka) and 1918 Srimongal earthquake (M = 7.6, 150 km from Dhaka) had their epicenters within Bangladesh and they caused considerable damage locally. Two great (M > 8) earthquakes occurred in Bihar in 1934 and in Assam in 1950, but they were too far to cause any damage in Bangladesh. It should be noted that large earthquakes in the region have not been occurring for quite a long time (around 75 years) and hence, the possibility of a major earthquake occurring soon is quite high. Dhaka is one of the oldest historical city in the Indian sub-continent and now the capital of Bangladesh, is vulnerable to earthquakes. The geotectonic set up of the country, which is located along two of the planet’s active plate boundaries, suggests high probabilities of damaging future earthquakes and the possibility of rarer but extraordinarily large earthquakes that can cause damage far from their epicenters.

2.6 Most Vulnerable Areas of Bangladesh for Earthquakes

Figure 2.1 which represent a seismic hazard map which is being provided by the science and information and communications technology ministry. This hazard map divides the country into three earthquake vulnerability zones. Panchagarh, Rangpur, Gaibandha, Kurigram, Jamalpur, Sherpur, Mymensingh, Netrakona, Sunamganj, Kishoreganj, Moulvibazar, Sylhet, Habiganj and Brahmanbaria are placed in the highest risk zone. Parts of Thakurgaon, Sirajganj, Tangail, Rangamati, Khagrachhari and Cox's Bazar also fall into the moderate risk zone category, said Prof Ansary. Barisal, Patuakhali, Barguna, Bagharhat, Shatkhira considered as low risk hazard prone area.

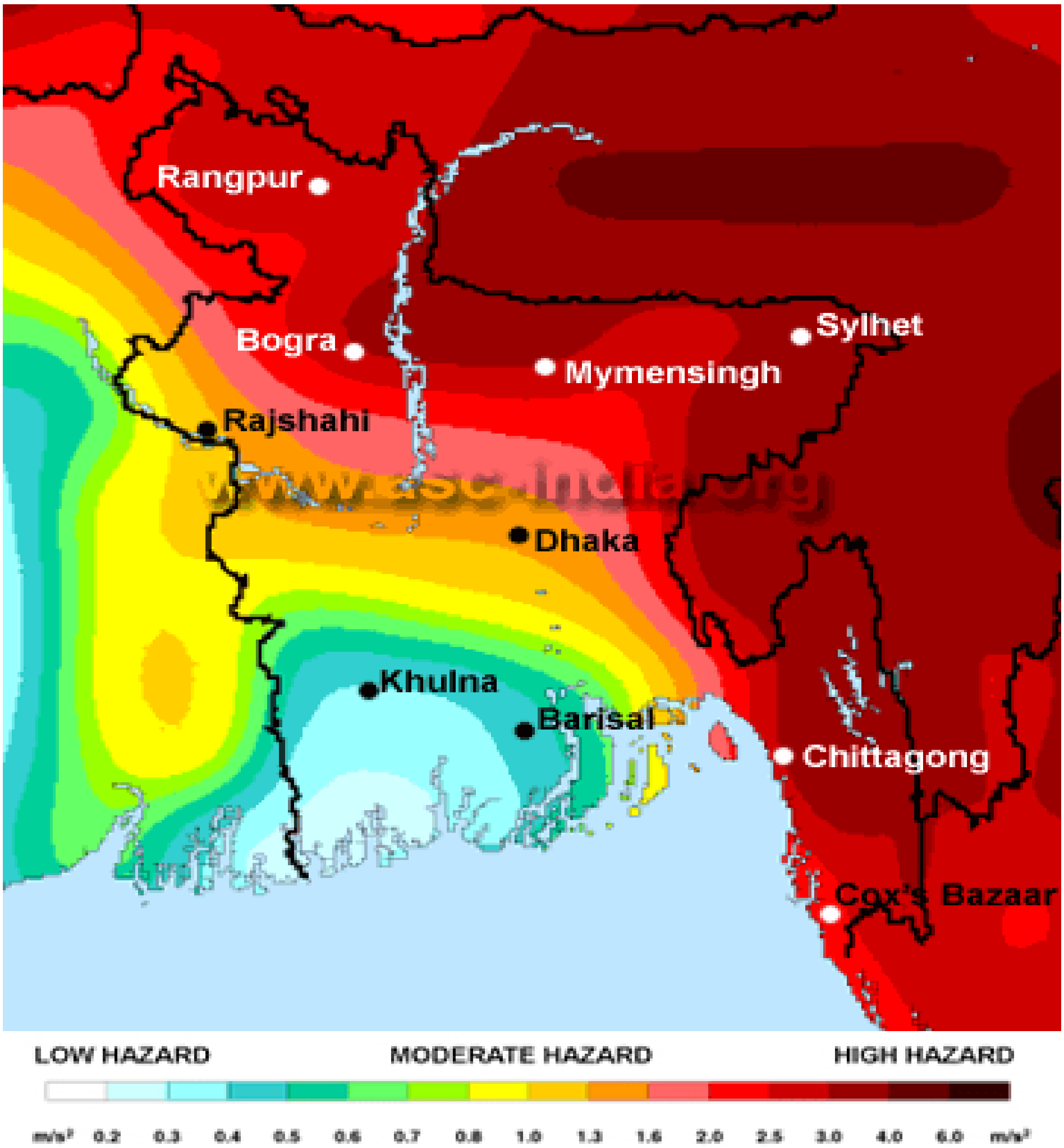


Figure: 2.1 Seismic Hazards Map (www.asc.india.org.).

2.7 Seismic Activity of Bangladesh

Bangladesh is possibly one of the country's most vulnerable to potential earthquake threat and damage.The Seismic activity of Bangladesh is shown in Figure 2.2. An earthquake of even medium magnitude on Richter scale can produce a mass graveyard in major cities of the country, particularly Dhaka, Sylhet and Chittagong. Construction of new buildings strictly following building code or development of future controls on building construction is the activities, which will be functional in future. However, under the present stage of human occupancy, buildings, infrastructures and other physical structures of different areas of a city will not be equally vulnerable to any such shock. Earthquake vulnerability of any place largely depends on its geology and topography, population density, building density and quality, and finally the coping strategy of its people and it shows clear spatial variations. It is thus necessary to identify the scale of such variations and take necessary measurements to cope with that Geographically Bangladesh is located close to the boundary of two active plates: the Indian plate in the West and the Eurasian plate in the East and North. As a result the country is always under a potential threat to earthquake at any magnitude at any time, which might cause catastrophic death tolls in less than a minute.

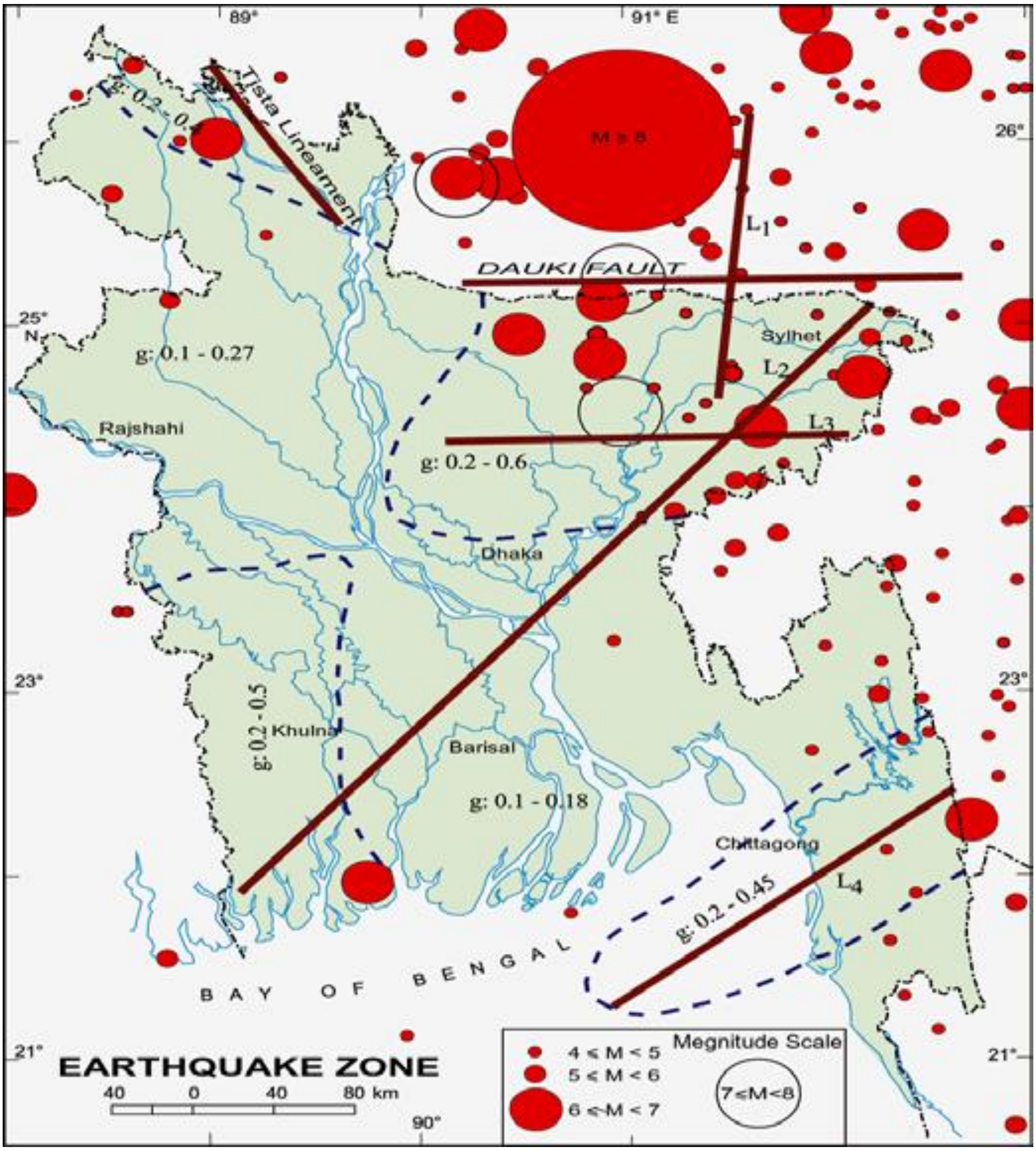


Figure: 2.2 Seismic Activities of Bangladesh (Banglapedea, 2004).

2.8 Building Frame System

Building frame system is a structural system with an essential complete space frame providing support for gravity loads. Resistance to lateral loads is provided by shear wall or braced frame separately. In seismic zone 3 and 4 shear wall must be detailed. There no special detailing requirements for the shear walls in lower seismic zones. Wall bearing system, Moment resisting frame system, Dual system and Special structural system are main types of building frame systems. Different building frame systems are described below.

2.8.1 Wall Bearing System

A structural system with bearing walls providing support for all or major portions of the vertical loads. A load bearing wall or bearing wall is a wall that is an active structural element of a building, that is, it bears the weight of the elements above share wall, resting upon it by conducting its weight to a foundation structure. Figure 2.3 is an example of load bearing wall building elevation. The materials most often used to construct load-bearing walls in large buildings are concrete, block, or brick. By contrast, a curtain wall provides no significant structural support beyond what is necessary to bear its own materials or conduct such loads to a bearing wall. Load- bearing walls are one of the earliest forms of construction.

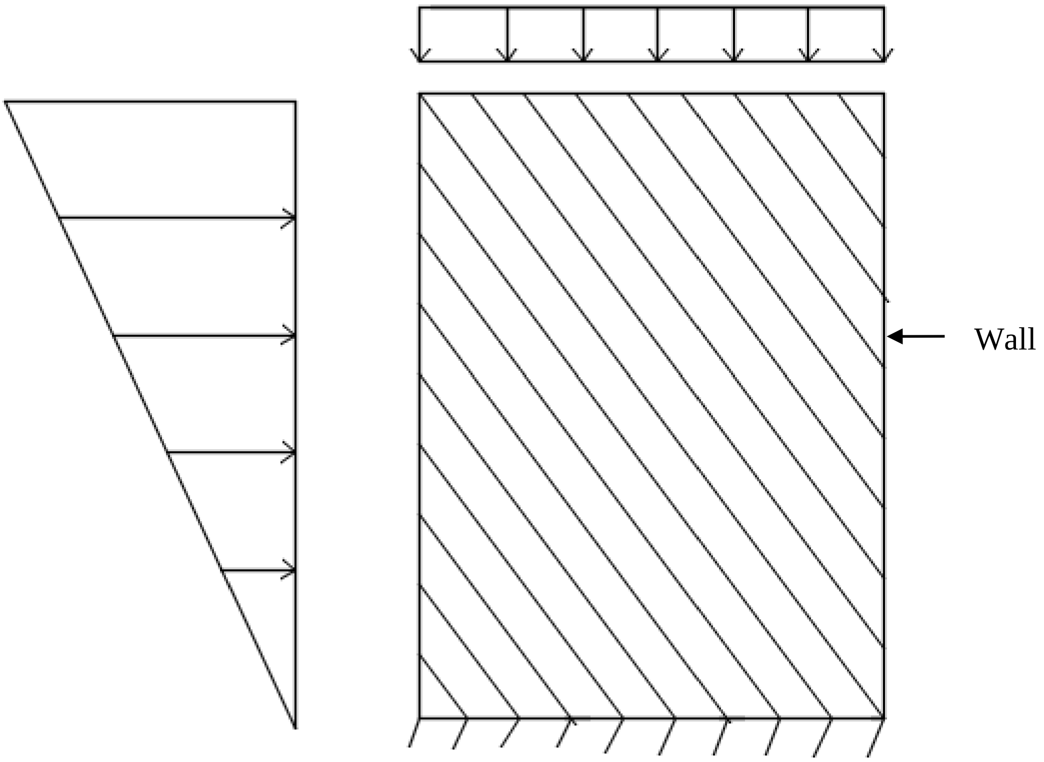


Figure: 2.3 Wall Bearing Systems.

2.8.2 Moment Resisting Frame

Moment resisting frames are rectilinear assemblages of beams and columns, with the beams rigidly connected to the columns. Resistance to lateral forces is provided primarily by rigid frame action that is, by the development of bending moment and shear force in the frame members and joints. By virtue of the rigid beam and column connections, a moment frame cannot displace laterally without bending the beams or columns depending on the geometry of the connection. The bending rigidity and strength of the frame members is therefore the primary source of lateral stiffness and strength for the entire frame. Figure 2.4 is an example of a moment resisting frame building. Moment resisting frame system may be classified as special moment resisting frame, intermediate moment resisting frame and ordinary moment resisting frame. Different types of moment resisting frames has described below.

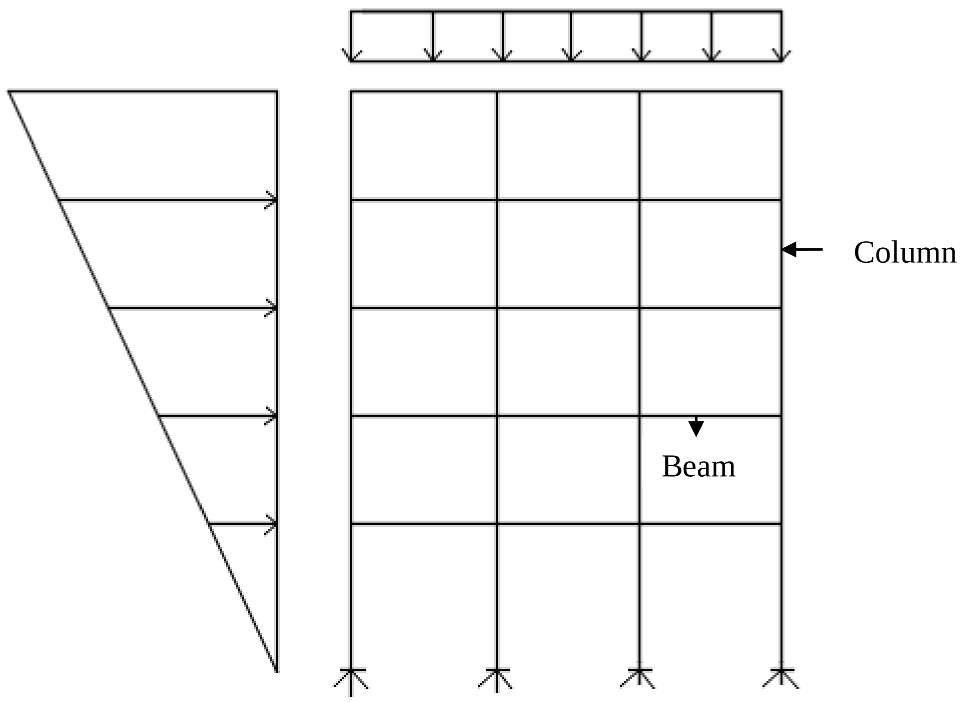


Figure: 2.4 Moment Resisting Frame.

2.8.2.1 Ordinary Moment Resisting Frame

A frame consists of two columns (vertical elements) and one beam (horizontal element) connecting the tops of the columns. Specifically, a frame makes the connections between the beams and columns rigid. For RC, that means there is reinforcing steel that bends from the column to the beam, and the concrete for the beam is intended to bond with the concrete in the column. Both continuity of reinforcement and concrete are required to make the frame resist moments. Ordinary frame is frame with just ordinary detailing for the members and joints. Special frame is frame with special ductile detailing for frames for members and joints. These provide the least resistance to lateral motion and so are only recommended for zero/low seismic regions.

2.8.2.2 Intermediate Moment Resisting Frame

IMF is the next level up, designed to resist limited inelastic deformations as the result of lateral forces. As per the AISC, they must use pre qualified connections or have passed a qualifying cyclic test, proving their ability to sustain inter-story drift angle of up to 0.02 radians. Thus, IMF's are only installed in low- to mid-seismic regions.

2.8.2.3 Special Moment Resisting Frame

Special proportioning and detailing requirements are critical in resisting strong earthquake shaking with substantial inelastic behavior. These moment resisting frames are called Special Moment Frames because of these additional requirements, which improve the inelastic response characteristics of these frames in comparison with less stringently detailed Intermediate and Ordinary Moment Frames.

SMF connections are the strongest available. They are designed to withstand dramatic inelastic deformation in both members and connections when assaulted by lateral forces. They also require the use of pre-qualified connections that have passed a qualifying cyclic test. These connections must sustain inter-story drift angle of up to 0.04 radians. SMFs are used in regions with mid to high seismic activity. A properly detailed SMF is among the most ductile lateral force resisting systems.

2.8.3 Dual System

A dual system is a structural system in which an essentially complete frame provides support for gravity loads, and resistance to lateral loads is provided by a specially detailed moment-resisting frame and shear walls or braced frames. Both shear walls and frames participate in resisting the lateral loads resulting from earthquakes or wind or storms, and the portion of the forces resisted by each one depends on its rigidity, modulus of elasticity and its ductility, and the possibility to develop plastic hinges in its parts. The moment resisting frame may be either steel or concrete, but concrete intermediate frames cannot be used in seismic zones 3 or 4. The moment resisting frame must be capable of resisting at least 25 percent of the base shear, and the two systems must be designed to resist the total lateral load in proportion to their relative rigidities. In the dual system, both frames and shear walls contribute in resisting the lateral loads. Figure 2.5 shows an elevation of a dual system building frame.

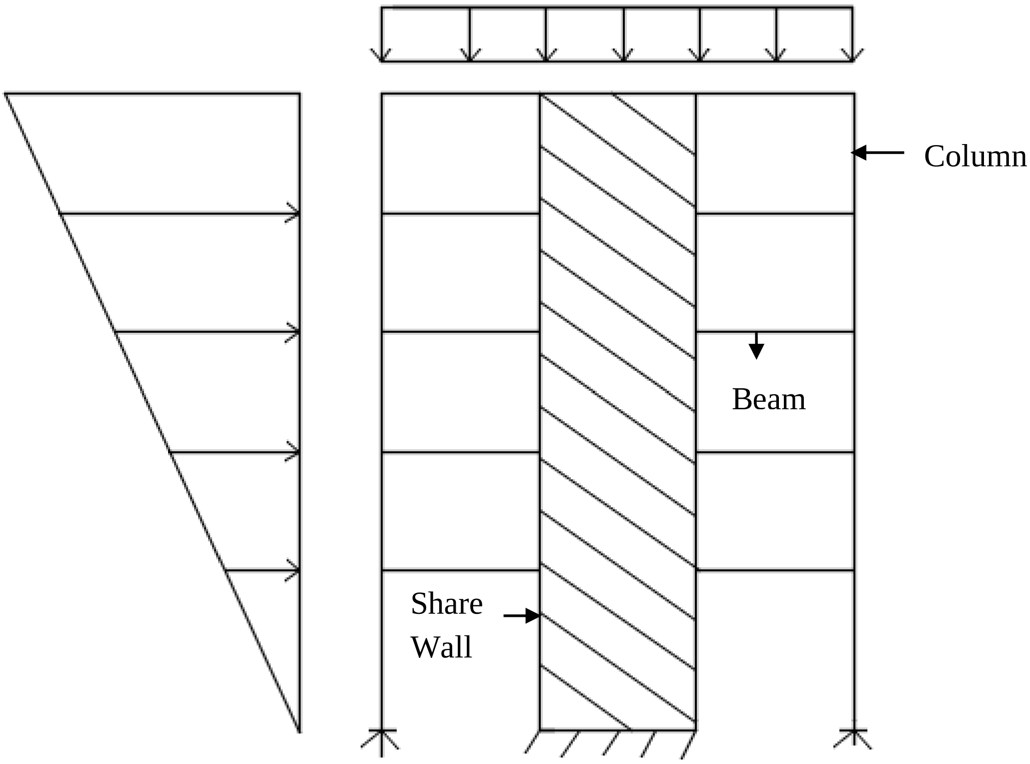


Figure: 2.5 Dual Frame Systems.

2.9 Different Seismic Codes

A building code is a set of rules that specify the standard for constructed objects such as building and non building structures. Building must conform to the code to obtain planning permission, usually from a local council. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of building and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority. Different building codes are described below.

2.9.1 UBC Uniform Building Code (UBC)

The International Conference of Building Officials (ICBO) was founded in 1922. The UBC addressed seismic design in "Section 2312 Earthquake Regulations" written into the main code body, beginning in 1927 after the 1925 Santa Barbara earthquake (Beavers, 2002).In 1943, the first jurisdiction to adopt UBC provisions was the city of Los Angeles (Atkinson and Kiland,2004).

2.9.2 The National Building Code (NBC)

The Building Officials and Code Administrators International were founded in 1915. The National Building Code published by this organization is known as the BOCA model building code and was predominantly used in the upper Midwest and northeastern U.S. In 1950, the BOCA code adopted a seismic design method much like the 1927 UBC method.

2.9.3 Standards from ANSI and ASCE

In 1945, ANSI published ANSI A58.1 (Beavers, 2002), the first national standard to consider earthquake loads. The Lateral Forces of Earthquake and Wind, which was eventually, incorporated into the ASCE - 7. Minimum Design Loads for Buildings and Other Structures replaced the ANSI standard in 1952. This standard is the first to use a dynamic approach to seismic design (Beavers, 2002).

2.9.4 International Building Code (IBC)

The IBC began in 1997 with the merger of the ICBO, BOCA and SBCCI. In 2000, the IBC published the first code resulting from the merger, the 2000 edition of the International Building Code (IBC). The earthquake regulations of the IBC 2000 differed from the 1997 UBC and were based on the 1997 NEHRP Provisions. Beginning with the 2006 IBC, the ASCE 7 - 05 is adopted by reference for determining earthquake forces, though some information is still contained in the IBC.

2.9.5 American Society of Civil Engineers (ASCE -7)

The ASCE 7 - 98 had incorporated many of the recommendations of the ATC - 306 and subsequent NEHRP documents. In 1998 ASCE 7 published the values of R for different structural system from their organization given in Appendix A. Here it is to be mentioned that it was their first publication. Afterwards some states, such as California, still imposed stricter requirements, or referenced other standards for determining earthquake forces, rather than adopting the IBC at the local level. California adopted the Building Construction and Safety Code 2003, NFP 5000 - 03 as the model building code for seismic design, but reversed the decision in 2006 when the state adopted the IBC as the model building code.

