ENDURANCE CAPABILITY OF DIFFERENT GRADES OF REINFORCING BARS IN HIGH RISE BUILDING DURING EARTHQUAKE

By

S. M. SHORAB PATWARY

MD. SAIFULLAH

DIPU KUMAR ROY

MD. KAMAL UDDIN

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

Department of Civil Engineering

Sonargaon University

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

Section: 16D

Semester: Summer-2022

ENDURANCE CAPABILITY OF DIFFERENT GRADES OF REINFORCING BARS IN HIGH RISE BUILDING DURING EARTHQUAKE

S. M. SHORAB PATWARY	BCE 1901016184
MD. SAIFULLAH	BCE1901016019
DIPU KUMAR ROY	BCE1901016171
MD. KAMAL UDDIN	BCE1901016169

<u>Supervisor</u>
HEMLITA MONDAL

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

Department of Civil Engineering

Sonargaon University

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

Section: (16D-Manama)

Semester:-4th Year (Summer-2022)

BOARD OF EXAMINERS

The project and thesis titled "**Endurance capability of different grades of reinforcing bars in a high-rise building during the earthquake** ", submitted by S.M. Shorab Patwary ID: BCE 1901016184, Md. Saifullah- ID: BCE1901016019**,** Dipu Kumar Roy- ID: BCE1901016171, Md. Kamal Uddin- ID: BCE1901016169 students of the Department of Civil Engineering have been examined thoroughly and accepted in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering on 09 September 2022.

………………………………………

1. Hemlita Mondal — Chairman
   Lecturer
   Sonargaon University

………………………………………

2. Internal / External Member — Member

………………………………………

3. Internal / External Member — Member

DECLARATION

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

<u>**STUDENT NAME**</u>	<u>**STUDENT ID.**</u>	<u>**SIGNATURE**</u>
S. M. SHORAB PATWARY	BCE 1901016184	
MD. SAIFULLAH	BCE1901016019	
DIPU KUMAR ROY	BCE1901016171	
MD. KAMAL UDDIN	BCE1901016169	

Dedicated

To

"Our Respectful Teachers

And Parents"

ACKNOWLEDGEMENT

First of all, we like to show our highest gratitude to the Almighty Allah who has been faithful and supplied us with abundant grace, and His kindness to us make it possible to complete the study and preparation of this project and thesis.

Our project and thesis work is a partial fulfillment of the requirement for the degree of Bachelor of Science (B.Sc.) in Civil Engineering. This thesis works not have been possible without some important persons. We express our gratefulness and thanks to them for their assistance in the preparation of this project and thesis.

We are very much grateful to our supervisor, Miss. Hemlita Mondal, Lecturer of the Department of Civil Engineering, Sonargaon University Bangladesh for her sincere cooperation and sufficient time for discussions and continuous suggestions.

We are also grateful to Assistant Professor S. M. Yashin the Head of the Department of Civil Engineering, Sonargaon University Bangladesh for giving us a patient hearing, sufficient time for discussions, and continuous suggestions and guidance for the preparation of this 'Project and Thesis'. He is also our respected teacher who helped us a lot in many ways unlimitedly not only in the preparation of this project and thesis but also to fulfill the requirements for earning the degree of B.Sc. in Civil Engineering.

Finally, we would like to give our gratitude to all of our teachers at the University for their Cooperation and dedicated teaching for the achievement of the degree of B.Sc. in Civil Engineering. The cooperation and assistance of all the officers and staff of the Sonargaon University Bangladesh are healthfully acknowledged.

ABSTRACT

In Civil Engineering construction, a variety of materials compete and this is initiating a nonstop technological invention. This invention not only concerns the enhancement of the materials themselves but also results in the preface of new technologies and approaches for fabrication, joining and construction. There's growing interest within the reinforced concrete assiduity in using advanced-strength construction materials for certain operations. In more recent times, it has been set up possible to produce steels, at fairly low cost, whose yield strength is 3 to 4 times further than that of ordinary reinforcing steels. Likewise, it's possible to produce concrete 4 to 5 times as strong in compression as the further than ordinary concrete. These high-strength materials offer numerous advantages. At present in our country, high-strength concrete having a compressive strength of further than 4000 psi is possible and again, advanced strength reinforcing bars with a yield stress of,72,000 psi are available for structural construction which may reduce the cost of construction and ameliorate structural safety.

The primary focus of this study is to find out the effects of using different grades of bars on the responses of high-rise structures towards EQ and Wind and also to compare the structural performances among them. To achieve this thing, a floor plan, a model of three 20-storied structures has been done, which is located in Dhaka, Bangladesh. All loads are applied according to Bangladesh National Building Code (BNBC). All the models have been developed for analogous lading scripts using the same structural systems. Three structure models have been created considering 40- grade, 60- grade and 75- grade bars and analogous concrete compressive strength. Relative studies have been carried out in terms of story relegation, story drift, shear forces, capsizing moment, stiffness, etc. for all structures and eventually try to present the configurations which have better performance.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 General

Reinforced concrete is used as a construction material in every country, including Bangladesh. Reinforced concrete is a governing structural material in engineered construction. The universal nature of reinforced concrete construction stems from the wide vacuity of reinforcing bars and the components of concrete, stones, sand, and cement, the fairly simple experience required in concrete construction, and the frugality of the reinforced concrete compared to other forms of constructions(Bosunia,Z.M. Shamim; 2008). With the recent advancement in concrete technology and the vacuity of various types of mineral and chemical admixtures and really important superplasticizers, concrete with a compressive strength of over 100 MPa can now be produced commercially with a respectable position of variability using ordinary aggregates (FIP/ CEB, 1990). These developments have led to increased operations of high-strength concrete around the globe.