2.9.6 FEMA - 350 and ATC - 63 (2009 - Present)

In September of 2004, FEMA awarded a contract to ATC to recommend method for quantifying the building system seismic performance factors and response parameters used in seismic design. As stated previously, current values of R listed in NEHRP and ASCE 7 - 05 use the judgment of designers and limited qualitative comparisons to other similar systems. The NEHRP Provisions include more than 75 structural systems, each with an assigned R factor based on expert judgment, but many have never been tested or evaluated after major seismic events.

2.9.7 Bangladesh National Building Code (BNBC)

The purpose of the code is to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of buildings within Bangladesh in order to safeguard, within achievable limits, life, limb, health, property and public welfare. The updated BNBC- 15 has 10 parts with a total of 49 chapters. Part - 6 structural design has 13 chapter which is the maximum among all the parts. Seismic Zone expression of the proneness of a region earthquake occurrence in the historical past including the expectations in future. A region experiencing more frequent and large earthquakes has a higher seismicity compared to one with less frequent and small earthquakes. In the preparation of seismic zoning map the common data which are considered include Soil types, foundation conditions, ground structure and its dynamic characteristics, intensity distribution during past earthquakes, ground motion attenuation characteristics, envisaged development and location of major cities, economic status and simplification shape. According to upcoming BNBC - 2015 the country has been divided into four seismic zones with different levels of ground motion. Figure 2.7 presents a map of Bangladesh showing the boundaries of the four zones. Each zone has a seismic zone coefficient (Z) which represents the maximum considered peak ground acceleration (PG) on very stiff soil/rock (site class SA) in units of g (acceleration due to gravity). The zone coefficients (z) of the four zones are: Z = 0.12 (Zone 1), Z = 0.20 (Zone 2), Z = 0.28 (Zone 3) and Z = 0.36 (Zone 4)

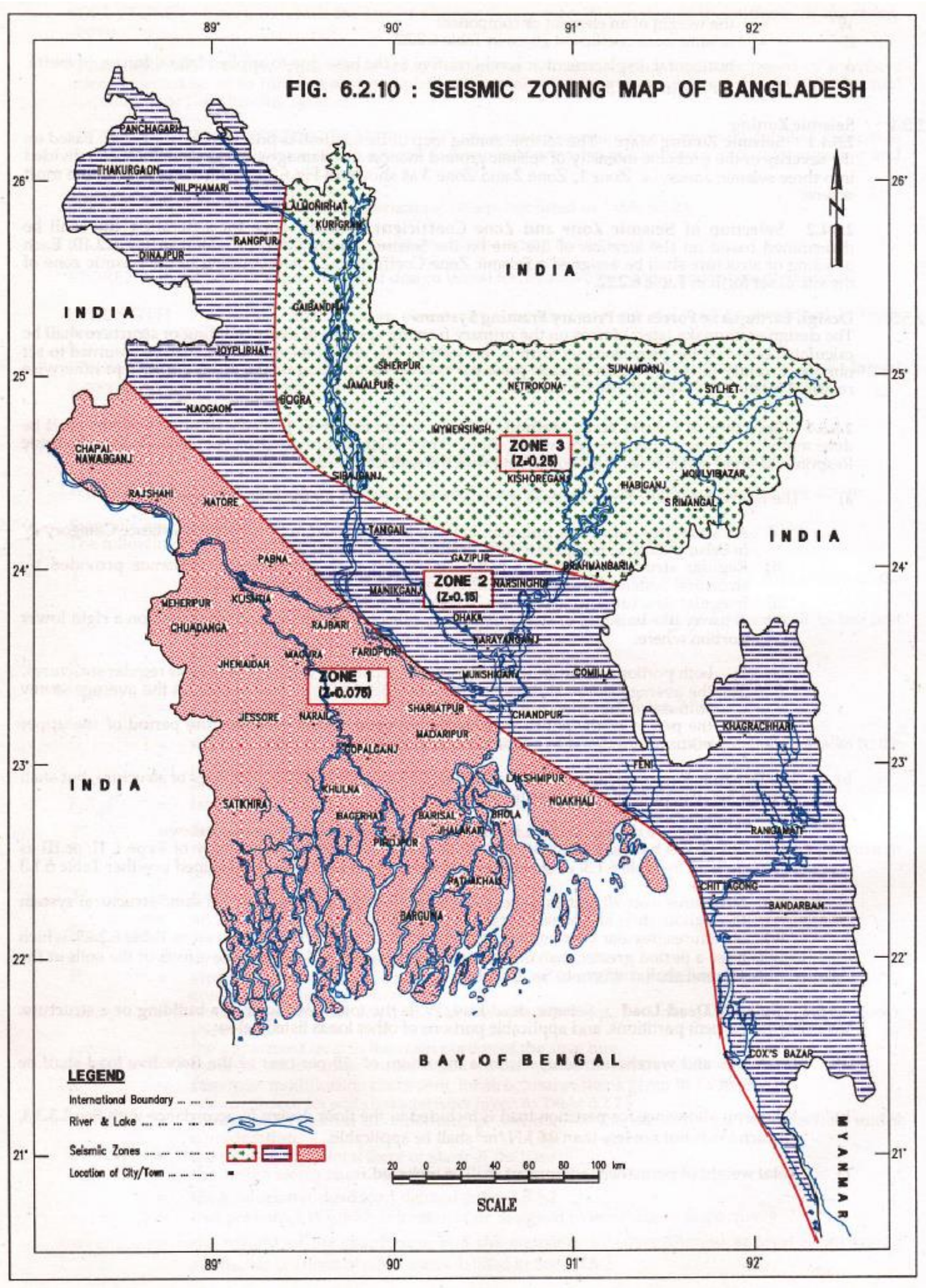


Figure: 2.6 Seismic Zoning Map (BNBC 1993).

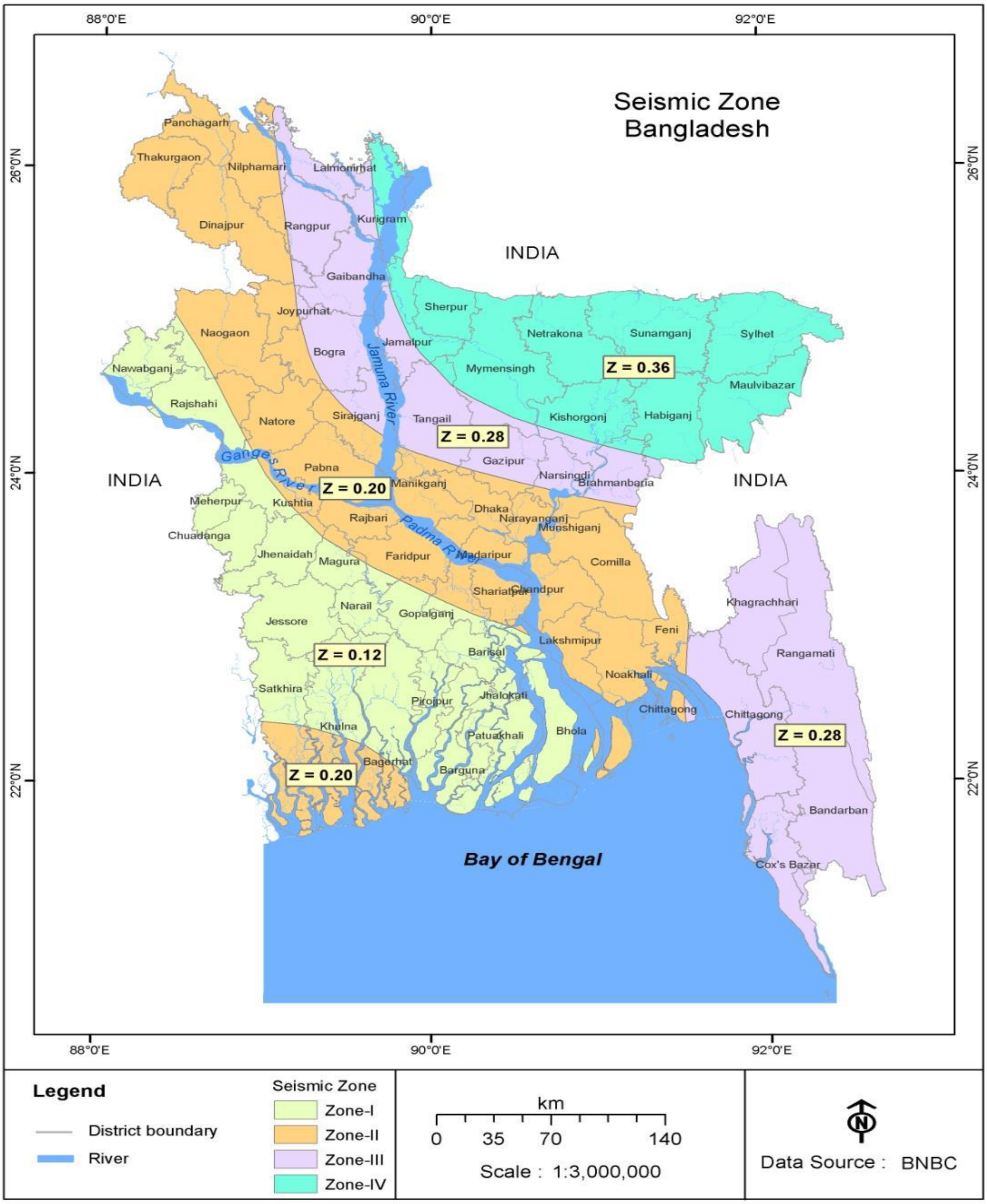


Figure: 2.7 Seismic Zoning Map (BNBC 2015).

2.10 Analysis of Seismic Force

Seismic force analysis is a subset of structural analysis and is the calculation of the response of a building. Two methods for determining the seismic forces on a building are the equivalent lateral force (EFL) procedure and the dynamic response method. Both procedures consider lateral forces action on the building in the direction of the ground motion; the main difference lies in the magnitude and distribution of the lateral forces over the height of the building. Dynamic analysis should be performed to obtain the design of seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings (a) Regular buildings with height greater than 40 m in zones 2, 3, 4 and greater than 90 m in zone 1(b) Irregular buildings with height greater than 12 m in zones 2, 3, 4 and greater than 40 m in zone 1.

Dynamic analysis may be carried out through the following two methods:

(i) Response Spectrum Analysis method is a linear elastic analysis method using modal analysis procedures, where the structure is subjected to spectral accelerations corresponding to a design acceleration response spectrum. The design earthquake ground motion in this case is represented by its response spectrum.

(ii) Time History Analysis method is a numerical integration procedure where design ground motion time histories (acceleration record) are applied at the base of the structure. Time history analysis procedures can be two types: linear and non-linear.

2.10.1 The Dynamic Response Method

Structural analysis is mainly concerned with finding out the behavior of a physical structure when subjected to force. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. In essence all these loads are dynamic, including the self weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. Dynamic loads include people, wind, waves, traffic, earthquakes, and blasts. Any structure can be subjected to dynamic loading. Dynamic analysis can be used to find dynamic displacements, time history, and analysis. In the response spectrum analysis method, the base shear Vrs; each of the story shear, moment and drift quantities; and the deflection at each level shall be determined by combining their modal values. The combination shall be carried out by taking the square root of the sum of the squares (SRSS) of each modal value or by the complete quadratic combination (CQC) technique. The complete quardratic combination shall be used where closely spaced periods in the translational and torsional modes result in cross - correlation of the modes. A base shear, V shall also be calculated using the equivalent static force procedure. Where the base shear, V_{rs} is less than 85 percent of V all the forces but not the drifts obtained by response spectrum analysis shall be multiplied by the ratio $\frac{0.85\ V}{Vrs}$.

2.10.2 Time History Analysis

The time varying forces in the ground generates earthquake loads and the pattern of load specified as a time history of ground excitation is the most accurate means of representing earthquake actions. The difficulty with carrying out analysis procedures to compute the responses of a structure for this type of load is that the form of the acceleration time history is to be clearly known.

2.10.3 Equivalent Static Load Method

In this method the dynamic earthquake effect is represented by an equivalent static load at different levels proportion to mass at the led Earthquake load is a dynamic load. Due to earthquake load, a structure librates III different mode shapes and load on the structure and its intensities and direction is dependent on the mode shapes. Equivalent static load method is an assumption of linear mode shape for the first mode of the structure. It is basically calculation of the base shear from an earthquake load and its comparison with the base shear capacity of the building (BNBC, 2015) 2.18

2.11 Calculation of Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on soil conditions at the site and proximity to potential sources of seismic activity (such as geological faults).probability of significant seismic ground motion and the level of ductility and over strength associated with various structural configurations and the total weight of the structure are also responsible for base shear variations. Base shear also depends on the fundamental (natural) period of vibration of the structure when subjected to dynamic loading

Base share, $V = S_a \times W$ (2.1)

Here, $S_a = 2\ ZIC_s / 3R$ (2.2)

The terms in the right side of the equation explained below.

2.11.1 Zone Coefficient, Z

This is the coefficient that represents the earthquake severity of the regions. According to upcoming BNBC - 2015 the country has been divided into four seismic zones with different levels of ground motion. Figure 2.14 presents a map of Bangladesh showing the boundaries of the four zones. Each zone has a seismic zone coefficient (Z) which represents the maximum considered peak ground acceleration (PG) on very stiff soil / rock (site class SA) in units of g (acceleration due to gravity). The zone coefficients (Z) of the four zones are Z = 0.12 (Zone 1), Z = 0.20 (Zone 2), Z = 0.28 (Zone 3) and Z = 0.36 (Zone 4)

2.11.2 Structure Importance Coefficient, I

This is the coefficient that accounts the importance of structure for post earthquake activities. The earthquake lateral force is multiplied by some factor called structure importance co - efficient and are designed for a higher level of force so that the possibility of these structure being undamaged during an earthquake remains higher. But in BNBC 2015 (draft), importance co - efficient is denoted by I for all cases. In BNBC 2015, importance co - efficient is described for four different cases. Building shall be assigned a seismic design category among B, C or D based on seismic zone, local site conditions and importance class of building, as given in table 2.3 .Seismic design category D has the most stringent seismic design detailing, while seismic category B has the least seismic design detailing. Table 2.2 defines different occupancy categories and corresponding importance factor.

Table - 2.2 Structural Importance Factors.

Occupancy Category	BNBC ,1993	BNBC,2015
Essential Facilities	1.25	1.50
Hazardous Facilities	1.25	1.25
Special occupancy Structure	1.0	1.0
Standard Occupancy Structure	1.0	1.0
Low - risk structure	1.0	1.0

Table - 2.3 Seismic Design Categories of Buildings.

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,S_1,S_2	D	D	D	D	D	D	D	D

2.11.3 Normalized Response Spectrum Acceleration (C_s)

Damping factor is the effect of inherent energy dissipation mechanisms in a structure (due to sliding, friction, etc.) that results in reduction of effect of vibration, expressed as a percentage of the critical damping for the structure. BNBC 2015 suggests that 5 % damped design spectrum to be properly modified for an actual damping factor. BNBC 2015 introduces four equations each operating within a range of time period to determine C_S. C_S defined by these equations

$C_s = S \{1+ T / T_B (2.5\eta -1)\}$ for $0 \le T \le T_B$ (2.3)

$C_s = 2.5\eta$ for $T_B \le T \le T_C$ (2.4)

$C_s = 2.5\eta (T_C / T)$ for $T_C \le T \le T_D$ (2.5)

$C_s = 2.5\eta (T_C \times T_D / T)$ for $T_D \le T \le 4$ sec (2.6)

Here, S (soil factor) = for this study selected soil is SC and soil factor value is 1.15.

$T = C_t (h_n)^m$, h_n is the height of selected structure and m is moment coefficient of selected structure. $C_t = 0.0488$ and h_n = (80 feet and 150 feet), m = 0.75 for selected intermediate dual frame structure.

T_B = Lower limit of the period of the constant spectral acceleration (Table 2.5).

T_C = Upper limit of the period of constant spectral acceleration (Table 2.5).

T_D = Lower limit of the period of the constant spectral displacement (Table 2.5).

η = Damping correction factor as a function of damping with a reference value of critical damping with a reference value of $\eta = 1$

2.11.4 Time Period (T)

The fundamental building period is simply the inverse of the building frequency at which it wants to vibrate when set in motion by some sort of disturbance (in building design, typically a seismic or wind event) based on the system's mass and stiffness characteristics. Buildings with shorter fundamental period attract higher seismic forces as the code-based design spectrum exhibits higher accelerations at shorter periods. Co - efficient from obtained from table - 2.4

According to BNBC - 2015 we know that, $T = C_t \times (h_n)^m$

Here, C_t = Co - efficient of time period (Table - 2.4)

m = 0.9 for concrete moment resisting frames.

m = 0.8 for steel moment resisting frames

m= 0.75 for eccentrically braced steel frames

m = 0.75 for all other structural systems.

Table - 2.4 C_o - efficient of Estimate Approximate Time Period.

Structural Types	BNBC 1993	BNBC 2015
Concrete moment resisting frames	0.073	0.0466
Steel moment resisting frames	0.083	0.0724
Eccentrically braced steel frame	0.073	0.0731
All other structural systems	0.049	0.0488

Table - 2.5 Site Dependent Soil Factor.

Soil Type	S	T_B	T_C	T_D
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

2.11.5 Seismic Weight, W

This is the seismic weight of the structure that participates in earthquake response of the structure. The total seismic dead load of a building and applicable portions of other loads. It represents the total mass of the building and includes the weights of structural slabs, beams, columns and walls, non-structural components such as floor topping, roofing, and fire proofing material, fixed electrical and mechanical equipment, partitions and ceilings. Values of different loads which requirements of a building obtained from table 2.6

Table - 2.6 Seismic Weights

Load Type	BNBC 1993	BNBC 2015
Live load	In storage and warehouse occupancies, a minimum 25 percent floor live load applicable	In BNBC 2015 (draft) a minimum of 25 % of live load is applicable for live load less than equal 3 KN / m^2.
Dead load	Where an allowance for partition wall load is included for floor design minimum 0.6 KN / m^2.	When partition locations are subject to change as in office buildings, a uniform distributed dead load of at least 10 psf of floor area is used in calculating W.

2.11.6 Response Modification Factor, R

Response modification factor is one of the seismic design parameters to consider nonlinear performance of building structures during strong earthquake. Relying on this, many seismic design codes led to reduce loads. In other words, response modification factor is the ratio of strength required to maintain the structural elasticity. In fact, the response modification factor (R) reflects the capability of a structure to dissipate energy through inelastic behavior. Systems undergoing inelastic response during severe earthquake incidents. In BNBC 1993, it is known as response modification coefficient. It is the factor by which the actual base shear force that would develop if the structure behaved truly elastic during earth quake is reduced to obtain design base shear. Response modification factor values for different structural systems described in table 2.7

Table - 2.7 Response Modification Factors

1. Frame Systems	Response Reduction Factors
2. Special Steel Concentrically braced frames	6
3. Special reinforced concrete shear wall	6.5
4. Ordinary reinforced masonry shear wall	3
5. Ordinary reinforced concrete shear wall	5.5

2.12 Vertical Distribution of Lateral Forces

$$S_a = \frac{2\,Z\,I\,Cs}{3R} \qquad (2.7)$$

S_a = Spectrum acceleration

Z = Seismic zonal coefficient

I = Structural importance factor

Cs = Normalized response spectrum acceleration

R = Response modification factor `

Base share, $V = S_a \times W$ (2.8)

In the absence of a more rigorous procedure the total lateral force, which is the shear V, shall be distributed along the height of the structure. The concentrated force F_t acting on the top of the building shall be determined as follows:

$F_t = 0.07\ TV$ when $T > 0.7$ second (2.9)

$F_t = 0.0$ when $T \leq 0.7$ second (2.10)

The remaining portion of the base share ($V - F_t$) shall be distributed over the height of the building including level – n according to the relation.

$$F_x = \frac{(V-Ft)\ Wx\ hx}{\sum_{i=1}^{n} Wi\ hi} \qquad (2.11)$$

At each story level - x, the force F_x shall be applied over the area of the building in proportion to the mass distribution at that level Figure 2.8

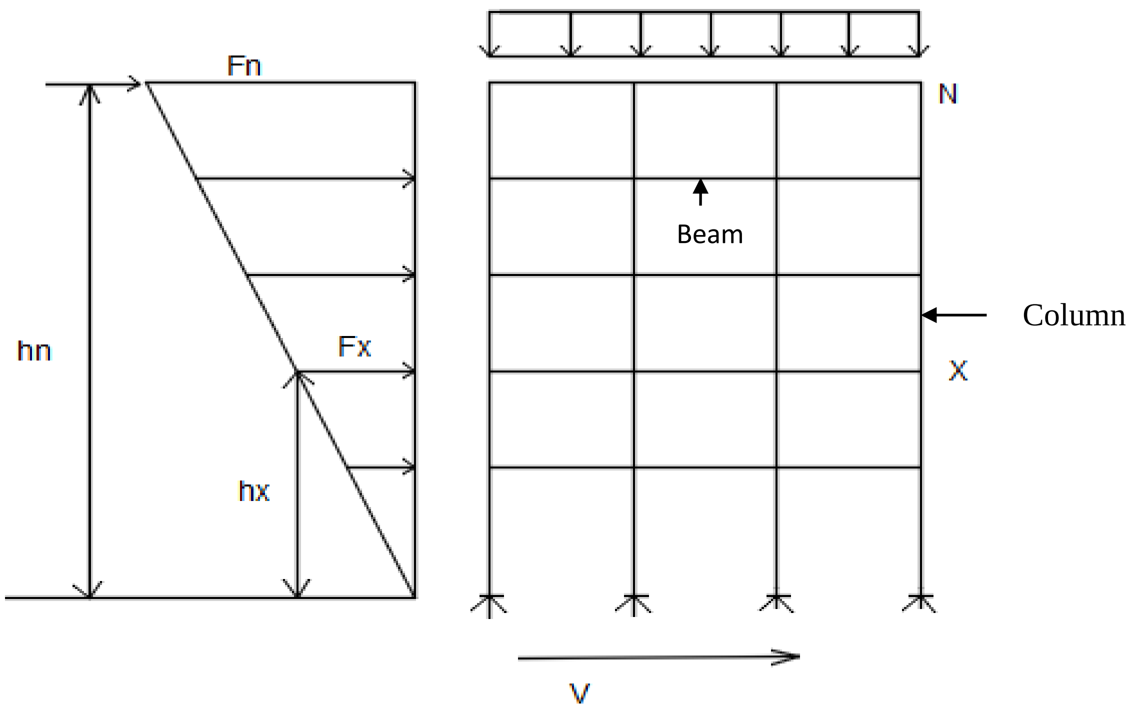


Figure: 2.8 Figure Distributions of Lateral Forces in Multistory Building.

2.13 Seismic Design Philosophy

Engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquakes such buildings will be too robust and also too expensive. Instead the engineering intention is to make buildings earthquake-resistant; such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, safety of people and contents is assured in earthquake resistant buildings, and thereby a disaster is avoided. This is a major objective of seismic design codes throughout according to BNBC - 2015 are (a) Under minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged; however building parts that do not carry load may sustain repairable damage. (b) Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake; and (c) Under strong but rare shaking, the main members may sustain severe (even irreparable) damage, but the building should not collapse.

2.14 Detailing of Reinforcement According to Seismic Design Philosophy

Good structural analysis and design must be complemented with appropriate reinforcement detailing to insure that the structure as a whole behaves as it is modeled by the designer. On the other hand, a poorly detailed structure may suffer from unsightly cracks, excessive deflection or even collapse. Good details and bar arrangements should be practical, buildable, cost-effective, and suitable for their intended use. Reinforcement is provided mainly to resist internal tensile forces calculated from analysis. Also, reinforcement is provided in compression zones to increase the compression capacity, enhance ductility, reduce long term deflections, or increase the flexural capacity for beams. There is more to design than calculating the forces in the structural members and proportioning the sections. Flexural Members, Flexural reinforcements, transverse reinforcements of beam, longitudinal reinforcements of columns, beam column joint reinforcements described below.