1.2 Background of study

In Civil Engineering construction, a variety of materials contend and this is initiating a nonstop technological invention. This invention not only concerns the enhancement of the materials themselves but also results in the preface of new technologies and styles for fabrication, joining and construction.

There's growing interest within the reinforced concrete assiduity in using advanced-strength construction materials for certain operations. In more recent times, it has been set up possible to produce brands, at fairly low cost, whose yield strength is 3 to 4 times further than that of ordinary reinforcing brands. Likewise, it's possible to produce concrete 4 to 5 times as strong in contraction as further as ordinary concrete. These high-strength materials offer numerous advantages. At present in our country, high-strength concrete having a compressive strength of further than 4000 psi is possible and again, advanced strength reinforcing bars with yield stress of 70,000 psi is available for structural construction which may reduce the cost of construction and upgrade structural safety(Noor,M.A. and Ahmed,A.U.; 2008).). A structural engineer should have acceptable knowledge about effects of using high-strength construction materials on the efficient and economical design of structures.

The primary focus of this study is to find out the effects of using different grades of bars on the responses of high-rise structures towards EQ and Wind and also to compare the structural performances among them. To achieve this goal, a floor plan, a model of three 20- storied building has been done, which is located in Dhaka, Bangladesh. All loads are applied according to Bangladesh National Building Code (BNBC). All the models have been developed for similar loading scenarios using the same structural systems. Three building models have been created considering 40-grade, 60-grade and 75-grade bars and similar concrete compressive strength. Comparative studies have been carried out in terms of story displacement, story drift, shear forces, overturning moment, stiffness, etc. for all

Structures and finally try to present the configurations which have better performance.

1.3 Objectives of the study

• To determine the impacts of using 40-grade, 60-grade & 75-grade on the responses of high-rise structures towards EQ and Wind.

• To make a comparison among the performances of 40-grade, 60-grade over 72- grade reinforcing bars in terms of story displacement, story drift, shear forces, overturning moment, stiffness, etc.

1.4 Scopes/Limitations of the study

1. To conduct the study, edge supported floor system had been selected.
2. Standard Live Loads, Earthquake and wind loads were considered as per BNBC.
3. Volume of materials and their cost analyses were not considered.
4. Plumbing works, electrification works, brickworks, and labor works, were not considered.
5. Analyses of structures were done by ETABS

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter elaborated a detailed literature review that was required for proper knowledge and brief ideas on the slab design procedure as well as the lateral loads concept.

2.2 What is Rebar?

Steel reinforcement bars or rebar are used to enrich the tensile strength of the concrete, since concrete is comparably weak in pressure, but is strong in compression. Steel is only used as rebar because the extension of steel due to high temperatures (thermal expansion measure) nearly equals that of concrete

Types of Steel Reinforcement Bars:

The major types of steel bars used in the construction are as follows,

1. Mild Steel Bar: The skin of the mild steel bars is plain and round in shape. They're available in different sizes of 6 mm to 50 mm. They're used in concrete for special purposes, similar as dowels at expansion joints, where bars must slide in a metal or paper sleeve, for constriction joints in roads and runways, and for column spirals. They're easy to cut and bend without damage.

Figure 2.1: Mild Steel Bar

For structural buildings like bridges and other heavy structures, mild steel bar is not recommended due to no great bonding between concrete and steel, slippage and strength.

Grades in mild steel bars:

Mild Steel Bars

• Mild steel bars grade-I designated as Fe 410-S or Grade 60.

• Mild steel bars grade-II designated as Fe-410-o or Grade 40.

• Medium Tensile Steel Bars designated as Fe- 540-w-ht or Grade 75.

2. Deformed Steel Bar

Deformed steel bars have ribs, lugs and indentation on the skin of the rod, which reduces the major challenge that is faced by mild steel bar due to slippage and good cling is achieved between concrete and rebar. The tensile properties are advanced compared to other rebars. These bars are manufactured in segments from 6 mm to 50 mm dia.

Types of Deformed Steel Bars

TMT Bars (Thermo-Mechanically Treated Bars)

Thermo-Mechanically Treated rods are burning treated rods that are high in strength applied in reinforced cement concrete (RCC) work. It's the rearmost conclusion in the MS steel rods with superior properties like strength, ductility, welding capability, bending capability and top quality norms at the transnational position.