2.14.1 Flexural Member

A flexural member is a member that is subject to both tension and compression within its depth. A beam is usually a flexural member as the load applied will cause (usually) the bottom flange to go into tension and the top flange to be compressed. Flexural members are defined as structural members that resist earthquake-induced forces but have a factored axial compressive load that does not exceed Ag f'_c / 10, where Ag is the gross area of the cross section. The members must have a clear span to effective depth ratio of at least 4, a width to depth ratio of at least 0.3, and a web width of not less than l0 in. nor more than the support width plus three quarters of the flexural member depth on either side of the support. The minimum clear span to depth ratio helps ensure that flexural rather than shear strength dominates member behavior under inelastic load reversals. Minimum web dimensions help provide adequate confinement for the concrete, whereas the width relative to the support (typically a column) is limited to provide adequate moment transfer between beams and columns (BNBC, 2015).

2.14.2 Flexural Reinforcement of Beam

Designing a beam involves the selection of its material properties (i.e., grades of steel bars and concrete) and shape and size; these are usually selected as a part of an overall design strategy of the whole building. And, the amount and distribution of steel to be provided in the beam must be determined by performing design calculations. Longitudinal bars are provided to resist flexural cracking on the side of the beam that stretches. Since both top and bottom faces stretch during strong earthquake shaking, longitudinal steel bars are required on both faces at the ends and on the bottom face at mid length. Longitudinal reinforcement requirement are as follows:

a) At any section of a flexure member and for the top as well as for the bottom reinforcement, the amount of reinforcement shall be not less than 0.25 f_c' / f_y b_w. d
b) Lap splices of flexure reinforcement shall be permitted only if hoop or spiral reinforcement is provided over the lap length. Maximum spacing of the transverse reinforcement enclosing the lapped bars shall not exceed d / 4 or 100 mm.
c) The positive moment strength at the face of the joint shall not be less than one-third the negative moment strength provided at that face .Neither the negative nor positive moment strength at any section along the length of the member shall be less than one - fifth of the maximum moment strength provided at the face of either joint. Longitudinal steel bars are required on both faces at the ends and on the bottom face at mid length. Details of longitudinal reinforcements has shown in Figure 2.9

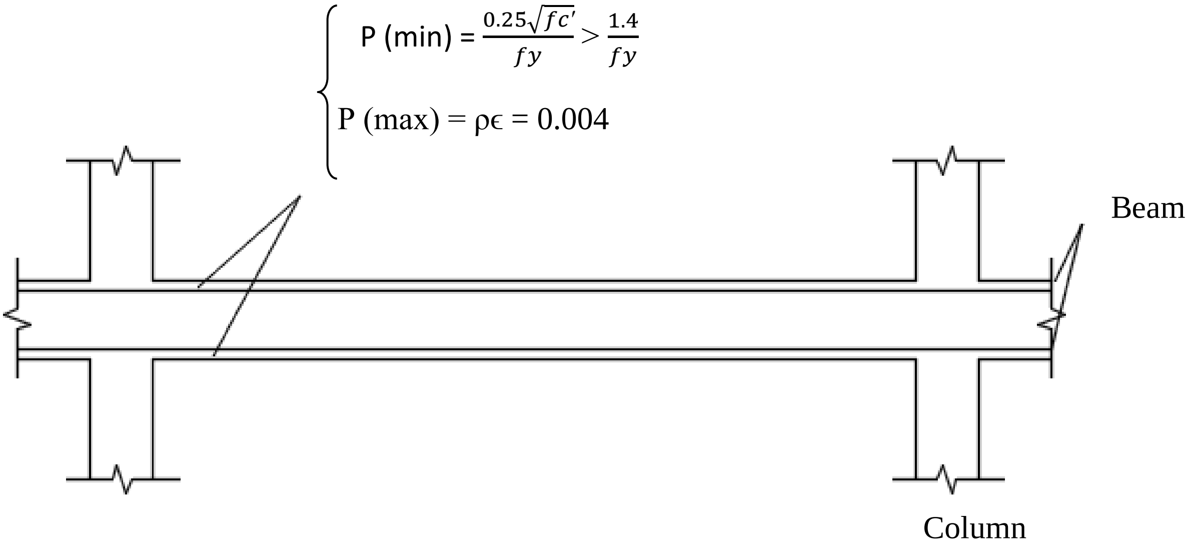


Figure: 2.9 Locations and Amount of Longitudinal Reinforcements of Beam.

2.14.3 Transverse Reinforcement of Beam

Reinforcement bars provided perpendicular to the longitudinal reinforcement is referred to as transverse reinforcements. Transverse reinforcements according BNBC 2015 are the first hoop shall be located not more than 50 mm from the face of the supporting member maximum spacing of the hoops shall not exceed (i) d / 4 (ii) eight times the diameter of the smallest longitudinal bars, (iii) 24 times the diameter of the hoop bars, and (iv) 300 mm. Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to and where hoops are not required, stirrups with seismic hooks shall be spaced not more than d / 2 thought the length of the member. Hoops in flexural members are allowed to be made up of two pieces of reinforcement consisting of a U stirrups having hooks not less than 135° with 6 diameter but not less than 754 mm extension anchored in the confined core and a cross tie to make a closed hoop. Figure 2.10 shows details of transverse reinforcements of beams.

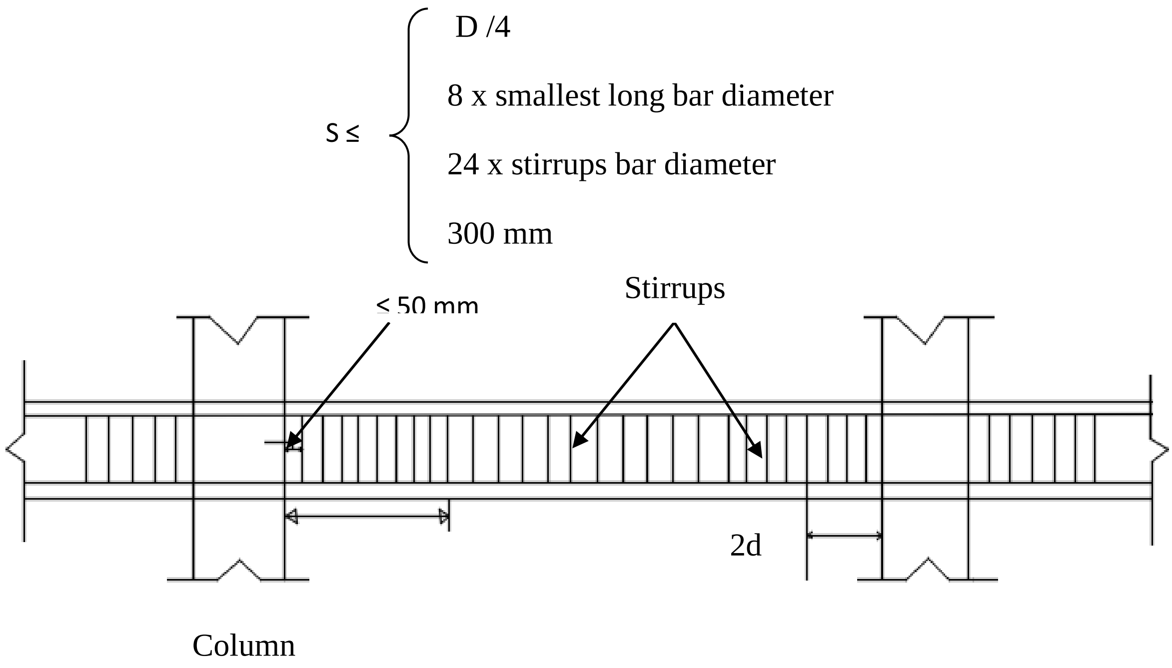


Figure: 2.10 Transverse Reinforcements of Beams (BNBC, 2015).

In regions of high seismic risk, the transverse reinforcement for confinement must consist of hoops. Hoops are required over a length twice the member depth measured from face of support or in each direction from any section where yielding is expected. Wherever inelastic deformation causes the development of yielding away from the end of a member, this point is treated as a column face for determine the requirements for closed hoops. Spacing of hoops must not exceed d / 4, 8 times diameter of the smallest longitudinal bar, 24 times the diameter of the hoop bars or 12 inch in Figure - 2.11.Along the remainder of the members, stirrups at no more than d / 2 spacing are required (BNBC, 2015).

2.14.4 Longitudinal Reinforcement of Columns

The main reinforcement in columns is longitudinal, parallel to the direction of the load and consists of bars arranged in a square, rectangular, or circular shape. The provisions of longitudinal reinforcements of column are the reinforcement ratio; ρ shall not be less than 0.01 and shall not exceed 0.06. Lap splices are permitted only within the centre half of the member length and shall be design as tension splices. Welded splices and mechanical connections are allowed for splicing the reinforcement at any section provided not more than alternate longitudinal bars are spliced at a section and the distance between splices is 600 mm or more along the longitudinal axis of the reinforcement. Figure - 2.11 shows longitudinal reinforcements of column.

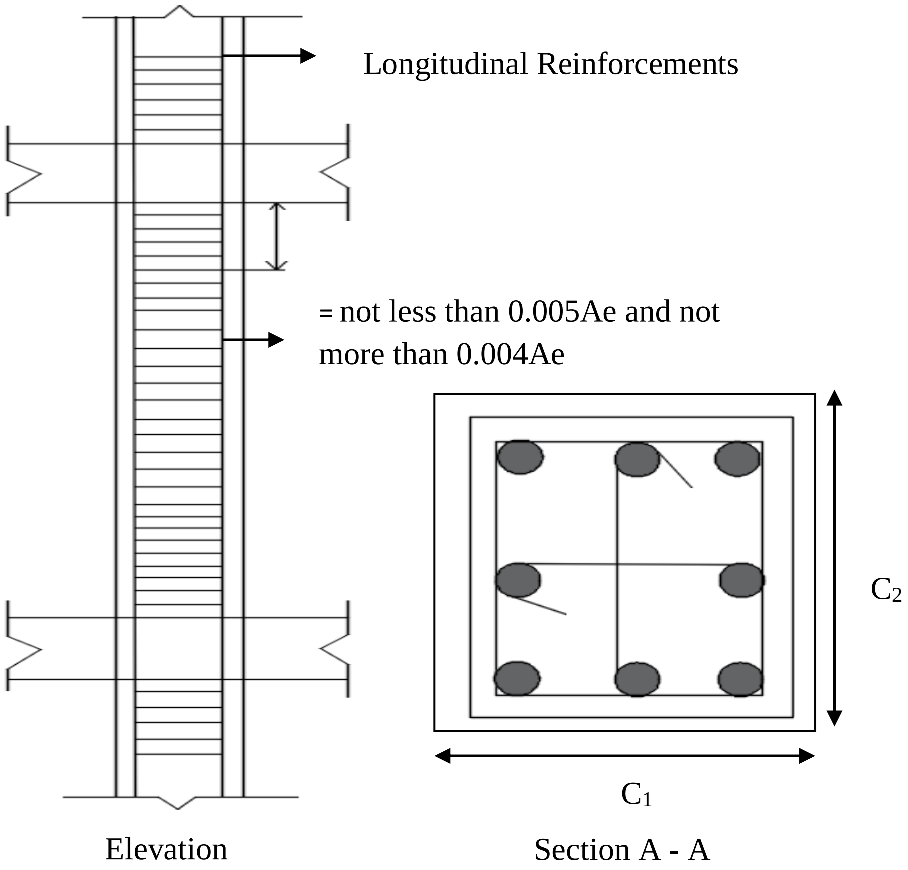


Figure: 2.11 Longitudinal Reinforcements of Column.

2.14.5 Transverse Reinforcements of Column

Column ends require adequate confinement to ensure column ductility in the event of hinge formation. They also require adequate shear reinforcement in order to prevent shear failures prior to the development of the flexural capacity of the section. The correct amount, spacing, and location of the transverse reinforcement must be provided. Maximum tie spacing of column shall not exceed S_o over a length l_o measured from the joint face. The spacing S_0 shall not exceed (i) 8 times the diameter of the smallest longitudinal bar enclosed, (ii) 24 times the diameter of the tie bar, (iii) one - half of the smallest cross-sectional dimensions of the frame member, and (iv) 300 mm. The length l_0 shall not be less than (i) one sixth of the clear span of the member, (ii) maximum cross sectional dimension of the member, and (iii) 450 mm. The first tie shall be located not more than S_o / 2 from the joint face and tie spacing shall not exceed $2s_o$ throughout the length of the member. The correct amount, spacing, and location of the transverse reinforcement must be provided so that both the confinement and shear requirements are satisfied in Figure - 2.12

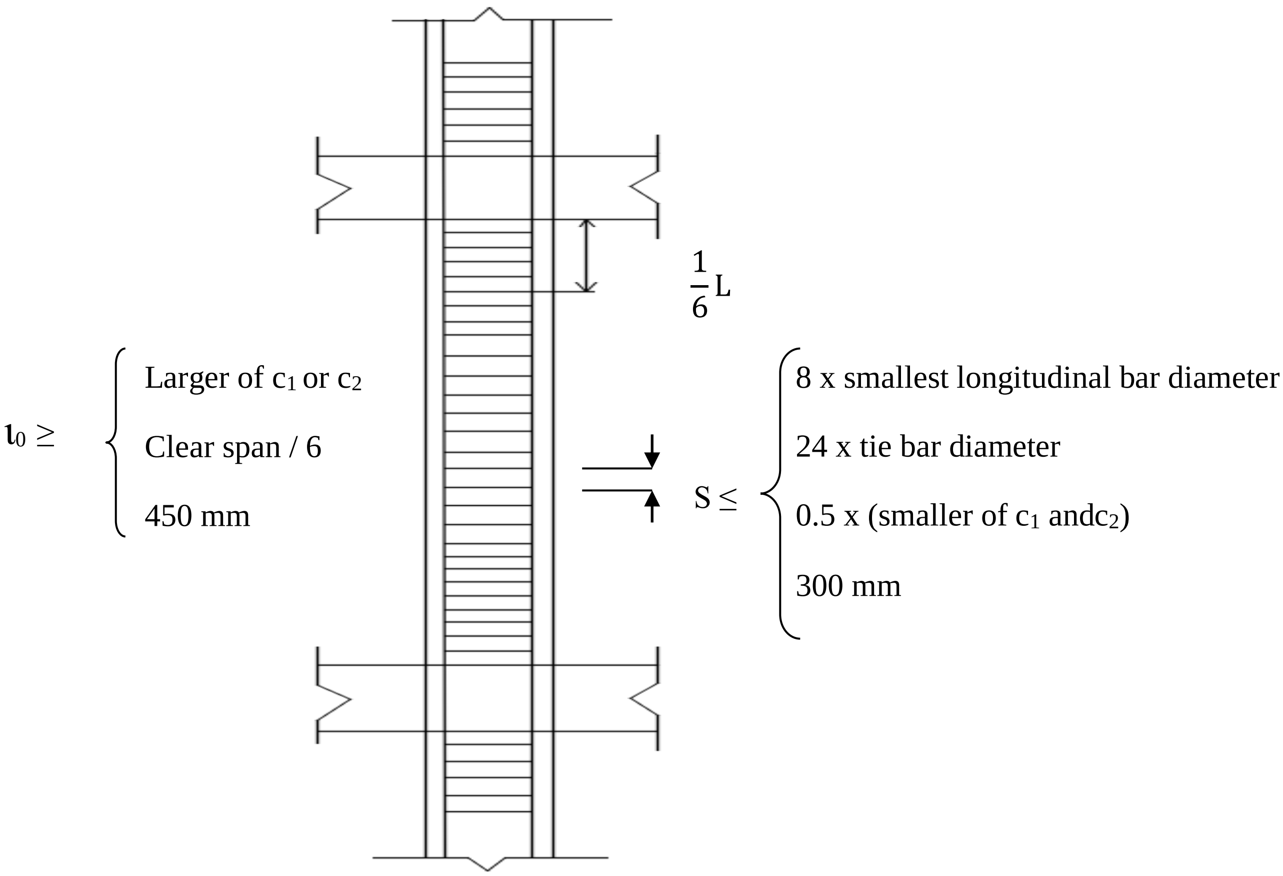


Figure: 2.12 Transverse Reinforcements of Columns.

2.14.6 Beam - Column Joint

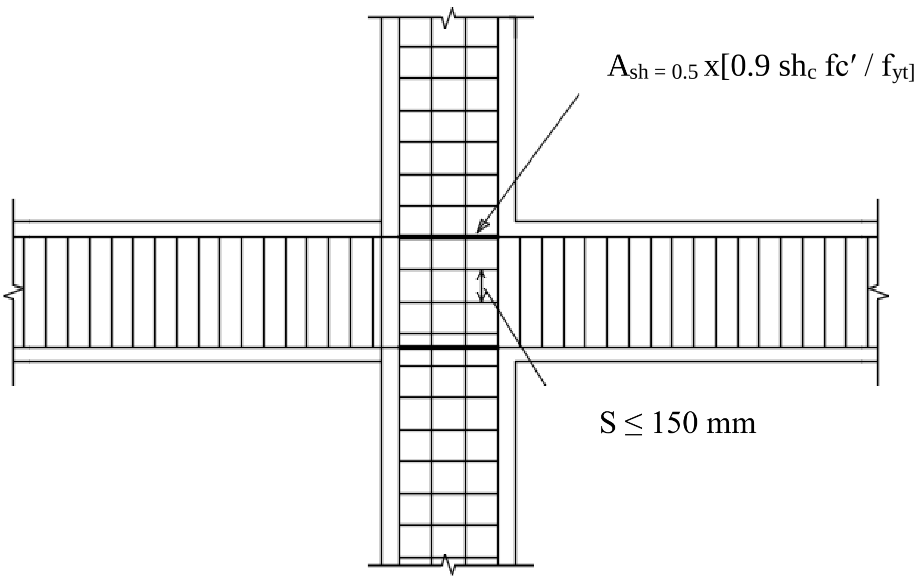
A beam and column joint undergoes serious stiffness and strength degradation when subjected to earthquake loads. A joint should exhibit a service load performance equal to or greater than that of the members it joins; that is, the failure should not occur within the joints. Should there be a failure due to overloading, it should occur in beams through large flexural cracking and plastic hinge formation, and not in columns. A joint should possess strength not less than the maximum demand corresponding to the development of the structural plastic hinge mechanism of the structure. Beam and column joint should respond elastically during moderate earthquakes and the deformation of joints should not increase the storey drift significantly.

2.14.6.1 Longitudinal Reinforcement

The provisions of longitudinal reinforcements of beam and column joint forces in longitudinal beam reinforcement at the faces of joints of reinforced concrete frames shall be determined for a stress of $1.25f_y$ in the reinforcement and Joint strength shall be calculated by the appropriate strength reduction factors. Beam longitudinal reinforcement terminated in a column shall be extended to the far face of the confined column core and anchored in tension. Where longitudinal beam reinforcement extends through a beam and column joint, the column dimension parallel to the beam reinforcement shall not be less than 20 times the diameter of the largest longitudinal beam bar for normal weight concrete. For light weight concrete, the dimension shall not be less than 26 times the bar diameter.

2.14.6.2 Transverse Reinforcement

Transverse hoop reinforcement shall be provided within the joint, unless the joint is confined by structural members. Within the depth of the shallowest framing member, transverse reinforcement equal to at least one half the amount required shall be provided where members frame into all four sides of the joint and where each member width is at least three - fourths the column width. Details of required transverse reinforcements for beam - column shown in Figure 2.13 and Figure - 2.14



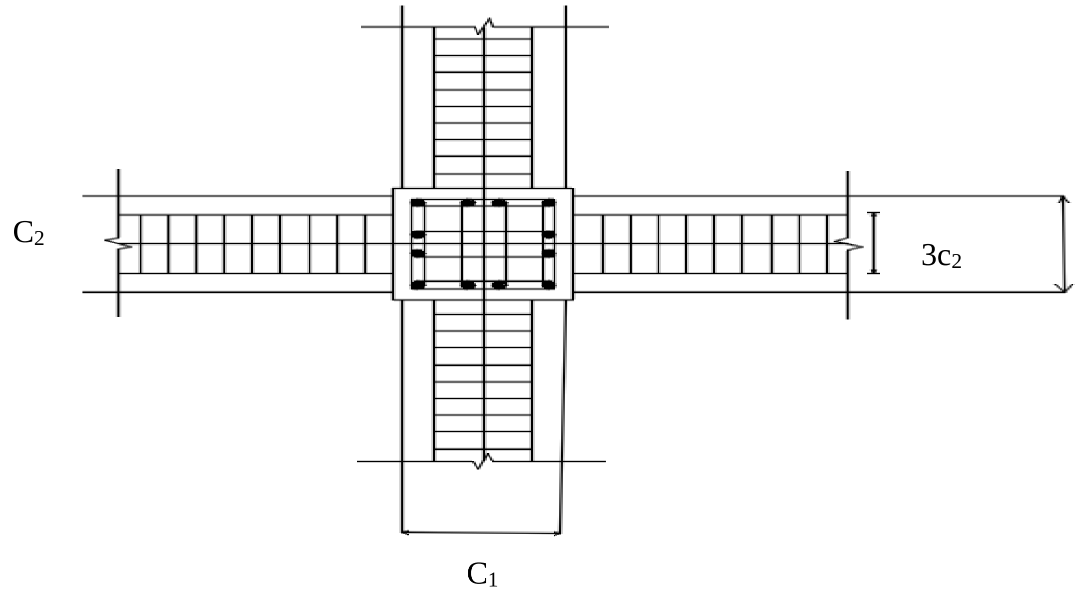


Figure: 2.13 Transverse Reinforcement Requirements for joint Confined by Structural Member.

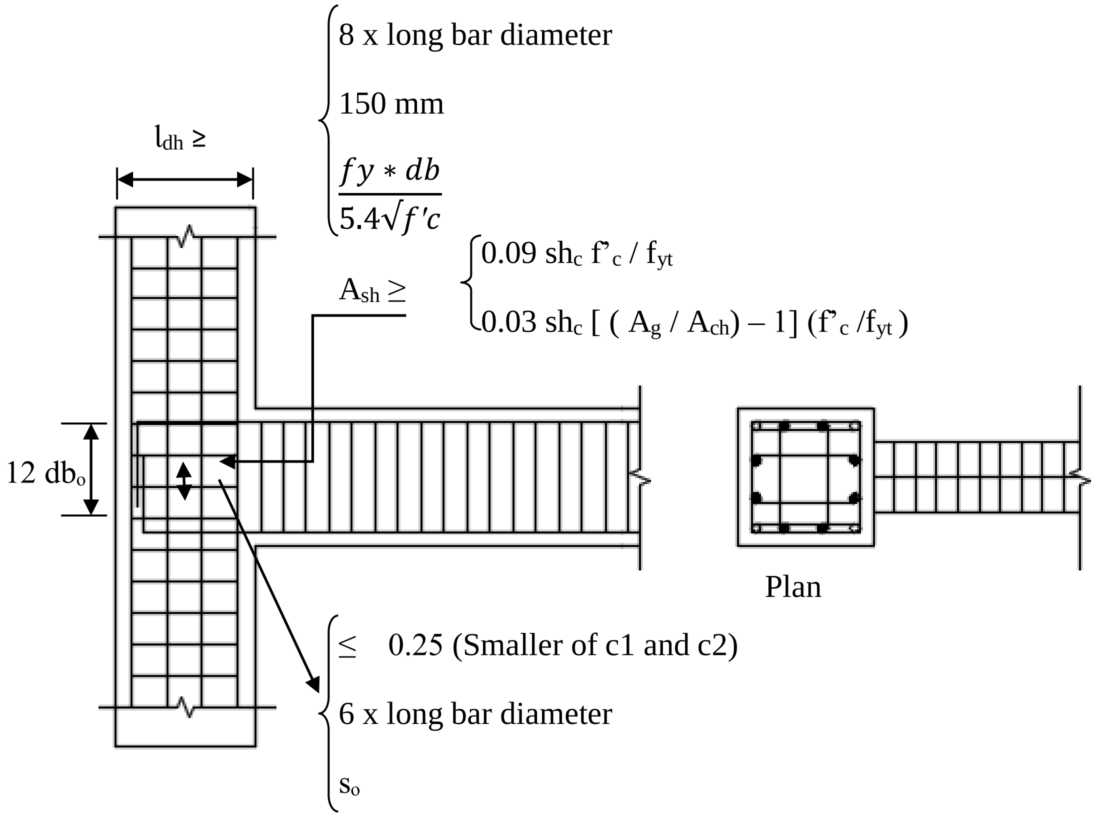


Figure: 2.14 Transverse Reinforcement Requirements for joint not Confined by Structural Member.

2.14.6.3 Anchoring Beam Bars

The gripping of beam bars in the joint region is improved first by using columns of reasonably large cross sectional size. The American Concrete Institute recommends a column width of at least 20 times the diameter of largest longitudinal bar used in adjoining beam (Murty, 2005).In exterior joints where beams terminate at columns Figure 2.15, longitudinal beam bars need to be anchored into the column to ensure proper gripping of bar in joint. The length of anchorage for a bar of grade Fe 415 (characteristics tensile strength of 415 MPa) is about 50 times its diameter.

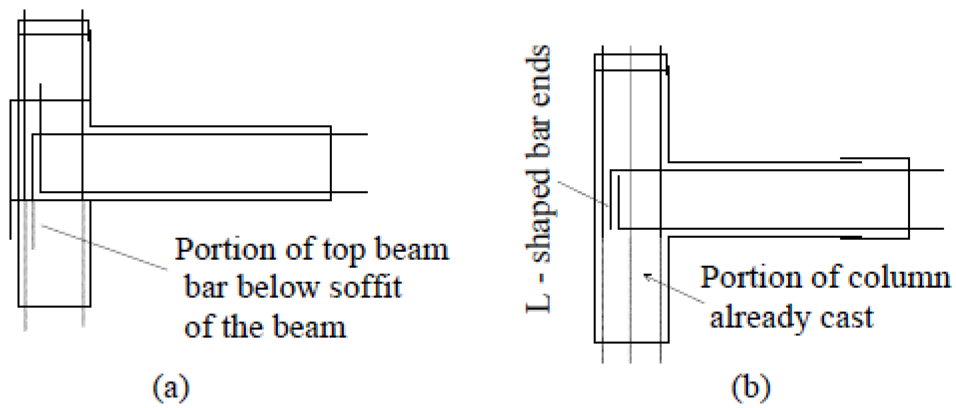


Figure: 2.15 Anchorage of Beam bars in Exterior Joint.

2.15 Shear Wall

Shear wall is a structural member used to resist lateral forces i.e. parallel to the plane of the wall. For slender walls where the bending deformation is more, Shear wall resists the loads due to cantilever action. In other words, Shear walls are vertical elements of the horizontal force resisting system. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced concrete wall. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting forces. This leads to the failure of the structures by shear. Shear walls are especially important in high rise buildings subject to lateral wind and seismic forces. Generally, shear walls are either plane or flanged in section, while core walls consist of channel sections. They also provide adequate strength and stiffness to control lateral displacements. The shape and plan position of the shear wall influences the behavior of the structure considerably. Structurally, the best position for the shear walls is in the center of each half of the building.

2.15.1 Reinforcement Bars in RC Walls

The sum of the areas of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross sectional area of the wall and the area of reinforcement in either direction shall not be less than 0.007 times the gross cross-sectional area of the wall. The spacing of reinforcement shall not exceed 1.20 m. The diameter of reinforcing bar shall not less than 10 mm except that joint reinforcement may be considered as part of all of the requirements for minimum reinforcements.

2.15.2 Boundary Elements

Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile wav, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without losing strength (Figure - 2.16, Figure - 2.17). End regions of a wall with increased confinement are called boundary elements. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames sometimes; the thickness of the shear wall in these boundary elements is also increased. RC walls with boundary elements have substantially higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls without boundary elements. Boundary members to shall be as follows according to BNBC -2015:

d) Boundary members shall be provided when the failure mode is flexure and the maximum extreme fiber stress exceeds 0.2fm′ .The boundary members may be discontinued where the calculated compressive stresses are less than 0.15 fm′. Stress may be calculated for the factored forces using a linearly elastic model and gross section properties.

e) When the failure mode is flexure, boundary member shall be provided to confine all vertical reinforcement whose corresponding masonry compressive stress exceeds $0.4f_{m'}$.The minimum length of the boundary member shall be 3 times the thickness of the wall.

f) Boundary members shall be confined with minimum of 10 mm diameter bars at a maximum of 200 mm spacing or equivalent within the grouted core and within the region defined by the base of the shear wall and a plane at a distance L_w above the base shear wall.

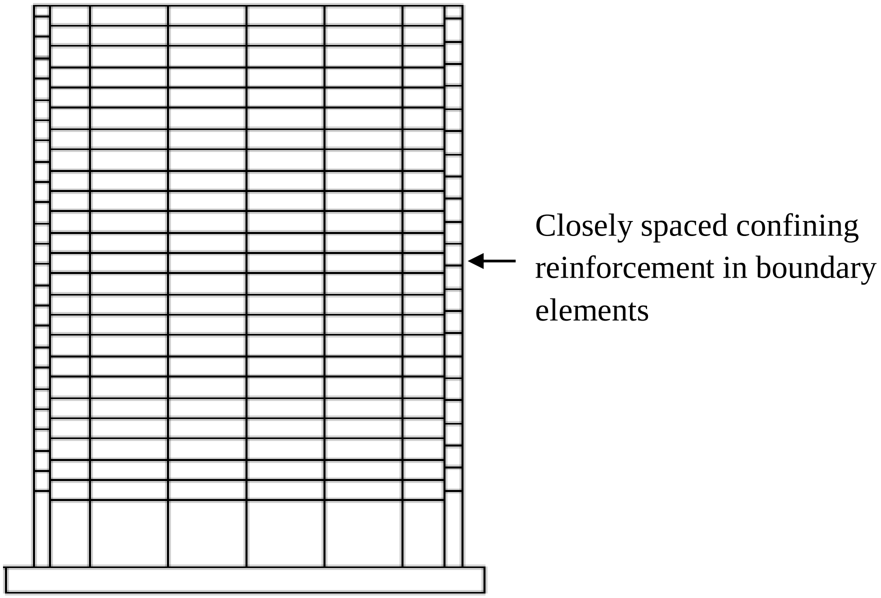


Fig: 2.16 Boundary Elements of Shear Wall.

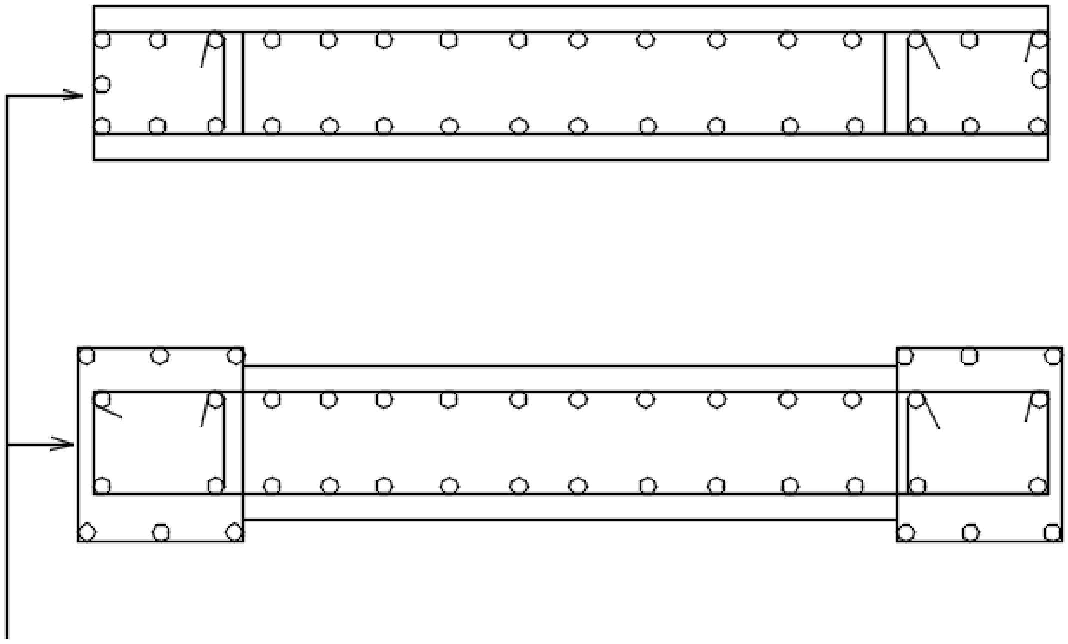


Figure: 2.17 Shear Wall Reinforcements

2.16 Estimating and Costing

Estimating can be done at various stages of project duration depending on the purpose of estimation. First estimation is done before construction starts for the purpose of making budget of the project or bidding the project as a contractor. There are various types of estimation can be done depending on project manual and drawing provided and the purpose of using estimated data. Detail Estimate, unit estimate, model estimate, comparison estimate, parametric estimate are common types of estimate. Accuracy in estimate is very important, if estimate is exceeded it becomes a very difficult problem for engineers to explain, to account for and arrange for the additional money. Inaccuracy in preparing estimate, omission of items, changes in designs, improper rates, etc. are the reasons for exceeding the estimate, though increase in the rates is one. The rate of each item should also be reasonable and workable. The rates in the estimate provide for the complete work, which consist of the cost of materials, cost of transport, cost of labor, cost of scaffolding, cost of tools and plants, cost of water, taxes, establishment and supervision cost, reasonable profit of contractor, etc. The primary object of the estimate is to enable one to know beforehand, the cost of the work (buildings, structures, etc). The estimate is the probable cost of a work and is determined theoretically by mathematical calculations based on the plans and drawing and current rates. There are numerous methods to calculate the project cost. Approximate estimate may be prepared by various methods but accurate estimate is prepared by detailed estimate method**.** Preparation of detailed estimate consists of working out the quantities of different items of work and then working out the cost.

2.16.1 Details of Measurements and Calculation of Quantities

The whole work is divided into various items of work as layout, earthwork, shuttering, reinforcement fabrication, concreting, etc. Details of measurement of each item of work are taken out and quantities under each item are computed in prescribed form details of Measurement Form.

2.16.2 Abstract of Estimated Cost

The cost under item of work is calculated from the quantities already computed at workable rate, and the total cost is worked out in a prescribed form, Abstract of Estimate Form. A percentage of 3 to 5 percent is added for contingencies, to allow for petty contingent expenditures, unforeseen expenditures, changes in design, changes in rates, etc. which may occur during the execution of the work. A percentage of 1 to 2 per cent is also added to meet the expenditure of work-charged establishment. The grand total thus obtained is the estimated cost of the work.

2.16.3 Analysis of Materials

In recent times, reinforced concrete buildings have become common in Bangladesh, particularly in towns and cities. Reinforced concrete (or simply RC) consists of two primary materials, namely concrete with reinforcing steel bars. Concrete is made of sand, crushed stone (called aggregates) and cement, all mixed with pre determined amount of water. Concrete can be molded into any desired shape, and steel bars can be bent into many shapes. High strength concrete is influenced by properties of cement; sand aggregates & water and cement ratio have compressive strength above 40 MPa. To achieve high strength, it is necessary to use lowest possible water and cement ratio, which invariably affects the workability of the mix and necessitates the use of special vibration techniques for proper compaction. In this study 60,000 psi yield stress steel has used for building frame analysis and estimate the material cost. Concrete strength also depends on aggregate size and shape. Aggregates are the important constituents of the concrete which give body to the concrete and also reduce shrinkage.

2.17 Conclusion

From the review of literature presented in this chapter it has become clear about tectonic location of Bangladesh and causes of earthquakes. Effects of earthquakes and vulnerability of structure are also discussed in this chapter. From the discussion of different structural systems obtained a complete knowledge on building structures. the code specified guidelines and seismic design philosophy highlighted here which provided details knowledge on different building codes and specifications of seismic design criteria according to upcoming BNBC 2015. It also gave comparative ideas for different seismic zones, base shear, time period, response modification factors and others between BNBC 1993 and upcoming BNBC 2015. Procedures of materials estimation and calculation of materials quantities, analysis of materials also delineated in this literature.

CHAPTER - 3

CASE STUDY OF SELECTED STRUCTURES

3.1 General

The main objective of this study is to find out the difference in analysis results and construction materials required of a structure due to seismic load in four different seismic zones of Bangladesh. The materials (reinforcement and concrete) those are generally available in Bangladesh. Two different heights (80 ft. and 150 ft.) of intermediate moment resisting frame structure has been considered for analysis and design to find out the variations of story drift, story displacement, base shear, reinforcements in four seismic zones of Bangladesh. This chapter will discuss about design criteria, building loads, material property, structural system, response modification factor, structural stability, drift, overturning moment according to BNBC - 2015. Analysis and design of these structures have been carried out by using ETABS - 16. Various results have been discussed in chapter four.

3.2 Design Criteria

Building design criteria are those parameters which are required for analysis of a structure. Important parameters are structural element size and shape, material property, loads (dead load, live load, floor finish, partition walls loads, live load, seismic load, and wind load). Seismic zones, soil type, structural system, load combination are also most important for building analysis and design. In this study clayey sand(SC) type soil, compressive strength of concrete 4000 psi, yield stress of steel 60,000 psi , intermediate moment resisting frame are considered for analysis and design of these building in four seismic zones of Bangladesh.

3.3 Loads

A building load is simply a force that a building frame needs to resist. Assessment of their effects is carried out by the methods of structural analysis. Dead loads, live loads, wind loads, snow loads, earthquake loads are load types that acting on a structure. In this study, selected live load, partition wall load and floor finish load are considered 40 psf, 60 psf and 25 psf, respectively.

3.4 Load Combinations

After establishing the design loads of the proposed project, the next thing to consider is to determine the appropriate design load combinations. Generally, load combination is composed of individual loads, i.e. dead load superimposed dead loads and live loads that are combined together to come up for a strength design and allowable stress design. By the ASCE7-10 (section 1.2.1) code definition, strength design is the product of the nominal strength and a resistance factor while the allowable stress design is composed of computed forces produced in the member by factored loads that shall not exceed the member design strength. Each design code and standards had a different recommendation when it comes to loading combinations. In this article, we will emphasize the design load combinations as recommended by ASCE7-10 for basic design load combinations with the touch of UBC97 seismic load combinations. Let us bear in mind that the use of design load and load combinations is depending on the approved code and standards authorize by your local authority having jurisdiction. Before we proceed into the lists of load combinations, let us take a look at the following symbols used: Ak= load or load effect arising from extraordinary event D= dead load, Dt = weight of ice, E = Earthquake Load, H= lateral earth pressure load L = live load, Lr = roof live load, R= rain load, S = Snow load, T = self-straining load, W= wind load, Wi = wind on ice

3.4.1 Horizontal Earthquake Loading

The directions of application of seismic forces for design shall be those which will produce the most critical load effects. Earthquake forces act in both principal directions of the building simultaneously. In order to account for that,

(a) For structures of Seismic Design Category B, the design seismic forces are permitted to be applied independently in each of two orthogonal directions and orthogonal interaction effects are permitted to be neglected

(b) Structures of Seismic Design Category C and D shall, as a minimum, conform to the requirements of (a) for Seismic Design Category B and in addition the requirements of this Section. The structure of Seismic Design Category C with plan irregularity type V and Seismic Design Category D shall be designed for 100% of the seismic forces in one principal direction combined with 30% of the seismic forces in the orthogonal direction. Possible combinations are:

"±100% in x-direction ±30% in y-direction" or

"± 30% in x-direction ±100% in y-direction"

3.4.2 Vertical earthquake loading

The maximum vertical ground acceleration shall be taken as 50 percent of the expected horizontal peak ground acceleration (PGA). The vertical seismic load effect E_v may be determined as:

$E_v = 0.50(ah)D$ (6.2.56)

Where,

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

D = effect of dead load

3.4.3 Combination of earthquake loading with other loadings

When earthquake effect is included in the analysis and design of a building or structure, the provisions of load combinations are as per BNBC, 2015 presented in Table 3.1

Table: 3.1 Load Combinations (BNBC, 2015).

Serial	Basic Combinations
1.	1.4 (D+F)
2.	1.2 (D+F+T) + 1.6 (L+H) + 0.5 (Lr or R)
3.	1.2 D + 1.6 (Lr or R) + (1.0L or 0.8 W)
4.	1.2 D + 1.6 W + 1.0 L + 0.5 (Lr or R)
5.	1.2 D + 1.0 E + 1.0 L
6.	0.9 D + 1.6W + 1.6 H
7.	0.9D + 1.0 E + 1.6 H

In which,

D = Dead load; L = Live load; E = Earthquake load; F = Lateral forces; R = Rain water load; L_r = Roof live load

For design and analysis of this structure load combination no five has considered finding out the variation of story drift, story displacement, base shear difference, required reinforcement difference for four seismic zones in Bangladesh.

3.5 Structural System

Structural system is the particular method of assembling and constructing structural elements of a building so that individual elements transmit applied loads safely to the ground without exceeding the allowable stresses in the members. Moment resisting frames, bearing wall frames, dual system frames are basics types of structural systems. In this study a dual frames of structural system are considered.

3.6 Response Modification Factor

Response modification factor is one of the seismic design parameters to consider nonlinear performance of building structures during strong earthquake. Its magnitudes depend on the type and material of the structure. In the force based seismic design procedures, the response modification factor (R) is the one used to reduce the linear elastic response spectra to the inelastic ones. In other words, response modification factor is the ratio of strength required to maintain the structural elasticity. The response modification factor is determined as follows

$R = R_{\mu}.R_s$

Where, Rμ is a reduction factor due to ductility and R_S is the over strength factor. Different code has specified for the R value based on structural system. In this study two different heights of intermediate moment resisting frames (dual system) are considered for analysis and design. According to Bangladesh National Building Code 2015 the value of R for intermediate dual framing system (ordinary concrete) is 6.5.

3.7 Drift

Drift is defined as the lateral displacement. Storey drift is the drift of one level of a multistory building relative to the level below. Inter story drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height. Lateral deflection is the predicted movement of a structure under lateral loads and story drift is defined as the difference in lateral deflection between two adjacent stories during an earthquake or large lateral forces. The design story drift of each storey shall not exceed the allowable story drift as obtained from table 3.2 for any story.

Table: 3.2 Allowable Story Drift Limit (Δ_a)

Structure	Occupancy Category		
	I and II	III	IV
Structure, 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.	0.025 h_{sx}	0.020 h_{sx}	0.015 h_{sx}
Masonry Cantilever shear wall structures	0.010h_{sx}	0.010h_{sx}	0.010h_{sx}
Other masonry shear wall structure	0.007h_{sx}	0.007h_{sx}	0.007h_{sx}
All other structures	0.020h_{sx}	0.015h_{sx}	0.010hsx

3.8 Storey Displacement

Storey Displacement is the lateral displacement of the storey relative to the base. Story displacement is the absolute value of displacement of the storey under action of the lateral forces. The overall sway (horizontal deflection) at the top level of the building or structure due to wind loading shall be limited to $\frac{1}{500}$ times of the total height of the building above ground.

3.9 Overturning

Overturning moment is the torque due to the resulting applied forces about the points of contact with the ground or base. It is the perpendicular distance of the line of action of the force from base of the body. If this torque is more than the torque due to self weight about the base line the body will overturn. Over turning moments can be calculated from the triangle load distribution formula. In this study building overturning moments due to lateral load in X and Y direction are checked by ETABS 2016 analysis results. The overturning moments at level x, M_x shall be determined as follows:

$$M_x = \sum F_i (h_i - h_x)$$

F_i = portion of the seismic base shear, v induced at level i, i =1 to n.

h_i, h_x = Height from the base to level I or x.

3.10 Stability

Structure is in stable equilibrium when small perturbations do not cause large movements like a mechanism. Structure vibrates about it equilibrium position. Structure is in unstable equilibrium when small perturbations produce large movements and the structure never returns to its original equilibrium position. After analysis of a structure some parameter has been checked to see the structural stability. In this study drift, overturning moment, base shear and displacement has checked in for seismic zones in Bangladesh.

3.11 Models

150 feet and 80 feet of two heights of intermediate dual frames structures have been considered for this study which plans and elevations are shown in Figure 3.1, Figure 3.2 and figure - 3.3, 3.4, respectively. Same size of structural elements are considered for four seismic zones in Bangladesh .So the quantity of materials is varying for same structure in different seismic zones in Bangladesh. It is discussed in chapter four.

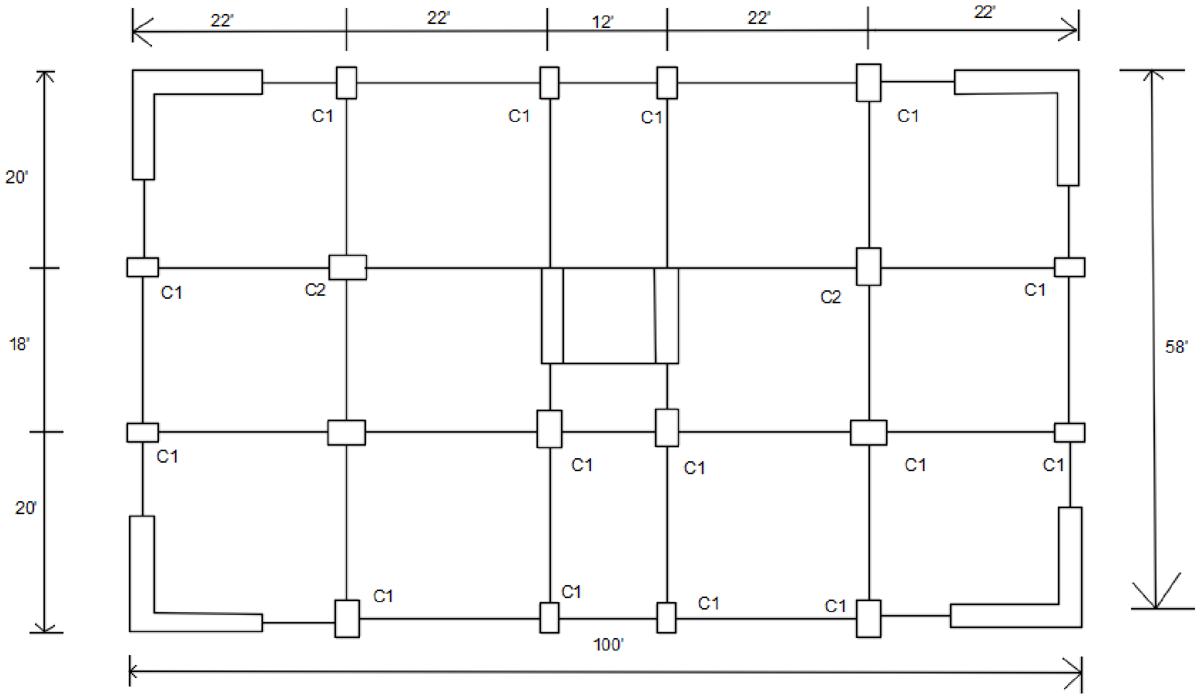


Figure: 3.1 Plan of Selected 80 feet Height Structure.