Figure 2.2: Deformed TMT Steel Bar

Physical Requirement of Mild Steel Bars

Table 2.1: Physical Requirement of Mild Steel Bars

Types of Nominal size of bar	Ultimate Tensile Stress in N/mm²	Yield Stress N/mm²	Elongation Percentage min
Mild Steel Grade I or Grade 60			
For Bars upto 20mm	410	250	23
For Bars above 20mm upto 50mm	410	240	23
Mild Steel Grade II or Grade 40			
For Bars upto 20mm	370	225	23
For Bars above 20mm upto 50mm	370	215	23
Medium Tensile Steel Grade -75			
For Bars upto 16mm	540	350	20
For Bars above 16mm upto 32mm	540	340	20
For Bars above 32mm upto 50mm	510	330	20

Characteristics of TMT Rebar:

• More rigidity and plasticity

• High yield strength and durability

• Further cling strength

• Earthquake resistance

• Erosion resistance

• High thermal resistance

• Economical and safe in usage

• Same strength at welded joints

• Average electrodes used for welding the joints

High Strength Deformed Bars

High strength deformed (HSD) bars are cold twisted steel bars with lugs, ribs, projection or deformation on the surface. It the extensively and majorly used for reinforcement purposes in construction. These bars are manufactured sizes from 4 mm to 50 mm dia.

Figure 2.3: Deformed HSD Steel Bar Characteristics of HSD Rebar

Characteristics of HSD Rebar

Low carbon value- HSD Bars have lower carbon status, performing in good ductility, strength and welding capability.

Super bonding strength – HSD bars are well known for their excellent bonding strength when used with concreate.

Welding capability- Since these bars have lower carbon content, they've 100 welding capability than conventional bars.

High tensile strength- HSD bars feature high tensile strength. They offer great asset in the construction process, where a lot of bending and re-bending is required.

Wide application range- These bars have wide application range like in constructing residential, commercial and industrial structures, bridges, etc.

Satisfactorily plasticity-minimal weight and maximum strength and suitable for both compression and tension reinforcement.

Other Types of Rebar

Depending upon the type of material used in the production of rebar, different types of rebar are:

1. European Rebar : European rebar is made of manganese, which makes them bend easily. They're not suitable for use in areas that are prone to extreme weather conditions or geological effects, such as earthquakes, hurricanes, or tornadoes. The cost of this rebar is low.

Figure 2.4: European Rebar

2. Carbon Steel Rebar

As the name represents, it is made up of carbon steel and is commonly known as Black Bar due to carbon color. The main drawback of this rebar is that it corrodes, which adversely affect the concrete and structure. The tensile strength ratio coupled with the value makes black rebar one of the best choices.

Figure 2.5: Carbon Steel Bar

3. Epoxy-Coated Rebar: Epoxy-coated rebar is black rebar with an epoxy coat. It has the same tensile strength, but is 70 to 1,700 times more resistant to corrosion. However, the epoxy coating is incredibly delicate. The greater the damage to the coating, the less resistant to corrosion.

Figure 2.6: Epoxy-Coated Bar

4. Galvanized Rebar: Galvanized rebar is only forty times more resistant to corrosion than black rebar, but it is more difficult to damage the coating of galvanized rebar. In that respect, it has more value than epoxy-coated rebar. However, it is about 40% more expensive than epoxy-coated rebar.

Figure 2.7: Galvanized Bar

5. Glass-Fiber-Reinforced-Polymer (GFRP): GFRP is made up of carbon fiber. As it is made up of fiber, bending is not allowed. It is very resistant to corrosion and is costly when compared to other rebars.

Figure 2.8: Glass-Fiber-Reinforced-Polymer Bar

6. Stainless Steel Rebar

Stainless steel rebar is the most expensive reinforcing bar available, about eight times the price of epoxy-coated rebar. It is also the best rebar available for most projects. However, using stainless steel in all but the most unique of circumstances is often overkill. But, for those who have a reason to use it, stainless steel rebar 1,500 times more resistant to corrosion than black bar; it is more resistant to damage than any of the other corrosive resistant or corrosive-proof types or rebar; and it can be bent in the field.

2.3 Design Issues Related to High Strength Reinforcing Bar [HSRB]:

Design professionals can design reinforced concrete structures with HSRB using the requirements and limits prescribed in ACI 318-19, which are summarized in Table 3 for deformed bars. It is important to note that some provisions of ACI 318 may need adjustment before HSRB can be used in applications where the yield strength is greater than the limits prescribed in Table 3 (for example, using longitudinal tension reinforcement with a yield strength of 100,000 psi in beams). As new research and/or new analytical studies becomes available related to the use of HSRB, it is anticipated that ACI 318 will be updated accordingly. For example, as discussed previously, ACI Committee 318 will be considering the general use of Grade 80 reinforcement in special seismic systems as well as some other possible modifications related to HSRB in the next edition of ACI 318 based on some recent research.

A brief summary is given below on some design issues related to the use of HSRB and the potential impact on ACI 318 provisions. The following list of issues and observations is not meant to be comprehensive nor is it meant to discourage the use of HSRB. Rather, it is provided so that design professionals have a clearer understanding of what ACI 318 provisions may need adjustment and what additional information is required for general use of HSRB beyond the limitations in Table 3. In-depth information on these and other issues can be found in ATC 115 (ATC 2014).