C1 = (18″ x 18″), C2 = (22″x22″), Beam =(12″ x 24″) , Wall thickness = 10″

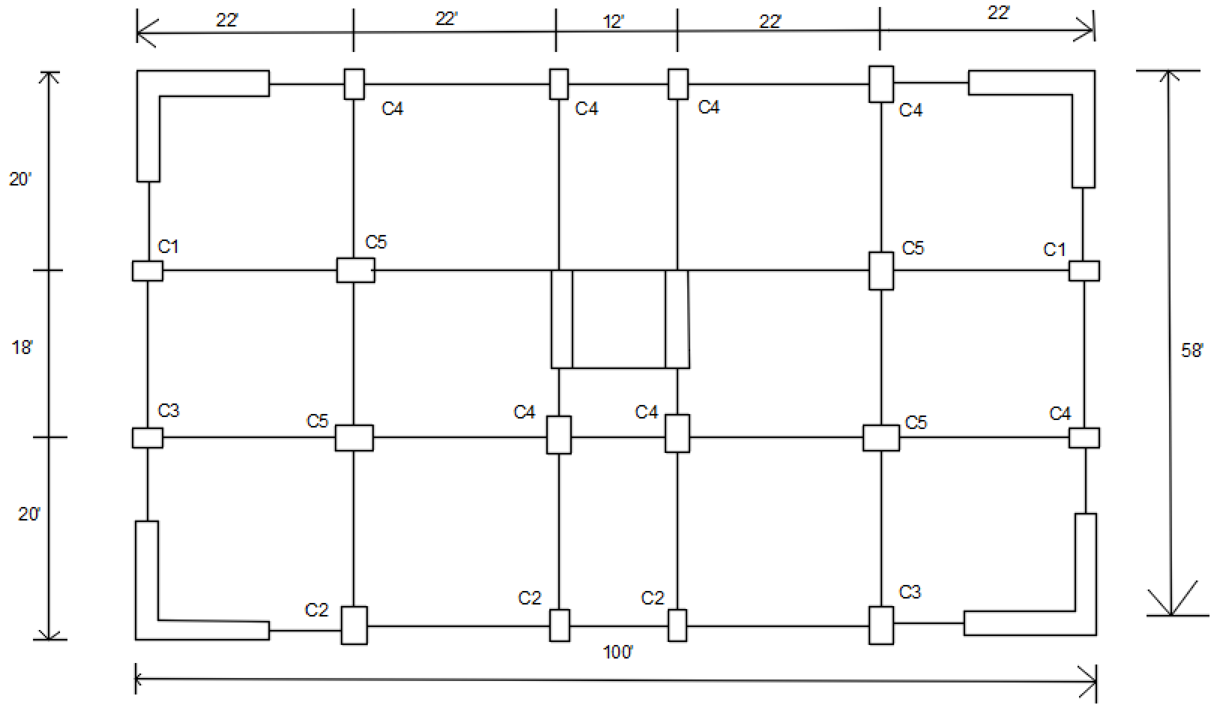


Figure: 3.2 Plan of Selected 150 feet Height Structure.

Here, C1 = 18″ x 20″, C2 = 20″ x 20″, C3 = 20″ x 22″ , C4 = 22″ x 22″ , C5 = 25″ x 25″

Beam = 12″ x 28″, Wall thickness = 15″

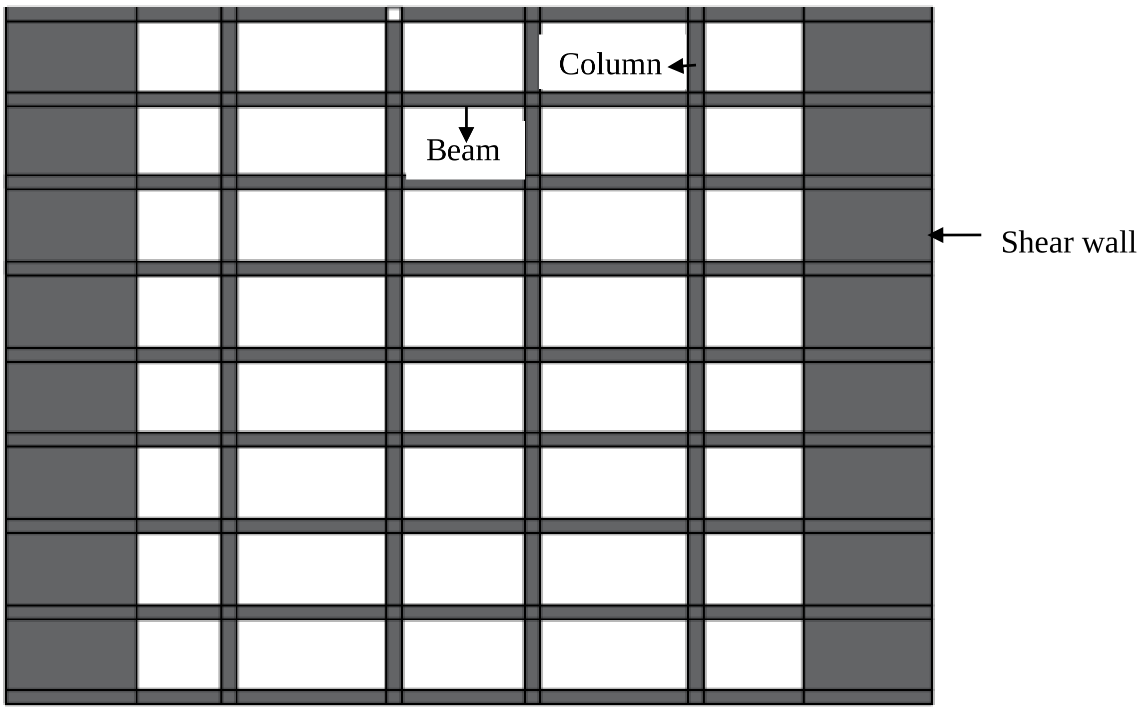


Figure: 3.3 Front elevation of Selected (80ft. height) Structure

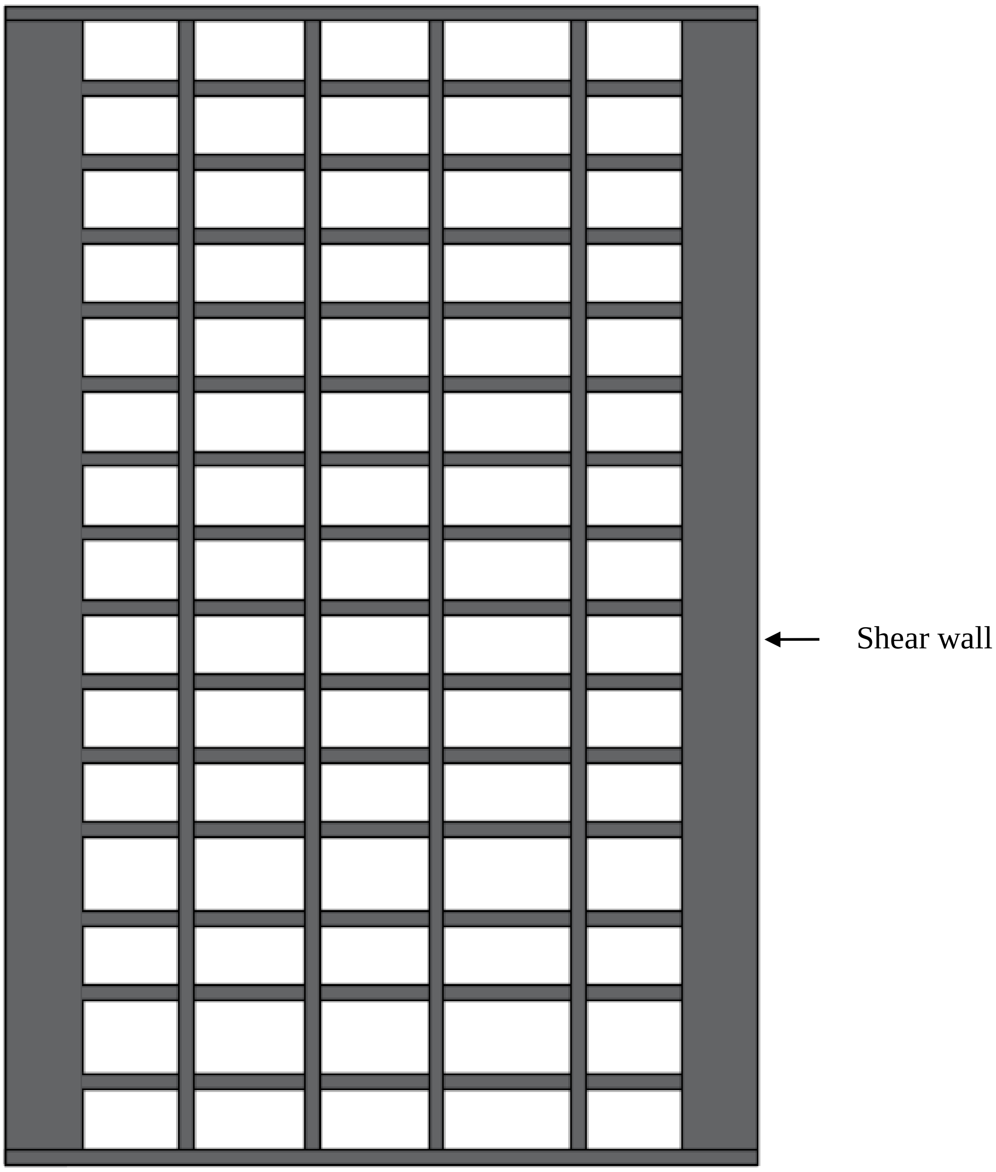


Figure: 3.4 Front Elevation of Selected (150ft. height) Structure.

3.12 Software

Civil Engineering software encompass arrange of tools to help of civil engineers during both the design and construction process. Civil engineering software's are Auto Cad, Revit, STAAD Pro, Sap -2000, ETABS, Rcon, Tekla, Matlab etc. Extended Three Dimensional Analysis of Buildings System (ETABS) non-leaner version 2016 has used for this study. Extended Three Dimensional Analysis of Building System (ETABS) has used for two different heights (80 feet and 150 feet) intermediate dual frame structure analysis and design. Analysis results of story drift and displacements discussed graphically in chapter four. Design results of structural member (beam, column and share wall) also presented graphically in chapter four.

3.13 Conclusions:

This chapter has been talked about building design criteria, building loads, and load combinations, building materials property, structural systems, story drifts and displacements according to BNBC - 2015.This chapter also has discussed on selected intermediate moment resisting frames which has been considered for this study. ETABS - 2016 has been used for analysis and design of these selected structures.

CHAPTER - 4

RESULTS AND DISCUSSION

4.1 General

Analysis and design has been carried out for two different heights of buildings (80 feet and 150 feet) are selected for this comparative study different for four seismic zones in Bangladesh. At first comparisons are carried out on analysis results such as story displacement, story drift and base shear in four seismic zones in Bangladesh. Comparisons also carried out on design results of those structures, to find out the variation of required materials due to seismic loads in four seismic zones in Bangladesh. It is to be noted that here only beam, column, share wall, required reinforcement have been calculated for comparing of those structures. Comparisons are also carried out on required reinforcement per square feet of this structure in four seismic zones.

4.2 Analysis Results

These structures (80 feet and 150 feet height) are analyzed as an intermediate moment resisting frames (dual system). Loads are considered as per BNBC, 2015 which has been already discussed in chapter three. Results have compared on storey displacement, storey drift, base share, required reinforcements for four seismic zones in Bangladesh.

4.2.1 80 feet Height Structure

This structure is analyzed as a dual frame system. Hence, constant wind velocity is considered in four seismic zones. Loads are considered as per BNBC, 2015 which has been discussed in chapter three. Results have been compared, on story deflection, story drift, base shear and required reinforcements per square area of this structure.

4.2.2 Storey Displacement

Story displacement for lateral loads at X and Y directions are shown in Figure 4.1 and 4.2 for four seismic zones. Allowable displacement due to lateral loads at different are also to compared with actual displacements in four seismic zones. The maximum story displacements of this building in Zone -1, Zone - 2 and Zone -3, Zone - 4 are 0.44 inch, 1.17 inch and 1.69 inch, 1.98 inch, respectively for X direction and The maximum story displacements of this building in Zone -1, Zone - 2 and Zone -3, Zone - 4 are 0.34 inch, 0.93 inch and 1.35 inch, 1.56 inch, respectively for Y direction.

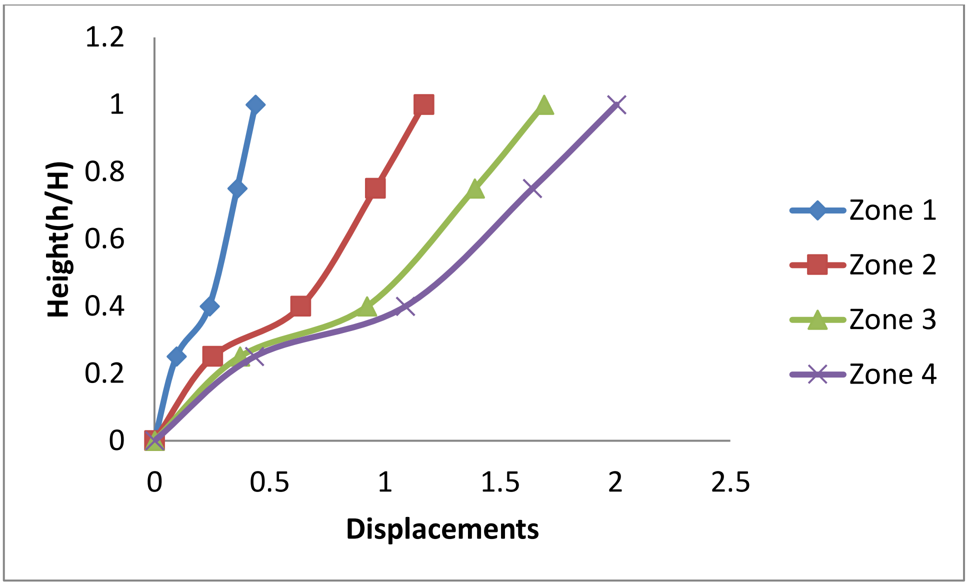


Figure 4.1: Storey Displacement along X direction for Four Seismic Zones.

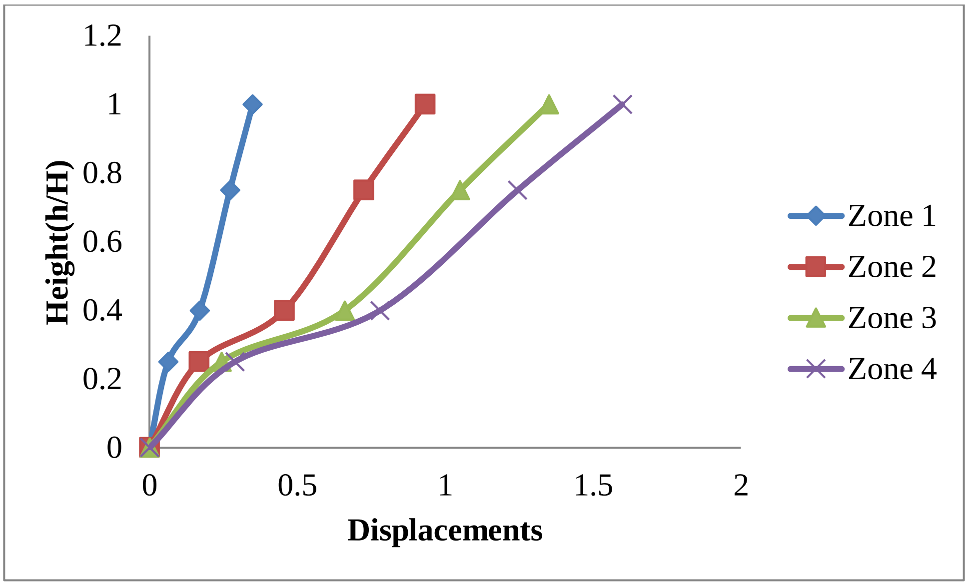


Figure 4.2: Storey Displacement along Y Direction for Four Seismic Zones.

4.2.3 Storey Drift

Story drift at different height of the structure due to lateral loads in X and Y direction are shown in Figure 4.3 and Figure 4.4 for four seismic zones. It is to be highlighted here that allowable drift at different storey height as per BNBC, 2015 are more than actual drift of this structure. Maximum story drifts of seismic Zone - 1, 2 and 3, 4 are 0.0006, 0.0016 and 0.0023, 0.0027, respectively in X direction and 0.0004 0.0012 and 0.0017.0.0021, respectively in Y direction.

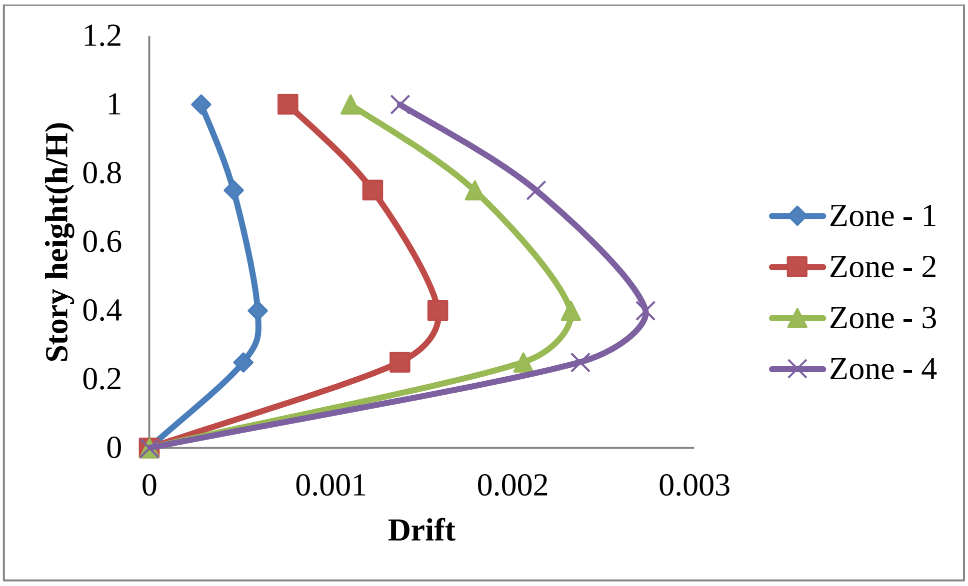


Figure: 4.3 Story Drift of This Structure along X Direction.

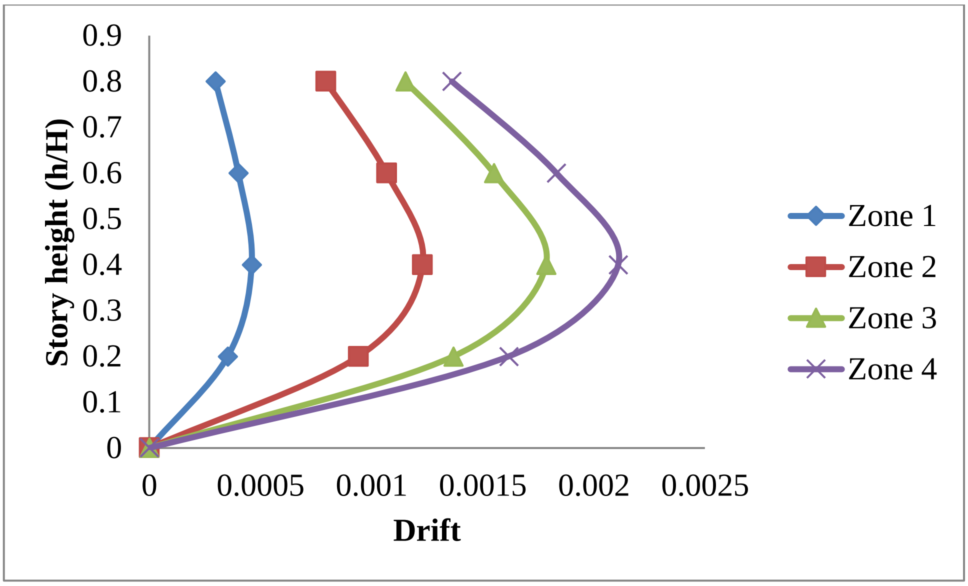


Figure: 4.4 Story Drift of This Structure along Y Direction.

4.2.4 Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on soil conditions at the site. Figure 4.5 shows the total base shear of this structure are 240.87 kips, 643 kips, 932 kips, and 1102 kips, respectively in four seismic zones.

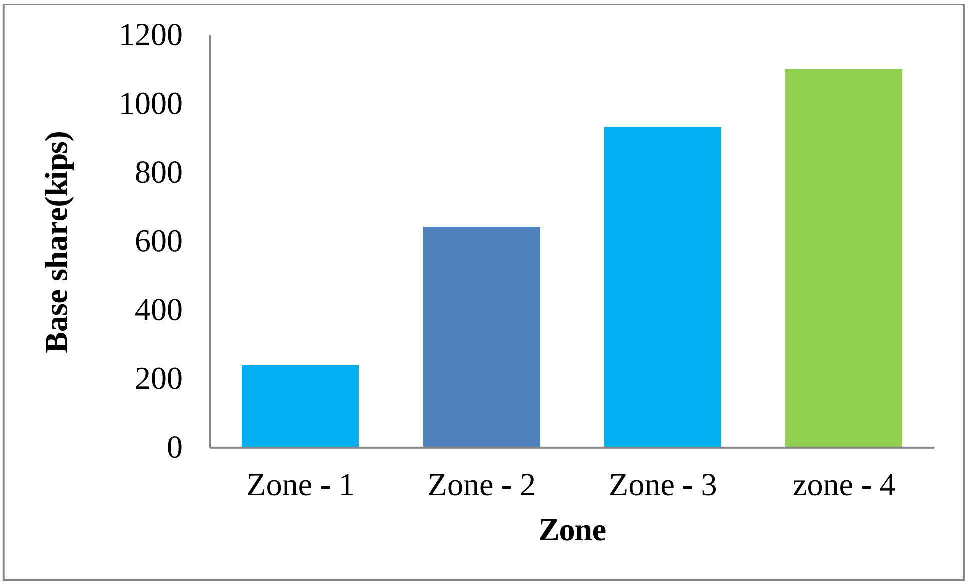


Figure: 4.5 Base Shears in Four Seismic Zones.

4.2.5 Selected Column (C1) Reinforcements

A column is considered for fixed value of R in four seismic zones.Here, analysis and design parameters for column elements are equal in four seismic zones,only seismic zone are varied.Reinforcement required of selected column (C1, Figure 4.6) of this selected structure (80 ft.) is given figure 4.6 for four seismic zones. It is estimated that the total reinforcement of selected column (C1) for these structues are 956 kg, 1091 kg ,1186 tons, 1281 kg for zone 1, 2, 3 and 4 respectively. It has observed that of this building due to seismic load required column reinforcement are 14%, 20%, 33% more than Zone - 2, Zone - 3, and Zone - 4, respectively, than Zone -1.

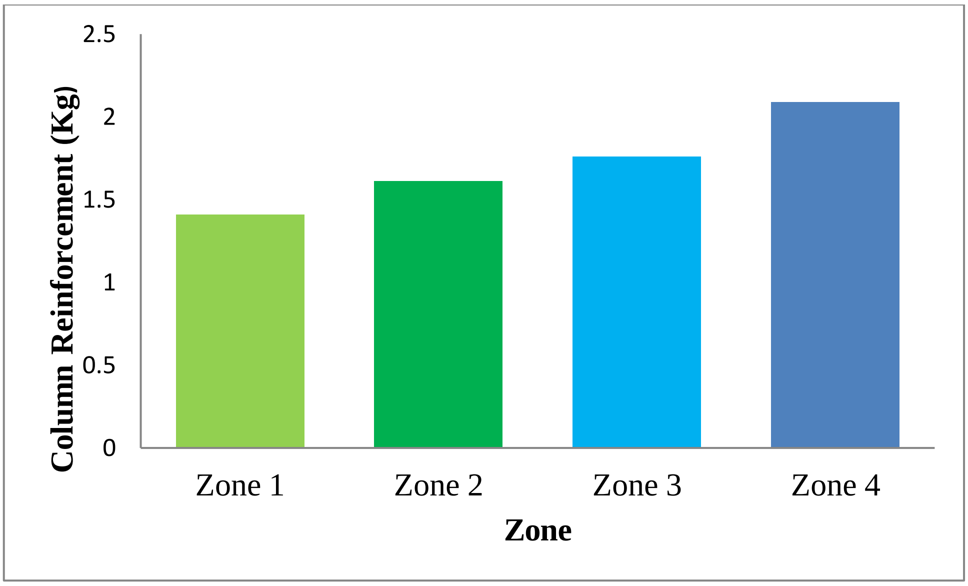


Figure : 4.6 Total Required Reinforcements of Selected column (C1) in Different Seismic Zones of Bangladesh.