Strength

1. Flexure and axial load strength

(a) Compression-controlled sections are defined as those where the net tensile strain ε_t does not exceed the compression-controlled strain limit ε_{ty}, which is defined in ACI 21.2.2.1 as f_y/E_s. The current definition of ε_{ty} is based on a stress-strain curve that is linear-elastic to the yield plateau. For HSRB with a rounded stress-strain curve (see Figure 3) where f_y must be determined by the 0.2% offset method, the definition of ε_{ty} may need to be revised from f_y/E_s. In lieu of revising the definition, specific values of ε_{ty} can be provided for different grades, similar to pre-stressed reinforcement (see ACI 21.2.2.2).

(b) Tension-controlled sections are defined as those where the net tensile strain ε_t is equal to or greater than the tension-controlled strain limit of 0.005. The limiting value of 0.005 is approximately 2.5 times the yield strain of 0.002 for ASTM A615 Grade 60 reinforcement. The yield strain will typically be larger for HSRB, so it may be appropriate to increase the tension-controlled strain limit of 0.005 to provide levels of ductility consistent with the current provisions.

(c) For non pre-stressed one-way slabs, two-way slabs, and beams, the net tensile strain ε_t must be equal to or greater than 0.004 to mitigate brittle flexural behavior in case of an overload (see ACI 7.3.3.1, 8.3.3.1, and 9.3.3.1, respectively). For HSRB, the elongation capacity εu is generally less than that for Grade 60 reinforcing bars, so the limit may need to be revised accordingly.

(d) Current methods for calculating the flexural strength of one-way slabs, two-way slabs, and beams assumes that the stress-strain curve of the reinforcement includes a yield plateau. For members reinforced with HSRB without a yield plateau, the current methods to determine flexural strength must be validated analytically and/or experimentally.

2. Shear strength

(a) Research has shown that one-way and two-way shear strength of the concrete is influenced by the longitudinal reinforcement ratio: the larger the ratio, the larger the concrete shear strength. Using HSRB may result in a smaller required longitudinal reinforcement ratio, which may lead to reduced concrete shear strength.

(b) For HSRB that are utilized as shear reinforcement, crack control needs to be addressed in cases where the yield strength exceeds 60,000 psi.

<u>Serviceability</u>

1. Deflections

(a) The minimum member thicknesses in ACI 7.3.1, 8.3.1, and 9.3.1 for one-way slabs, two-way slabs, CRSI Technical Note **11** and beams, respectively, need to be verified for members utilizing HSRB.

(b) The equation for the effective moment of inertia I_e of non pre-stressed members in ACI 24.2.3.5, which is used in calculating deflections of reinforced concrete members, needs to be verified for members utilizing HSRB.

(c) The time-dependent deflection factor λ_Δ in ACI 24.2.4.1.1 that is used in calculating long-term deflections is independent of the yield strength of the reinforcement in the member. This factor needs to be verified for HSRB.

2. Drift

(a) Depending on a number of factors, there is a potential for increased flexural cracking to occur in reinforced concrete flexural members with HSRB. As such, a reduction in the flexural stiffness is anticipated, resulting in possible larger drift.

(b) Increased cracking is not anticipated in columns with HSRB. However, the amount of longitudinal reinforcement and/or the size of the column may be decreased, which would have an impact on stiffness and drift.

Other Design Considerations

1. Because development and lap splice lengths are proportional to the yield strength, f_y, these lengths for HSRB are longer, with a percentage increase of 25%, 33%, 67% and 100% for Grades 75, 80, 100 and 120, respectively, over Grade 60 bars. The use of mechanical splices and headed bars should be considered where appropriate. Headed bar and coupler options are available to anchor and connect HSRB, including large bar sizes.

2. ACI 25.4.4.1(b) limits headed bars to a yield strength no greater than 60,000 psi. With the inordinately longer development and lap splice lengths of HSRB, a greater emphasis will be placed on utilizing headed bars. Thus, further research is required in order to justify using headed bars to develop HSRB.

3. As noted previously, the use of HSRB in seismic force-resisting systems is covered in NIST GCR 14-917-30 (2014). Pertinent design issues are covered in detail in that document.

Availability

Just like any other type of reinforcement, it is recommended to check with a local concrete contractor or reinforcing bar supplier to ensure that the grade and/or bar size of HSRB is available prior to design and production of the construction documents.

Provisions for the use of higher strength reinforcing bars have been incorporated into ACI 318 as new reinforcing steel products have become available. It is anticipated that this trend will continue as additional research and analytical studies validate the performance of HSRB in reinforced concrete members. Designers can specify and utilize HSRB (with yield strengths greater than 60,000 psi) based on the current provisions and limitations in ACI 318-14 (see Table 3 for deformed reinforcing bars). Proposed modifications to the next edition of ACI 318 with respect to HSRB are currently under consideration. A number of jurisdictions in the U.S. permit the use of HSRB above and beyond the limitations set forth in the current ACI 318.

Cost-effective reinforced concrete structures may be realized by taking advantage of the benefits of HSRB, which include smaller required bar sizes and/or a smaller number of required bars, less congestion, lower placement costs, and smaller member sizes. CRSI can assist designers and building authorities in all aspects on the use of HSRB. Contact CRSI for additional design information or questions about local code approval procedures.

2.4 ASTM A615 Reinforcement bar A615-75 Grade Steel

What is A615-75 Grade Steels?

A615-75 grade steel is a structural billet steel for structural applications. A615-75 grade is a material grade and designation defined in ASTM A615 standard. ASTM A615 is an international material standard for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement for strengthening application. A615-75 grade Steel is higher in strength as compared to A615-60 steel.

Dimensional Characteristics of A615-75 Grade Steels:

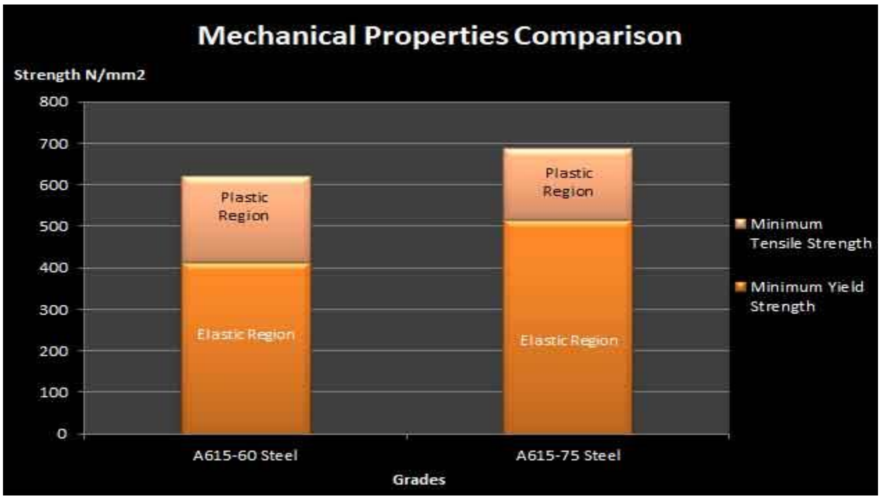
The applicable diameter for this A615-75 GRADE material as defined in the ASTM A615 ranges to 19.1-22.2 mm. The perimeter is usually around 59.869.8 mm. The cross-sectional area is about 284-387 mm^2.

The Chemical Composition of A615-75 Grade Steels:

ASTM A615 defines the chemical composition of A615-75 Grade steels as under: Only Maximum percentage of **Phosphorous** (P) is identified by the standard i.e. **0.060** Remaining is iron (Fe) percentage and with few other alloys and negligible impurities.

Mechanical Properties of A615-75 Grade Steels:

The tensile strength of the A615-75 Grade Steels is expressed in Newton per millimeters and it must be at-least 689 N/mm2 (MPa). The yield strength is minimum 517 N/mm2 (MPa). The minimum percentage ranges for elongation are 6% thicknesses.



The capability to meaningfully decrease cost is motive alone to stipulate Grade 75 reinforcing steel. Additional benefits comprise condensed congestion and, for pillars and shear wall chord reinforcing, the option of rarer column ties due to fewer vertical bars. From a sustainability viewpoint, there are also environmental remunerations for example less steel utilized equals rarer carbon emissions by utilizing Grade 75. Experts say a time will come that A615-60 steel will be replaced completely by A615-75 steel.

2.5 ASTM A615 Reinforcement Bar A615-60 Grade Steel

What is A615-60 Grade Steels?

A615-60 grade steel is a structural billet steel for structural applications. A615-60 grade is a material grade and designation defined in ASTM A615 standard. ASTM A615 is an international material standard for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement for strengthening application. A615-60 grade Steel is higher in strength as compare to A615-40 steel.

Dimensional Characteristics of A615-60 Grade Steels: The applicable diameter for this A615-60 GRADE material as defined in the ASTM A615 ranges to 22.2-28.7 mm. The perimeter is usually around 69.8-90 mm. The cross-sectional area is about 387-645 mm^2.

The Chemical Composition of A615-60 Grade Steels: ASTM A615 defines the chemical composition of A615- 60 Grade steels as under Only Maximum probability of Phosphorous (P) is identified by the standard i.e.0.060 Remaining is iron(Fe) percentage and with some other blends and negligible contaminations.

Mechanical Properties of A615-60 Grade Steels: The tensile strength of the A615- 60 Grade Steels is expressed in Newton per millimeter and it must be at least 620 N/ mm2 (MPa). The

yield strength is minimal 413 N/ mm2 (MPa). The minimum percentage ranges for extension are 9 thicknesses. 180-degree bends on 3.5 diameters.
ASTM A615 Grade 60 rebar is generally used as a tensioning stratagem in reinforced concrete and strengthened building materials structures holding the concrete in compression. It's generally used in Construction, Bridge Building, and Road Building etc.