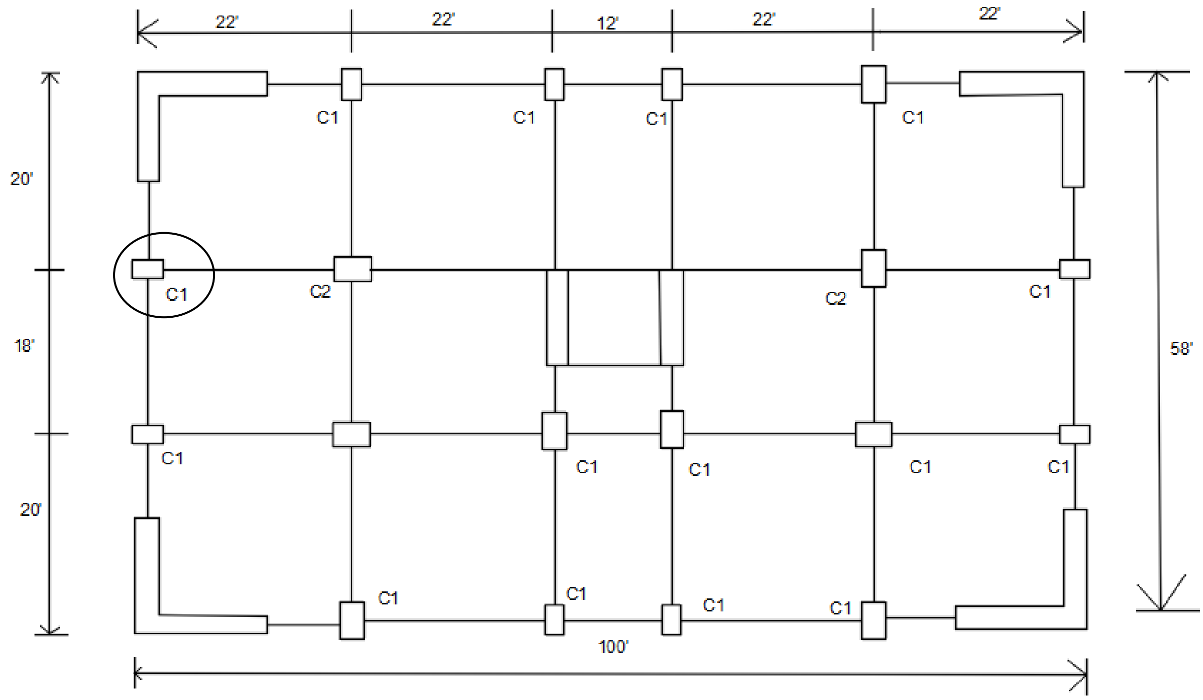


Figure : 4.7 Selected Column (C1) of This Structure in Different Seismic Zones of Bangladesh.

4.2.6 Total Column Reinforcements

Required reinforcements for total columns of this selected structure (80 ft.) is given Figure 4.8 for four seismic zones. It is estimated that the total reinforcement for columns for these structues are 18.20 tons, 20.91 tons ,22.85 tons, 26.81 tons for zone 1,2,3 and 4 respectively.

It has observed that of this building due to seismic load required column reinforcement are 12%, 22%, 40 % more than Zone - 2, Zone - 3, and Zone - 4, respectively, than Zone - 1.

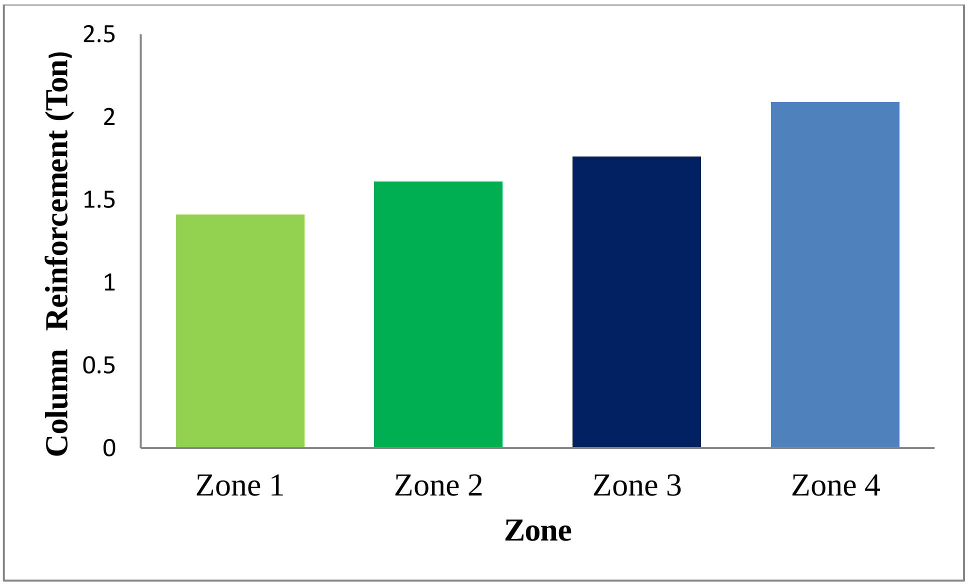


Figure : 4.8 Total Required Reinforcements of Columns in Different Seismic Zones.

4.2.7 Beam Reinforcements of Selected Beam (LB - 1)

Figure 4.9 shows the total required reinforcements of selected beam (LB -1, Figure 4.10) for this structure in four seismic zones. It is found that the total reinforcement required in zone - 1, zone - 2 and zone - 3, zones - 4 are 4.55 ton, 5.40 ton and 5.95 ton, 6.3 ton. It has estimated that required reinforcement of beam due seismic load for this building are 15 %, 25%, 40% more for Zone - 2, Zone - 3, Zone - 4 respectively, than Zone -1.

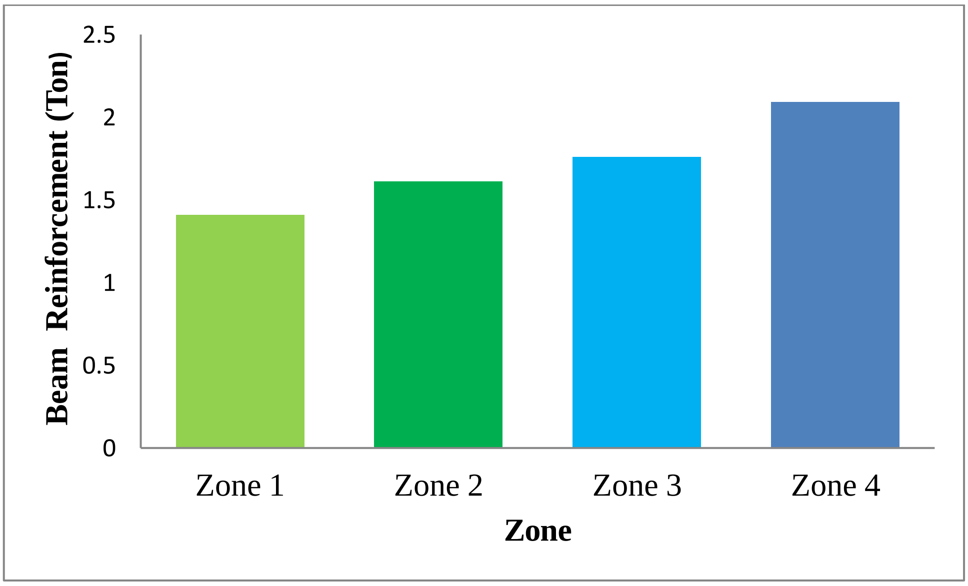


Figure: 4.9 Total Reinforcements of Selected Beam (LB - 1) in Four Seismic Zones.

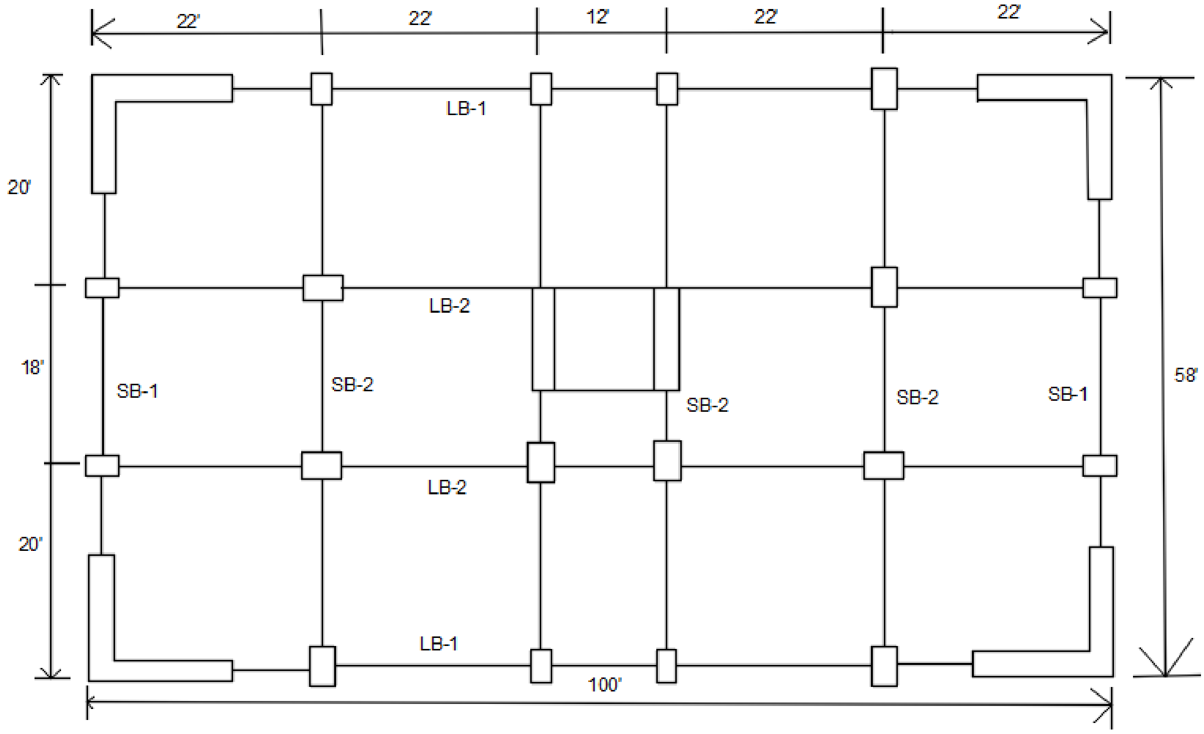


Figure: 4.10 Selected Beam (LB -1) of This Structure in Four Seismic Zones.

4.2.8 Total Beam Reinforcements

Figure 4.11 shows the total reinforcement required in beams for this structure in four seismic zones. It is found that the total reinforcement required in Zone - 1, Zone - 2 and Zone - 3, Zone - 4 are 35.11 tons, 38.50 tons and 41.33 tons, 49.70 tons. It has determined that required reinforcement of beam due seismic load for this building are 11 %, 22%, 40% more for Zone - 2, Zone -3, Zone - 4, respectively, than Zone -1.

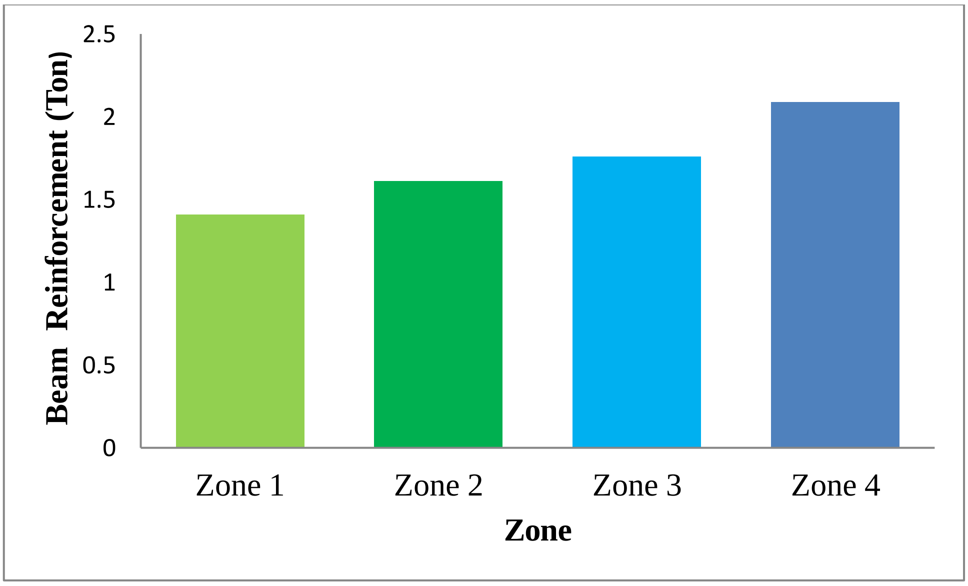


Figure: 4.11 Total Beam Reinforcements in Four Seismic Zones.

4.2.9 Shear Wall Reinforcements

Figure 4.12 shows the total required reinforcements of shear wall for this structure in four seismic zones. It is found that the total reinforcement required in Zone - 1, Zone - 2 and Zone - 3, Zone - 4 is 13 tons, 15 tons and 17 tons, 20 tons, respectively. Its has been observed that required reinforcement of shear wall for this building are 15%, 25%, 45%, more reinforcements for Zone - 2, Zone - 3, Zone - 4, respectively, than Zone -1.

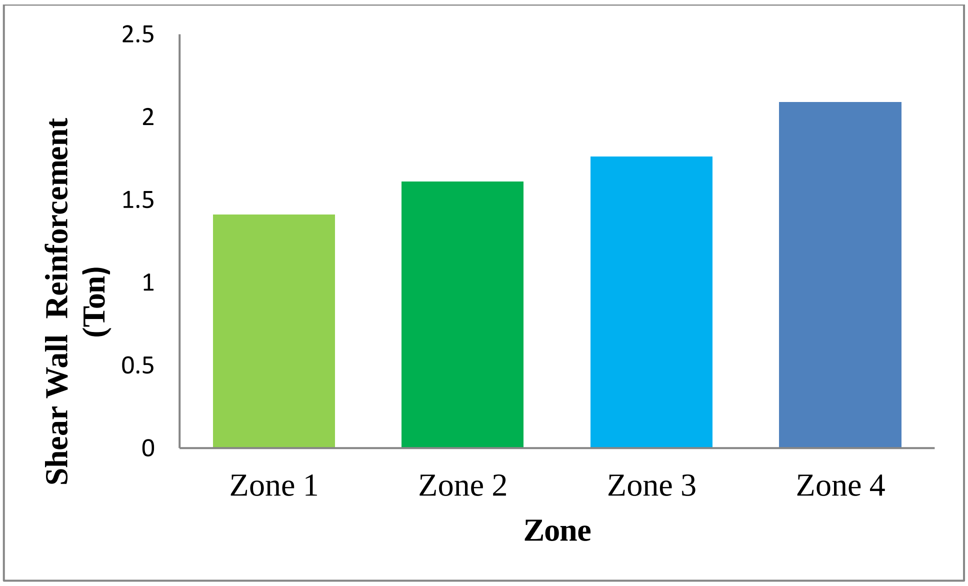


Figure: 4.12 Shear Wall Reinforcements in Four Seismic Zones.

4.2.10 Total Reinforcement for Beam, Column and Shear Wall

Total reinforcement required for structural elements (beams, columns and shear walls) of this selected structure in four seismic zones is shown in Figure 4.13. The required quantity of reinforcement for beam, column and shear walls in Zone -1, Zone - 2, Zone - 3 and Zone - 4 are 67 tons, 75 tons, 82 tons and 97 tons, respectively. It is found that total required reinforcements of structural elements (beam, column, shear wall) for this building are 15%, 25%, 45%, more reinforcement for Zone - 2, Zone - 3, Zone - 4, respectively, than Zone -1.

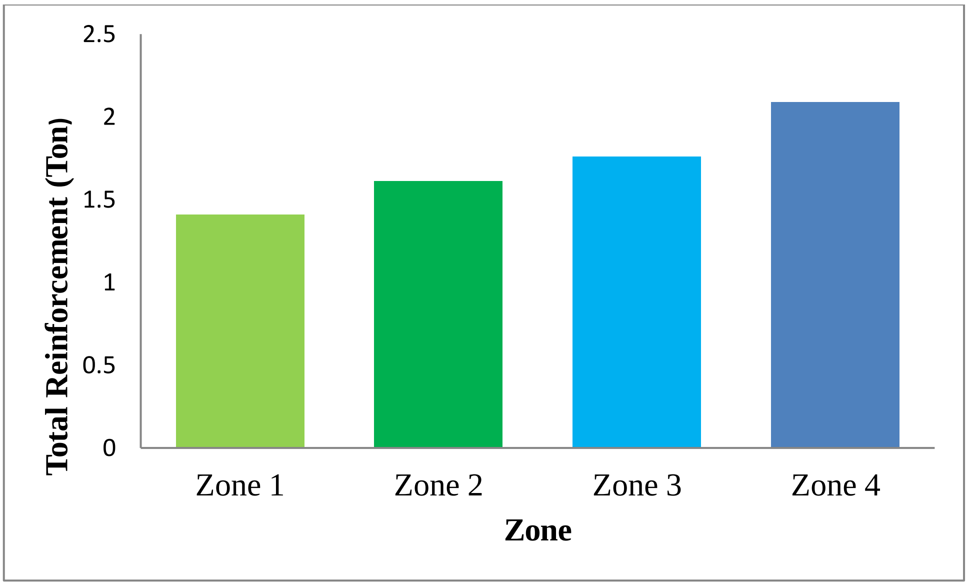


Figure: 4.13 Total Reinforcements of Structural Elements in Four Seismic Zones.

4.2.11 Required Reinforcements per Square Area

It has estimated (Figure 4.14) that average reinforcement required for square feet are of selected 80 feet height building in Zone -1, Zone - 2, and Zone - 3, Zone - 4 are 1.44 kg, 1.61 kg, and, 1.76 kg, 2.09 kg in Zone -1, Zone - 2, Zone - 3, and Zone - 4 respectively for beams, columns and shear wall. It is found that required reinforcements of this building 15%, 25%, 40%, more for Zone - 2, Zone - 3, Zone - 4, respectively, than Zone -1.

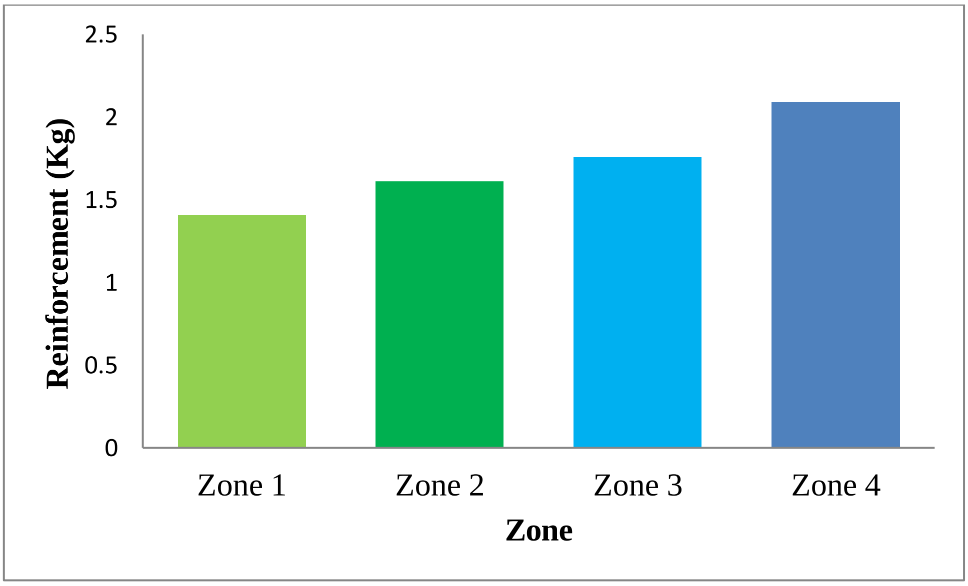


Figure: 4.14 Required Reinforcement of Structural Elements in each Square feet Area.

4.3 150 feet Height Structure

This structure is analyzed as an intermediate dual frame system. Hence, constant wind velocity is considered in four seismic zones. Loads are considered as per BNBC, 2015 which has been discussed in chapter three. Results have been compared, on story deflection, story drift, base shear and required reinforcements per square area of this structure.

4.3.1 Storey Displacement

Story displacement for lateral loads at X and Y directions are shown in Figure 4.15 and 4.16 for four seismic zones. Allowable displacement due to lateral loads at different are also to compared with actual displacements in four seismic zones. It is found that the displacements at different storey height due to lateral loads are less than its allowable limits for four seismic zones. Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.69 inch, 1.86 inch and 2.99 inch, 3.51 inch respectively in X direction. Also Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.67 inch, 1.79 inch and 2.88 inch, 3.39 inch respectively in Y direction.

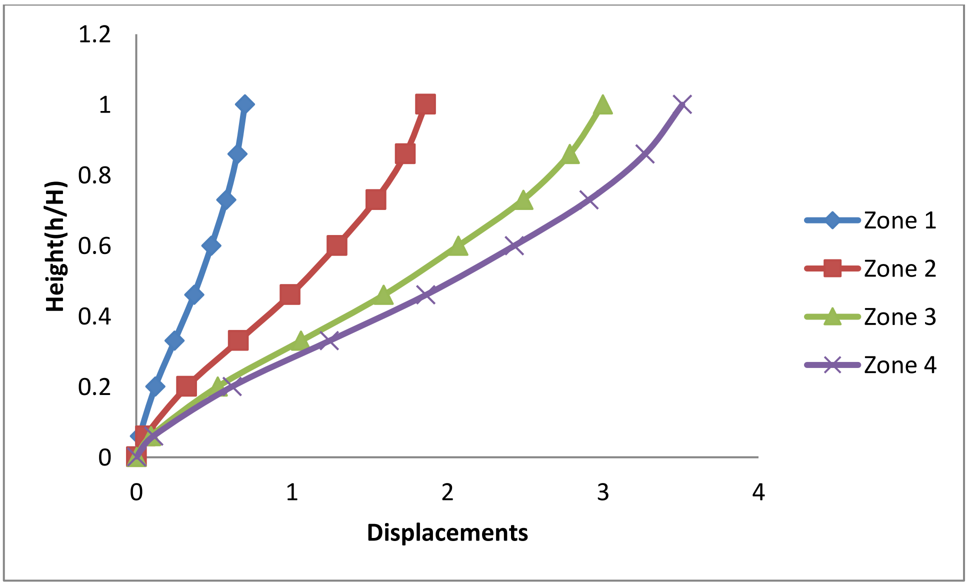


Figure 4.15: Storey Displacement along X Direction for Four Seismic Zones.

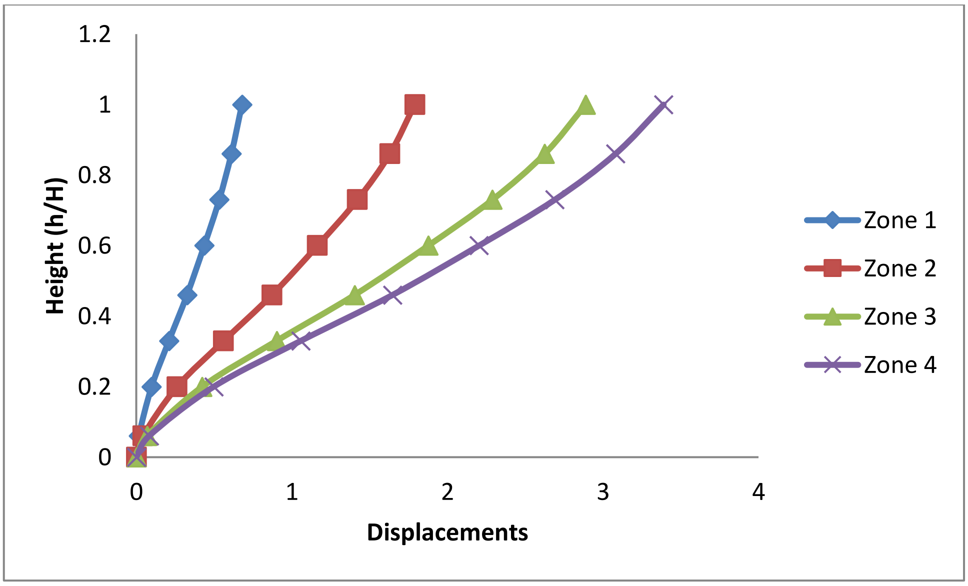


Figure 4.16: Storey Displacement along Y Direction in Four Seismic Zones.

4.3.2 Story Drift

Storey Drift at different height of the structure due to seismic loads in X and Y direction are shown in Figure 4.17 and 4.18 for four seismic zones. It is to be highlighted here that allowable drift at different storey height as per BNBC, 2015 are more than actual drift of this structure. Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.00052, 0.0014 and 0.0022, 0.0026, respectively in X direction. Also Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.00047, 0.0012 and 0.0020, 0.0024, respectively in Y direction.

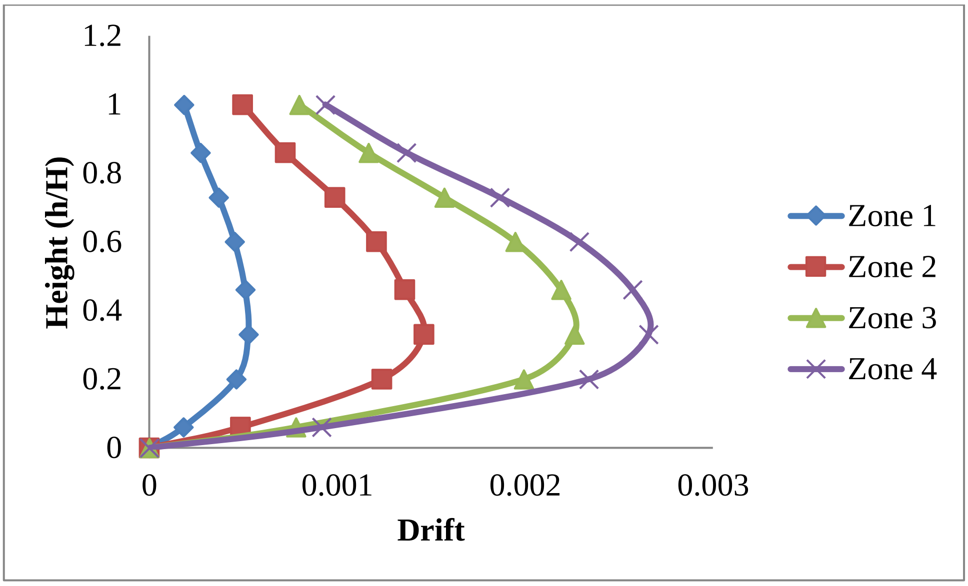


Figure: 4.17 Story Drift along X Direction.

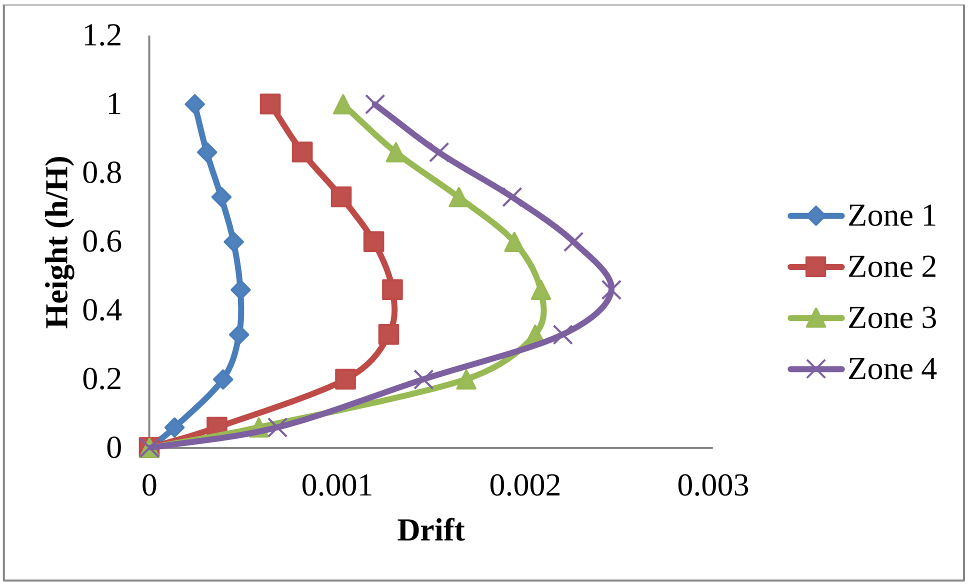


Figure: 4.18 Story Drift along Y Direction.

4.3.3 Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on soil conditions at the site. Proximity to potential sources of seismic activity (such as geological faults) Figure 4.19 shows the total base shear of this selected structure are 301 kips, 804 kips, 1295 kips, 1551 kips, respectively in four seismic zones.

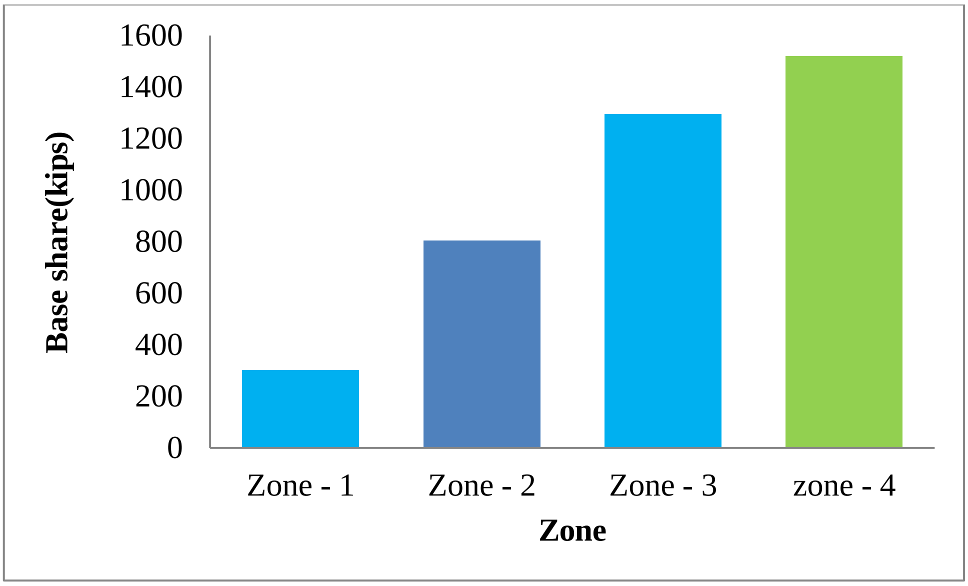


Figure: 4.19 Base Shears in Four Seismic Zones.

4.3.4 Total Reinforcements of Selected Column (C1)

A column is considered for fixed value of “R” in four seismic zones.Here,analysis and design parameters for column elements are equal in four seismic zones.But only seismic zone coefficient are varied. Reinforcement required of selected column (C1, Figure 4.21) of this selected structure (150 ft.) is given in Figure - 4.20 for four seismic zones. It is estimated that the total reinforcement for columns for these structues are 1800 kg, 2096 kg 2349 kg, 2596 kg, respectively for Zone - 1,2,3 and 4. It has observed that of this building due to seismic load required column reinforcement are 15%, 25%, 35% more than Zone - 2, Zone - 3, and Zone - 4, respectively, than Zone - 1.

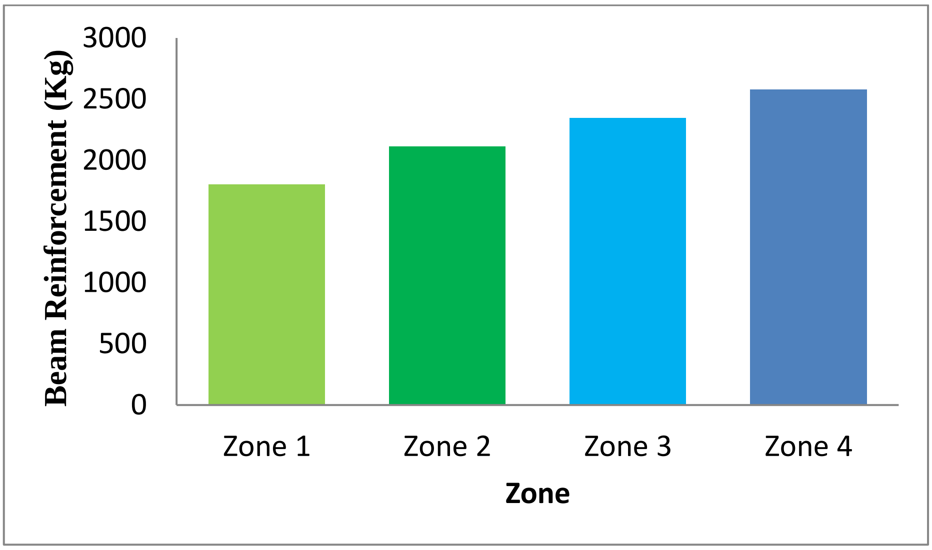


Figure: 4.20 Total Required Reinforcements Selected Column (C1) in Different Seismic Zone.

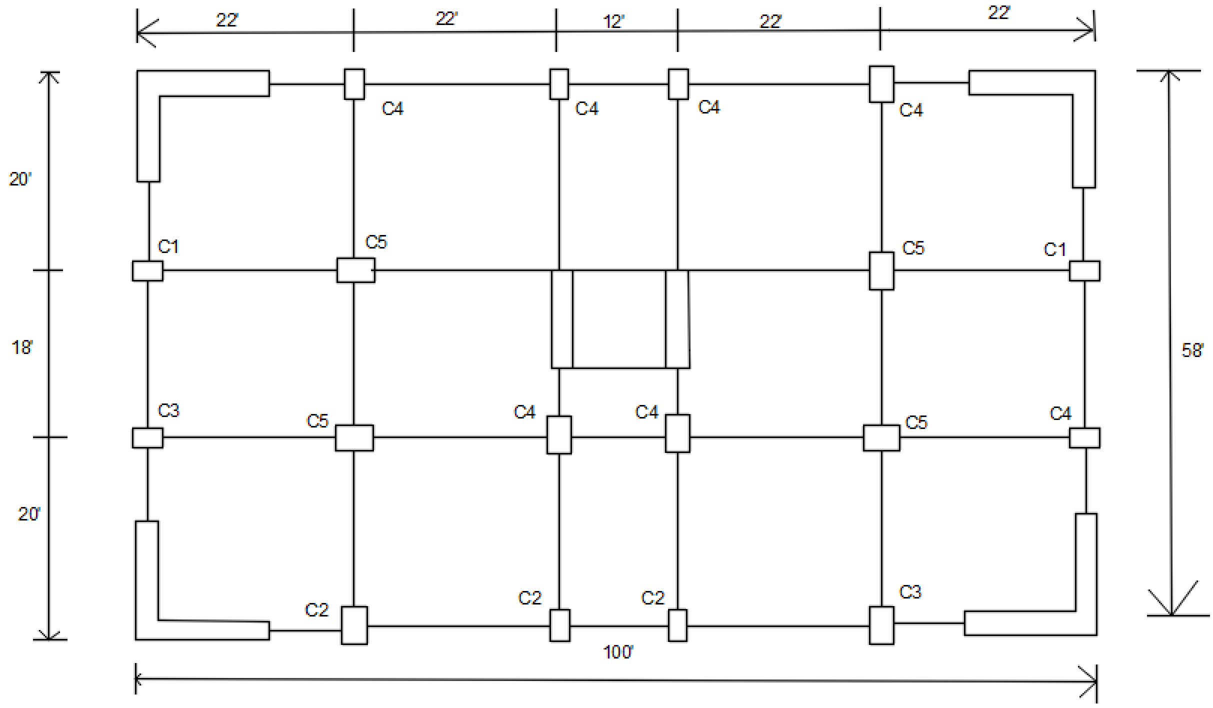


Fig: 4.21 Selected Column (C1) of This Structure in Different Seismic Zones.

4.3.5 Total Column Reinforcements

Reinforcement required for columns of these selected structure (150 ft.) is given in Figure 4.22 for four seismic zones. It is estimated that the total reinforcement for columns for these structues are 49 tons, 54 tons ,61 tons, 70 tons for zone 1,2,3 and 4, respectively.It is found that required reinforcements of columns for this buildings are 10 %, 25 %, 40 %, more for Zone - 2, Zone - 3, Zone - 4, respectively, than seismic Zone -1.

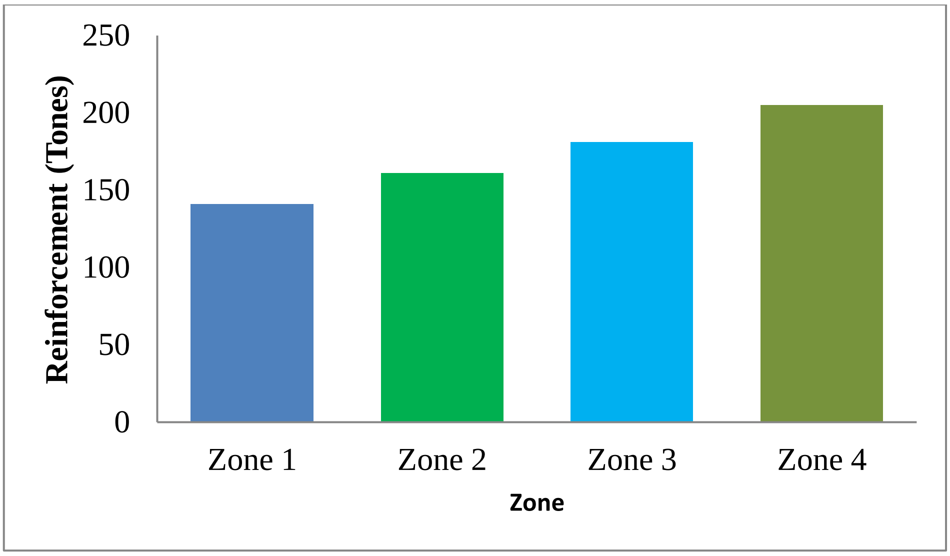


Figure : 4.22 Total Column Required Reinforcements in Different Seismic Zones.

4.3.6 Required Reinforcements of Selected Beam (LB -1)

Figure 4.23 shows the total reinforcement required for selected beam (LB -1, Figure 4.24) for this structure in four seismic zones. It is found that the total reinforcement required in Zone -1, Zone - 2 and Zone - 3, Zone - 4 are 11.62 tons, 12.65 tons and 15.84 tons, 16.307 tons, respectively. It is found that required reinforcements of selected column (LB -1) for this buildings are 10 %, 30 %, 40 %, more for Zone - 2, Zone - 3, Zone - 4, respectively, than seismic Zone -1.

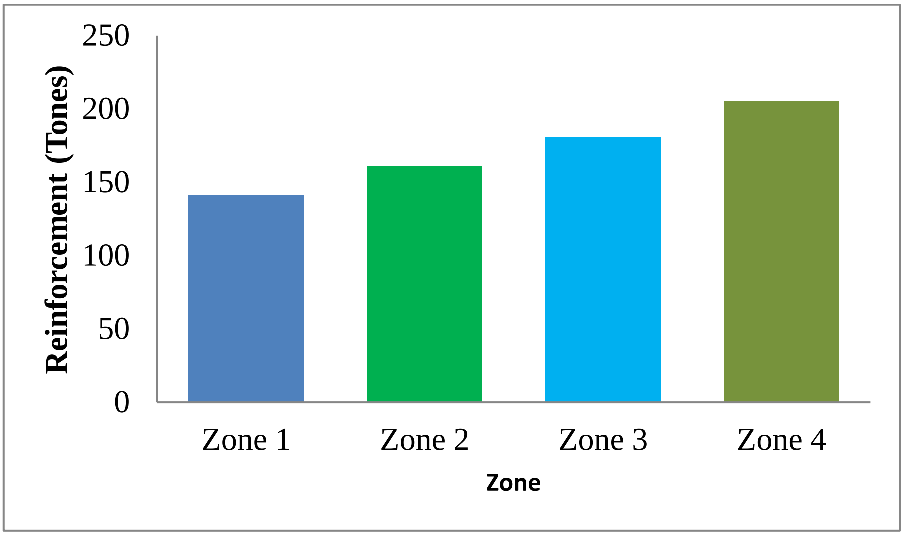


Figure: 4.23 Total Reinforcements of Selected Beam in Four Seismic Zones.

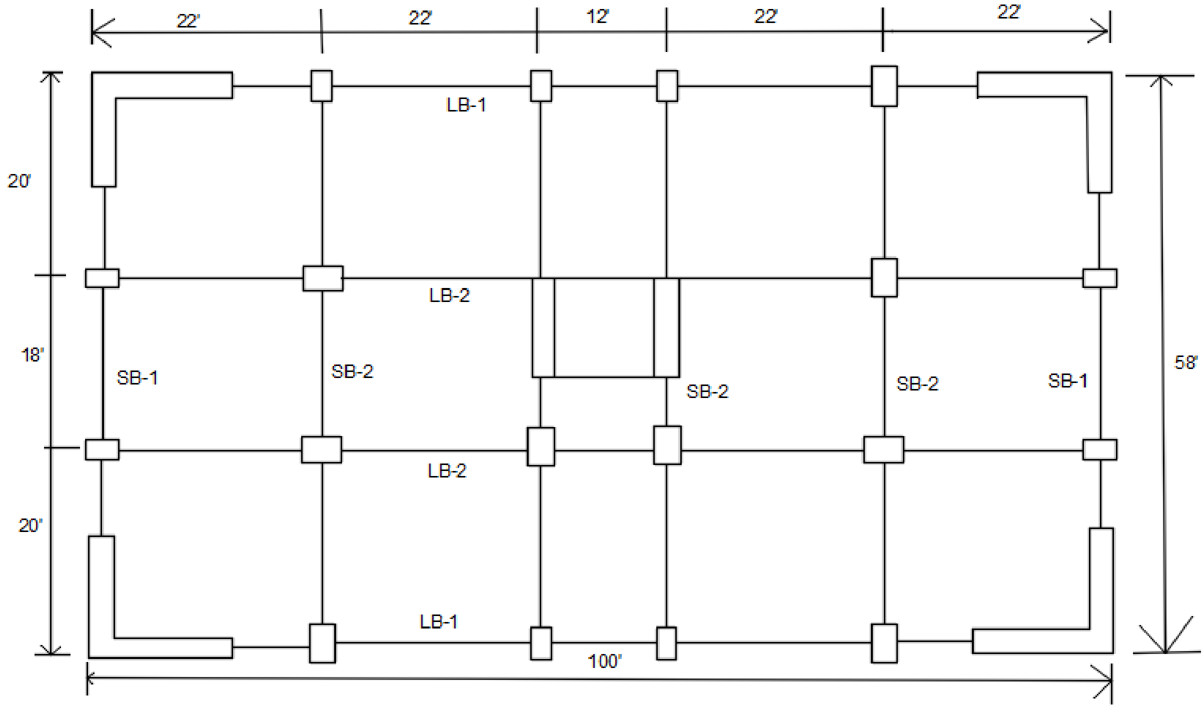


Figure: 4.24 Selected Beam (LB-1) of This Structure in Four Seismic Zones.

4.3.7 Total Beam Reinforcements

Figure 4.25 shows the total reinforcement required in beams for this structure in four seismic zones. It is found that the total reinforcement required in Zone -1, Zone - 2 and Zone - 3, zones - 4 are 68 tons, 80 tons and 91 tons, 101 tons, respectively. It is found that required reinforcements of columns for this buildings are 15 %, 35 %, 45 %, more for Zone - 2, Zone - 3, Zone - 4, respectively, than seismic Zone -1.

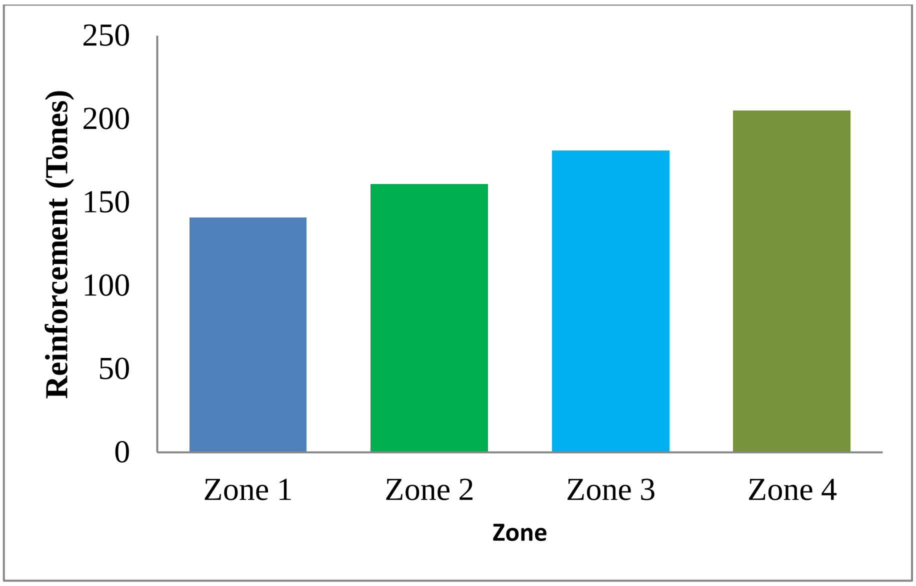


Figure: 4.25 Total Beams Reinforcements of This Structure in Four Seismic Zones.

4.3.8 Shear Wall Reinforcements

Figure 4.26 shows the total reinforcement required reinforcements in shear wall for this structure in four seismic zones. It is found that the total reinforcement required in Zone -1, Zone - 2 and Zone - 3, Zone - 4 are 24 tons, 27 tons and 29 tons, 34 tons, respectively. It is found that required reinforcements of shear walls for this buildings are 15%, 25%, 40%, more for Zone -2, Zone -3, Zone - 4, respectively, than seismic Zone -1.

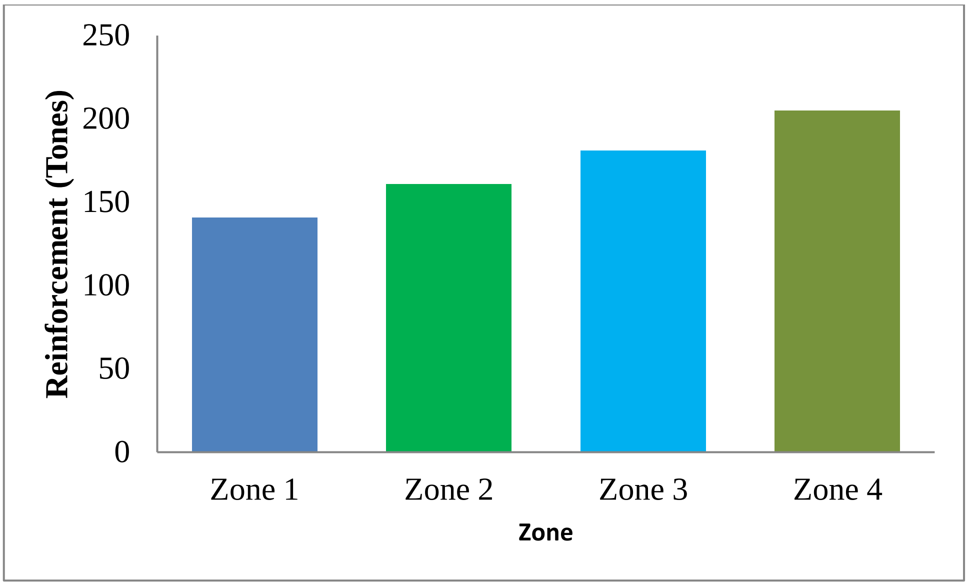


Figure: 4.26 Shear Wall Reinforcements of this Structure in Four Seismic Zones.