2.6 ASTM A615 Reinforcement bar A615-40 Grade Steel

APPLICATIONS:

ASTM A615 Grade 40 rebar is a common steel bar and is normally used as a tensioning device in reinforced concrete and reinforced masonry structures holding the concrete in compression. It's generally formed from carbon steel and is given ridges for better mechanical anchoring into the concrete.

MACHINING AND WELDING:

ASTM A615 Grade 40: The American Welding Society (AWS) D1.4 sets out the practices for welding rebar in the U.S. Without special consideration, the only rebar that is prepared to weld is W grade (Low- alloy — A706). Rebar that isn't produced to the ASTM A706 specification is generally not capable for welding without calculating the" carbon- equivalent". Material with a carbon- equivalent of lower than0.55 can be welded.(AWS D1.4)

ASTM A615 Grade 40 reinforcing bars are able of being bent cold wave around a pin without cracking on the outside of the bent portion, as follows Under3/4 ” diameter – Will bend 90º around a pin four times own diameter.3/4 ” diameter & over – Will bend 90º around a pin five times own diameter.

2.7 Grade 40 vs grade 60 rebar

Grade 60 rebar have much more use than grade 40 rebar. Grade 60 rebar is the most generally used rebar grade in current United States construction. Grade 60 steel is the most generally used in structures and concrete, as it's not substantially more costly than grade 40 steel, but offers much further strength. Grade 40 steel is frequently used for effects that don't require substantial structural strength. And grade 60 have much further application than grade 40 rebar.
Minimal Yield strength of grade 60 rebar is more than grade 40 rebar. minimal yield strength of grade 60 rebar is about 60ksi which is equal to 60000 psi(pounds square inches) equivalent to 420 grade of rebar in metric system, similar to 420MPa or 420N/ mm2 as minimal yield strength, still minimal yield strength of grade 40 rebar is about 40ksi which is equal to 40000psi(pounds square inches) equivalent to 280 grade of rebar in metric system, alike to 280MPa or 280N/ mm2 as minimal yield strength.

Minimal ultimate tensile strength of grade 60 rebar is more than grade 40 rebar. As ASTM A 615, minimal ultimate tensile strength of grade 60 is about 90000psi or 90ksi, however, minimal ultimate tensile strength of grade 40 is about 60000psi or 60ksi.

Grade 60 rebar is stronger than grade 40 rebar. Due to high ultimate tensile strength and yield strength in grade 60 rebar than 40, grade 60 rebar is stronger than grade 40 rebar.

Grade 40 rebar bend more smoothly than grade 60 rebar. Grade 40 rebar bend more smoothly than grade 60 rebar up to 180 ° while testing.

Ductility of grade 40 rebar is more than grade 60 rebar. Ductility is the property of steel reinforcement, it's capability to drawn or plastically deformed without fracture, grade 40 rebar is highly ductile in nature than grade 60 rebar. The percentage of carbon is more in grade 60 rebar than grade 40 rebar.

2.8 Stress-Strain Curves

The two principal numerical characteristics that determine the character of bar reinforcement are its yield point(usually identical in tension and compression) and its modulus of elasticity Es. The latter is virtually the same for all reinforcing brands(but not for pre-stressing steels) and is taken as E s = psi.

In addition, yet, the shape of the stress-strain curve, and specifically of its initial portion, has a significant influence on the performance of reinforced concrete members. Typical stress-strain curves for U.S. reinforcing steels are shown in Fig.2.8. The complete stress- strain curves are shown in the left portion of the figure; the right part gives the initial portions of the curves magnified 10 times.