4.3.9 Total Reinforcement for Beam, Column Shear Wall

Total reinforcement required for beams, columns of this selected structure in four seismic zones is shown in Figure 4.27 .The quantity of reinforcement for beam and column elements in Zone - 1, Zone - 2, Zone - 3 and Zone - 4 are 141 tons, 161 tons, 181 tons and 205 tons, respectively. It is found that required reinforcements of selected elements(Beam,Column, Shear wall) for this buildings are 15%, 30 %, 45%, more for Zone - 2, Zone - 3, Zone - 4, respectively, than seismic Zone -1.

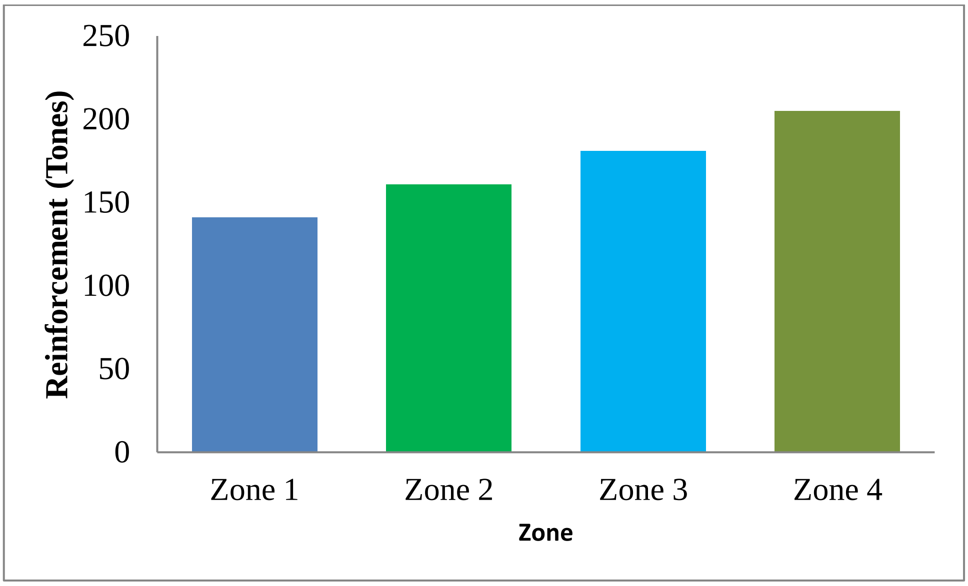


Figure: 4.27 Total Reinforcements of Structural Elements (beam, column and shear wall) in four Seismic Zones.

4.3.10 Required Reinforcements per Square Area

It has estimated that average reinforcement required for square feet are of selected building in Zone -1, Zone - 2, and Zone - 3, Zone - 4 are 1.62 kg, 1.85 kg, and 2.08 kg, 2.35 kg in Zone - 1, Zone - 2, Zone - 3, and Zone - 4 respectively for beams, columns shear wall. It is found that average required reinforcements of structural elements (columns,beams and shear walls) for this buildings are 15%, 25%, 45%, more for Zone -2, Zone -3, Zone - 4, respectively than seismic Zone -1 which represented by Figure - 4.28.

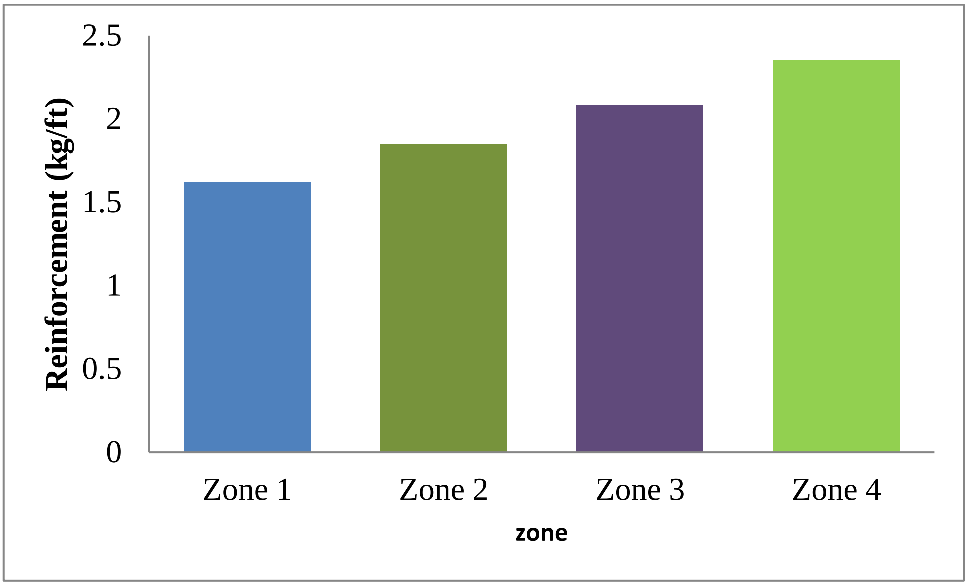


Figure: 4.28 Required Reinforcement in Each Square Feet Area.

4.4 Conclusions

Objectives of this study are to give variations of base shear, story drift, displacement, required reinforcements of selected structural frames among four seismic zones of Bangladesh. Due to those reasons two different heights (80 feet and 150feet) of intermediate dual frame structures selected for analysis and design by ETABS - 216. According to frames analysis and design results by ETABS - 2016 this chapter showed variations of base shear, story drift, story displacements, and total amount of required reinforcements of structural frames in different seismic zones of Bangladesh. Analysis and design results by ETABS - 2016 according to BNBC - 2015 showed that comparative results of story the maximum story displacements of this building in Zone -1, Zone - 2 and Zone -3, Zone - 4 are 0.43 inch, 1.169 inch and 1.69 inch, 1.98 inch, respectively for X direction and 0.34 inch, 0.93 inch and 1.35 inch, 1.55 inch, respectively for Y direction for 80 feet height building. Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.69 inch, 1.86 inch and 2.99 inch, 3.51

inch respectively in X direction. Also Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.67 inch, 1.79 inch and 2.88 inch, 3.39 inch respectively in Y direction for selected 150 feet height structure for four seismic zones of Bangladesh. Maximum story drifts of this building for seismic zone 1, 2 and 3, 4 are 0.0006, 0.0016 and 0.0023, 0.0027, respectively in X direction and 0.0004 0.0012 and 0.0017.0.0021, respectively in Y direction for 80 feet height building. On the other hand maximum story drift of seismic Zone - 1, 2 and 3, 4 are 0.00052, 0.0014 and 0.0022, 0.0026, respectively in X direction and 0.00047, 0.0012 and 0.0020, 0.0024, respectively in Y direction for 150 feet height building. From analysis results of selected 80 feet height structure base shear of this structures are 240.875 kips, 643 kips, 932 kips, and 1102 kips, respectively in four seismic zones. Base shear values of this selected 150 feet height structure are 301 kips, 804 kips, 1295 kips, 1551 kips, respectively in four seismic zones. Required average reinforcements required in each square feet area of this structure for beam and column elements in Zone -1, Zone -2, and Zone -3, Zone - 4, are 1.44 kg, 1.61 kg, and, 1.76 kg, 2.09 kg, respectively for 80 feet height building. According to design results of selected 150 feet intermediate dual frame structure by ETABS - 2016 according to BNBC - 2015 required average reinforcement for square feet are of selected building in Zone -1, Zone - 2, and Zone - 3, Zone - 4 are 1.62 kg, 1.85 kg, and 2.08 kg, 2.35 kg in Zone -1, Zone - 2, Zone - 3, and Zone - 4 respectively for beams, columns shear wall.

CHAPTER - 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 General

Bangladesh is located in a tectonically active region close to the plate boundaries of the Indian plate and the Eurasian plate. The effect of earthquake is more severe in an underdeveloped and a densely populated country like Bangladesh than any other developed countries. According to building codes, earthquake resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of the functionality should be limited for more frequent ones. Accurate historical information on earthquakes is very important in evaluating the seismicity of Bangladesh in close coincidences with the geotectonic elements.

The aim of this study is to gave an idea of the structural engineer about the costing of same structure in four seismic zones in Bangladesh. It may insist to contract proper seismic resistance building in four seismic zones of Bangladesh. To fulfill the aim of the study two different heights (150 feet and 80 feet) of building are considered as individual buildings are analyzed and designed separately, for four seismic loads as per BNBC- 2015. All these buildings are analysis considered intermediate moment resisting frame (dual system) with constant wind load. Selected structures are designed by using ETABS - 2016 considering seismic loads as per BNBC 2015 in four seismic zones of Bangladesh. Seismic detailing of various structural elements are done based on BNBC 2015.Finally, structural drawing are prepared of these building for cost estimation. The following conclusions could be done as per height of the structures.

5.2 Conclusions of the Study

After an extensive and systematical study, the following conclusions could be derived as per height of the structure.

a) 80 feet Height Structure

(1) The maximum story displacements of this building in Zone -1, Zone - 2 and Zone -3, Zone - 4 are 0.43 inch, 1.16 inch and 1.69 inch, 1.98 inch, respectively for X direction and 0.34 inch, 0.93 inch and 1.35 inch, 1.55 inch, respectively for Y direction.

(2) Maximum story drifts of this building for seismic zone 1, 2 and 3, 4 are 0.0006, 0.0016 and 0.0023, 0.0027, respectively in X direction and 0.0004 0.0012 and 0.0017.0.0021, respectively in Y direction.

(3) Base shear of this structures are 240.87 kips, 643 kips, 932 kips, and 1102 kips, respectively in four seismic zones.

(4) The required quantity of reinforcement for beam, column and shear walls in Zone -1, Zone - 2, Zone - 3 and Zone - 4 are 67 tons, 75 tons, 82 tons and 97 tons, respectively. It is found that total required reinforcements of structural elements (beam, column, shear wall) for this building are 15%, 25%, 45%, more reinforcement for Zone - 2, Zone - 3, Zone - 4, respectively, than Zone -1.

(5) Average reinforcements required in each square feet area of this structure for beam and column elements in Zone -1, Zone -2, and Zone -3, Zone - 4, are 1.44 kg, 1.61 kg, and, 1.76 kg, 2.09 kg , respectively.

b) 150 feet Height Structure

(1) Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.69 inch, 1.86 inch and 2.99 inch, 3.51 inch respectively in X direction. Also Maximum story displacements of seismic Zone - 1, 2 and 3, 4 are 0.67 inch, 1.79 inch and 2.88 inch, 3.39 inch respectively in Y direction.

(2) Maximum story drift of seismic Zone - 1, 2 and 3, 4 are 0.00052, 0.0014 and 0.0022, 0.0026, respectively in X direction and 0.00047, 0.0012 and 0.0020, 0.0024, respectively in Y direction.

(3) Base shear of this selected structure are 301 kips, 804 kips, 1295 kips, 1551 kips, respectively in four seismic zones.

(4) The required reinforcement for beam and column, shear wall elements in Zone - 1, Zone - 2, Zone - 3 and Zone - 4 are 144 tons, 166 tons, 188 tons and 212 tons, respectively. It is found that required reinforcements of selected elements(Beam,Column, Shear wall) for this buildings are 15%, 30 %, 45%, more for Zone - 2, Zone - 3, Zone - 4, respectively, than seismic Zone -1.

(5) The required average reinforcement for square feet are of selected building in Zone -1, Zone - 2, and Zone - 3, Zone - 4 are 1.44 kg, 1.61 kg, and 1.81 kg, 2.05 kg in Zone -1, Zone - 2, Zone - 3, and Zone - 4 respectively for beams, columns shear wall.

5.3 Recommendation for the Future Studies

1. Present study has done for intermediate moment resisting structural frames of structural dual system. Further study can be done for other structural systems which are given in BNBC, 2015.
2. This study has done for only regular type of structure. Further studies can be done for various irregular structures.
3. Study can be carried on varying wind load.

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APPENDIX

Modeling with Frame and Shell Element Using Finite Element Method

The physical structural members in a structural model are represented by objects. The geometry of an object is assign properties and loads to the object to completely define the model of the physical member. For analysis purpose ETABS -2016. The term element will be used more often than object, since what is described herein is the finite-element analysis portion of the program that operates on the element-based analysis model. However, it should be clear that the properties described here for elements are actually assigned in the interface to the objects and the conversion to analysis elements is automatic.

The Frame element is a very powerful element that can be used to model beams, columns, braces, and trusses in planar and three-dimensional structures. It includes the effects of biaxial bending, torsion, axial deformation, and bi axial shear deformations. The Shell element is a type of area object that is used to model membrane, plate, and shell behavior in planar and three-dimensional structures. The Shell element is a three or four node formulation that combines membrane and plate bending behavior.

Frame Element

The Frame element is used to model beam-column and truss behavior in planar and three-dimensional structures. The Frame element can also be used to model cable behavior when nonlinear properties are added (e.g., tension only, large deflections). This element will often be referred to simply as the frame element, although it can always be used for cable analysis. The Frame element uses a general, three- dimensional, beam-column formulation which includes the effects of biaxial bending, torsion, axial deformation, and biaxial shear deformations (Wilson, 1976).

A Frame element is modeled as a straight line connecting two points. In the graphical user interface, you can divide curved objects into multiple straight objects, subject to your specification. Each element has its own local coordinate system (Figure E1) for defining section properties and loads, and for interpreting output.

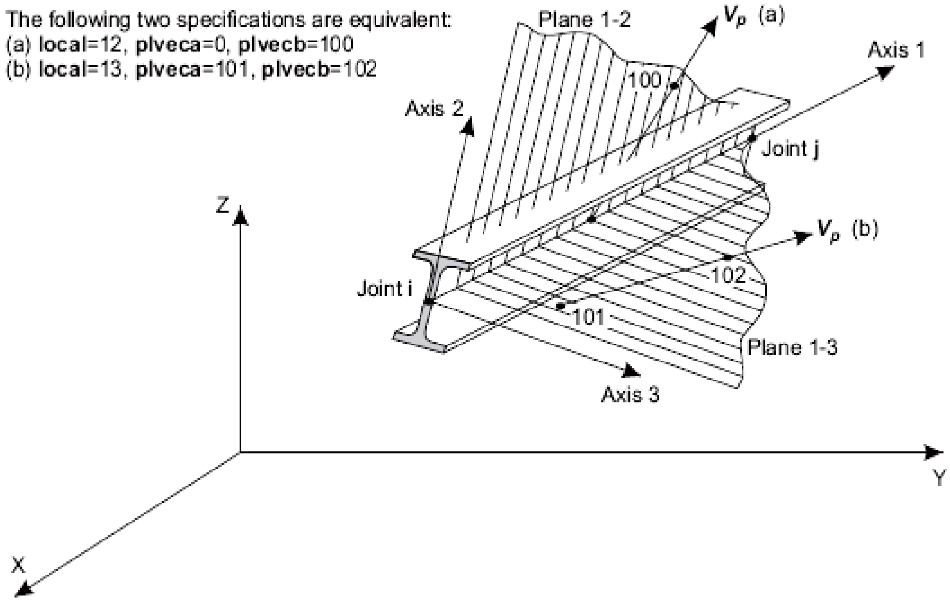

Figure E1: Frame element in local coordinate system.

Shell element:

Shell elements are used to model structural elements in which two dimensions are much greater than the third one and when the change of the analyzed feature across this third direction can be neglected. It is reasonable for static analysis of panel/planar elements such as slabs or walls as well as thin-walled spatial elements such as shells. The advantages of the use of shell elements, as you said, results mainly from time-saving due to reduced number of finite elements (and consequently the equations to solve). So, anytime you can reduce the problem to planar problem and neglect what happens at the thickness of the element.

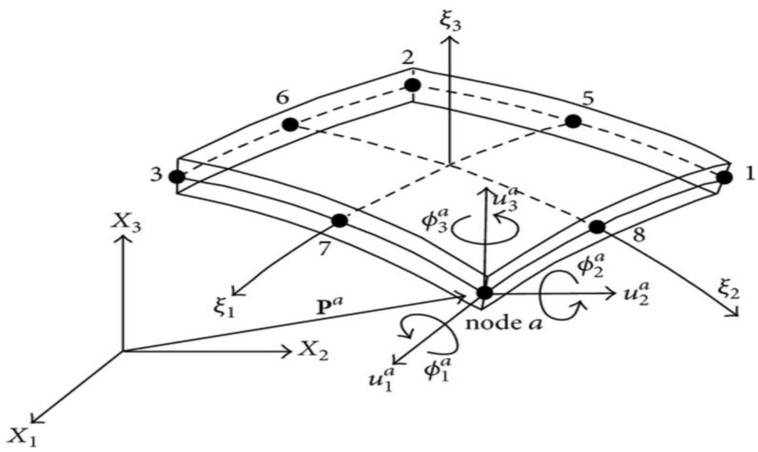

Figure E2: Plane element

Cost Estimation of Different Structural Members

Members	10 mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x18	205	-	284	467	-	14	13384
22x22	228	-	332	621	-	4	4724
							18108

Zone 1,Column(80 feet height building)

Beam

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
LB -1	190	-	116	188	-	2	988
LB-1	-	-	74	-	-	2	148
LB-2	190	-	-	474	-	2	1328
LB-2	-	-	-	100	-	2	200
SB-1	101	-	127	120		2	696
SB-1	-	-	12	-	-	2	24
SB-2	101	-	177			3	834
SB-2	-	-	-	57	-	3	171
							4389x8= 35112

Shear wall

Members	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	Total(kg)
Shear wall	1793	967	537	-	-	3842
Core wall	994	907	-	-	-	3808
						12698

Zone 2

Beam

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
LB-1	228	-	106	255	-	2	1178
LB-1	-	-	88	-	-	2	166
LB-2	228	-	-	425	-	2	1306
LB-2	-	-	-	141	-	2	282
SB-1	101	-	97	152		2	700
SB-1	-	-	36	-	-	2	72
SB-2	101	-	187			3	864
SB-2	-	-	-	85	-	3	255
						Sum	4823x8 =38584

Column

Member	10Ø	12Ø	16Ø	20Ø	25Ø	No	Total
18x18	-	-	332	554	-	14	12404
Tied	205	-	-			14	2870
22x22	-	-	-	1182		4	4728
Tied	228	-	-	-	-	4	912
						Sum	20914

Shear wall

Members	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	Total(kg)
Shear wall	1793	3628	4408	-	-	9829
Core wall	994	907	1076	-	-	2977
						12806

Beam

zone 3

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
LB-1	316	-	340	-	-	2	1312
LB-1	-	-	88	-	-	2	176
LB-2	316	-		510	-	2	1652
LB-2	-	-	88			2	166
SB-1	146	-	63	151	-	2	720
SB-1				85		2	170
SB-2	146	-	56	151	-	3	706
SB-2				85		3	255
							5157x8 =41256

Column

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x18	-	-	379	579	-	14	13412
Tied	228	-	-			14	3192
22x22	-	-	508	777		4	5140
Tied	278	-		-	-	4	1112
						Sum	22856

Shear wall

Members	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	Total (kg)
Shear wall	2491	3728	4400	-	-	10619
Core wall	2485	704	2755	-		6481
					Sum	17.1 ton

Zone 4

Beam

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total(kg)
LB-1	316	-	216	255	-	2	1574
LB-1	-	-	-	141	-	2	282
LB-2	316	-	-	516	-	2	1664
LB-2	-	-	-	141	-	2	282
SB-1	146	-	62	152		2	720
SB-1	-	-	78	-	-	2	156
SB-2	146	-	65	160		3	1113
SB-2	-	-	-	141	-	3	423
							6214x8= 49712

Column

Member	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x18	-	-	437	639	-	14	15064
Tied	228	-	-			14	2870
22x22	-	-	-	956	986	4	7768
Tied	278	-	-	-	-	4	1112
						Sum	26814

Shear wall

Members	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	Total
Shear wall	4484	3819	4600		-	12903
Core wall	2485	1738	3550			7773
						20.67 ton

Required reinforcements for 150 feet height building

Zone 1

Beam

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
LB-1	152	-	179	265	-	2	1192
LB-1	-	-	-	151	-	2	304
LB-2	152	-	285	-	-	2	874
LB-2	-	-	81	78	-	2	318
SB-1	114	-	198	-		2	624
SB-1	-	-	74	-	-	2	148
SB-2	114	-	177	-		3	873
SB-2	-	-	92	-	-	3	276
							4607x15 = 69135

Column

Member	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x20	-	-	1019	536	-	2	3110
Tied	241	-	-	-	-	2	282
20x20			-	2307	-	3	6921
Tied	228	-	-	-	-	3	684
20x22		-	-	2347	-	2	4694
Tied	240	-	-	-	-	2	480
22x22	-	-	1358	752	-	7	14770
Tied	250	-	-	-	-	7	1750
25x25			853	-	3075	4	15712
Tied	285	-	-	-	-	4	1140
							49544

Shear wall

Members	10Ø	12Ø	16Ø	20Ø	25Ø	Total
Shear wall	3363	9072	-	-	-	12435
Core wall	1863	3402	-	-		5265
						17770

Zone 2

Beam

Member	10Ø	12Ø	16Ø	20Ø	25Ø	No	Total
LB-1	190	-	-	511	-	2	1402
LB-1	-	-	-	141	-	2	282
LB-2	190	-	-	516	-	2	1412
LB-2	-	-	-	132	-	2	264
SB-1	114	-	62	152		2	656
SB-1	-	-	-	85	-	2	170
SB-2	114	-	94	152		3	1080
SB-2	-	-	52	-	-	3	156
							5422x15= 81330

Column

Member	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x20	-	-	1222	646	-	2	3736
Tied	228	-	-			2	456
20x20	-		-	2769		3	8703
Tied	240					3	720
20x22	-	-	734	1476	-	2	4420
Tied	252	-	-	-	-	2	504
22x22	-	-	-	2793		7	19551
Tied	264	-	-	-	-	7	1848
25x25		-	-	2430	1281	4	14844
Tied	300	-	-	-	-	4	1200
						Sum	55982

Shear wall

Members	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	Total
Shear wall	3363	9374	8601	-	-	21338
Core wall	2485	1738	2342	-		6565
					Sum	27903

Zone 3

Beam

Member	10Ø	12Ø	16Ø	20Ø	25Ø	No	Total
LB-1	316	-	-	587	-	2	1806
LB-1	-	-	-	122	31	2	306
LB-2	316	-	-	595	-	2	1822
LB-2	-	-	-	76	15	2	182
SB-1	152	-	-	384		2	1072
SB-1	-	-	-	84	-	2	168
SB-2	152	-	-	384		3	1608
SB-2	-	-	-	84	-	3	252
						Sum	7216 x15 =108240

Shear Wall

Members	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	Total
Shear wall	6080	4536	12126	-	-	22742
Core wall	2564	1134	3307	-	-	7005
						29.7

Column

Member	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
18x20	-	-	1252	777	-	2	4058
Tied	300	-	-			2	600
20x20			1290	777		3	6201
Tied	380					3	1140
20x22			1792	777		2	5138
Tied	399					2	798
22x22	-	-	898	1903		7	19607
Tied	318	-	-	-	-	7	2226
25x25			-	1404	3565	4	19876
Tied	475	-	-	-	-	4	1900
						Sum	61544

Zone 4

Beam

Member	10mmØ	12mmØ	16mmØ	20mmØ	25mmØ	No	Total
LB-1	316	-	-	595	-	2	1822
LB-1	-	-	-	84	92	2	352
LB-2	316	-	-	516	-	2	1664
LB-2	-	-	-	113	45	2	316
SB-1	152	-	84	384		2	1240
SB-1	-	-	78	-	-	2	156
SB-2	152	-	84	362		3	1794
SB-2	-	-	-	84	-	3	252
							7596 x15= 113940 kg.

Column

Member	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	No	Total (kg.)
18x20	-	-	1338	897	-	2	4470
Tied	361	-	-			2	722
20x20			477	927		3	4212
Tied	380					3	1140
20x22			299	2020		2	4638
Tied	399					2	798
22x22	-	-	-	4043		7	28301
Tied	418	-	-	-	-	7	2926
25x25			1755	1314	2050	4	20476
Tied	475	-	-	-	-	4	1900
						Sum	69583

Shear Wall

Members	10mmØ Tie bar	12mmØ	16mmØ	20mmØ	25mmØ	Total
Shear wall	6080	4536	16128	-	-	26744
Core wall	2564	1134	4032	-	-	7730
					Sum	34474