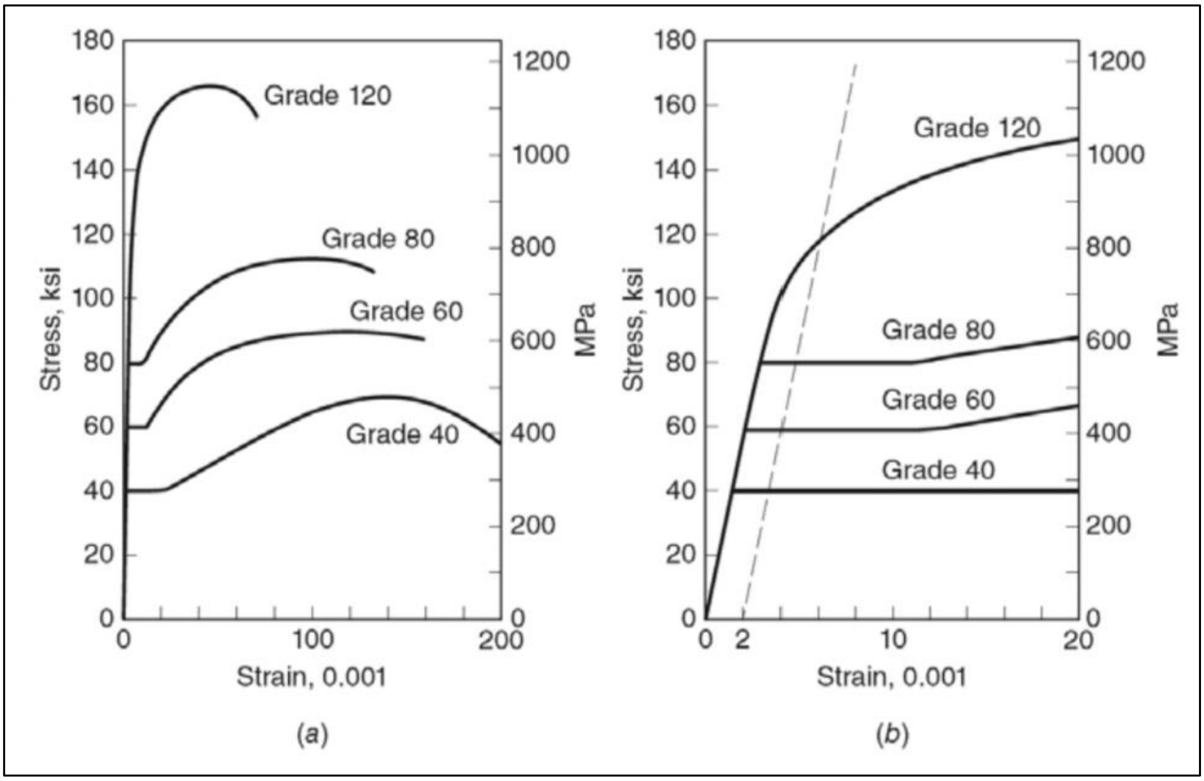


Figure 2.9: Typical stress-strain curves for reinforcing bars

Low- carbon steels, illustrated by the Grade 40 curve, show an elastic portion followed by a yield table, that is, a horizontal portion of the curve where strain continues to increase at constant stress. For alike steels, the yield point is that stress at which the yield table establishes itself. With farther strains, the stress begins to increase again, however at a slower rate, a process that's known as strain- hardening. The curve flattens out when the tensile strength is reached; it also turns down until fracture occurs. high- strength carbon steels, for example, those with 60 ksi yield stress or advanced, either have a yield plateau of much shorter length or enter strain- hardening immediately without any continued yielding at constant stress. In the latest case, the yield stress fy is determined using the 0.2 percent offset method. Using this method, a line with a strain intercept of 0.2 percent (or 0.002) is drawn parallel to the initial elastic portion of the stress- strain curve. The yield stress f y is defined by the point at which this line intercepts the stress-strain curve, as shown inFig.2.8b. Low- alloy, high- strength brands infrequently show any yield plateau and generally enter strain- hardening incontinently upon beginning to yield.

CHAPTER 3
METHODOLOGY OF THE STUDY

3.1 General

This chapter gives the outlines of the procedures that were followed to complete this study. Finally, deflection of the whole structure is provided to obtain the effects of lateral loadings on the structure.

3.2 Study procedures

Step-I: Selection and planning of the structure

Three 20 storied Residential cum commercial structural models having same plinth areas with beam column floor system had been selected. These models will have the following specifications for analysis purposes:

Type-I building- Structure with 40 Grade bar.

Type-II building- Structure with 60 Grade bar.

Type-III building- Structure with 75 Grade bar.

The Three structures have all the facilities and amenities such as passenger lifts, stairs, ramps, car parking etc.

Step-II: Selection of the material properties & loadings

As per discussions made in *Chapter 2* and based on design code/specifications of *ACI/BNBC*, material properties (compressive strength of concrete, yield stress of steel, unit weight of concrete, soil, brick etc.) and loadings (standard live load, floor finish, etc.) were selected. Wind and earthquake loads were also considered.

Step-III: Analysis & findings of the study

Same structure in three different Grade bars 40 Grade bar, 60 Grade bar and 75 Grade bar were analyzed by using ETABS 2019. Chapter 4 provides detailed analysis and findings of the study.

Step-IV: Conclusions & Recommendations

Based on study, few concluding remarks were drawn. To carry out further study on this topic, recommendations were proposed in the Chapter 5.

3.3 Design data and specifications considered in this study

The whole study was carried out based on few considerations and specifications which are summarized in Table 3.1 below.

Table 3.1: Summary of the design considerations and specification of the study

Items	Description
Design Code	• American Concrete Institute (ACI) Building design code, 2019. • Bangladesh National Building Code (BNBC), 2020.
Loadings	• Floor finish for all floors = 16.38 psf. • Floor finish for stair = 16.38 psf. • Floor finish for water tank (Top & Bottom) = 10 psf. • Floor finish for ramp = 15 psf. • Live load for all Ground floors= 100.2 psf. • Live load for all floors = 41.74 psf. • Live load for all stair = 100.2 psf. • Live load for ramp = 60 psf. • Live load for water tank (Top & Bottom) = 10 psf. • P.W. load for commercial floors = 49.46 psf. • P.W. load for residential floors = 54.20 psf. • Earthquake and wind load are considered.
Building Components	• Column type = Rectangular, Tied & C. • Footing type = Pile foundation. • Thickness of all partition walls = 5 inch. • Thickness of shear-wall = 12inch. • Thickness of Slab= 5.5 inch • Thickness of ramp= 10 inch.

Material Properties	• Yield strength of reinforcing bars, *fy* = 40, 60 & 75 ksi. • Concrete compressive strength, *f'c* = 4,000 psi. (for column & wall) • Concrete compressive strength, *f'c* = 3,000 psi. (for beam & slab) • Normal density concrete having, *wc* = 150 pcf. • Unit weight of brick, *wb* = 120 pcf. • Unit weight of water = 62.5 pcf.

3.4 Load Calculation

3.4.1 Load case according to the *BNBC* code

• **For frame design**

o For UDCon1 : 1.4 DL + 1.4 PW + 1.4 FF

o For UDCon2 : 1.2 DL + 1.6 LL + 1.2 PW + 1.2 FF

o For UDCon3 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 WIND Y

o For UDCon4 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + (-1.0) WIND Y

o For UDCon5 : 0.9 DL + 0.9 PW + 0.9 FF +1.0 WIND Y

o For UDCon6 : 0.9 DL + 0.9 PW + 0.9 FF + (-1.0) WIND Y

o For UDCon7 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 EQ (+X)

o For UDCon8 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + (-1.0) EQ (+X)

o For UDCon9 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 EQ (-X)

o For UDCon10 : 1.3 DL + 1.0 LL + 1.3 PW+ 1.3 FF + (-1.0) EQ (-X)

o For UDCon11 : 1.3 DL +1.0 LL + 1.3 PW + 1.3 FF + 1.0 EQ (+Y)

o For UDCon12 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + (-1.0) EQ (+Y)

o For UDCon13 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF +1.0 EQ (-Y)

o For UDCon14 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + (-1.0) EQ (-Y)

o For UDCon15 : 0.8 DL + 0.8 PW + 0.8 FF+ 1.0 EQ (+X)

o For UDCon16 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (+X)

o For UDCon17 : 0.8 DL + 0.8 PW + 0.8 FF+ 1.0 EQ (-X)

o For UDCon18 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (-X)

o For UDCon19 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (+Y)

o For UDCon20 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (+Y)

o For UDCon21 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (-Y) o For UDCon22 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (-Y)

• **For slab design**

o For UDSlbU1 : 1.4 DL + 1.4 PW + 1.4 FF

o For UDSlbU2 : 1.2 DL + 1.6 LL + 1.2 PW + 1.2 FF + 1.6 CL + 1.6 WP

o For UDSlbU3 : 1.2 DL + 1 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP+ 1.0 WIND Y

o For UDSlbU4 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + (-1) WIND Y

o For UDSlbU5 : 0.9 DL + 1.0 WIND Y

o For UDSlbU6 : 0.9 DL + (-1.0) WIND Y

o For UDSlbU7 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + 1.0 EQ (+X)

o For UDSlbU8 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + (-1.0) EQ (+X)

o For UDSlbU9 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + 1.0 EQ (-X)

o For UDSlbU10 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + (-1.0) EQ (-X)

o For UDSlbU11 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + 1.0 EQ (+Y)

o For UDSlbU12 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + (-1.0) EQ (+Y)

o For UDSlbU13 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + 1.0 EQ (-Y)

o For UDSlbU14 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 CL + 1.0 WP + EQ (-Y)

o For UDSlbU15 : 0.9 DL + 1.0 EQ (+X)

o For UDSlbU16 : 0.9 DL + (-1.0) EQ (+X)

o For UDSlbU17 : 0.9 DL + 1.0 EQ (-X)

o For UDSlbU18 : 0.9 DL + (-1.0) EQ (-X)

o For UDSlbU19 : 0.9 DL + 1.0 EQ (+Y)

o For UDSlbU20 : 0.9 DL + (-1.0) EQ (+Y)

o For UDSlbU21 : 0.9 DL + 1.0 EQ (-Y)

o For UDSlbU22 : 0.9 DL + (-1.0) EQ (-Y)

• **For wall design**

o For UDWal1 : 1.4 DL + 1.4 PW + 1.4 FF

o For UDWal2 : 1.2 DL + 1.6 LL + 1.2 PW + 1.2 FF + 1.6 WP + 1.6 SP

o For UDWal3 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 WP + 1.0 SP + 1 WIND Y

o For UDWal4 : 1.2 DL + 1.0 LL + 1.2 PW + 1.2 FF + 1.0 WP + 1.0 SP + (- 1) WIND Y

o For UDWal5 : 0.9 DL + 0.9 PW + 0.9 FF + 1.0 WIND Y

o For UDWal6 : 0.9 DL + 0.9 PW + 0.9 FF + (-1.0) WIND Y

o For UDWal7 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP + 1.0 SP + 1.0 EQ (+X) o For UDWal8 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP + 1.0 SP + (- 1.0) EQ (+X)

o For UDWal9 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP+ 1.0 SP + 1.0 EQ (-X)

o For UDWal10 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP +1.0 SP + (- 1.0) EQ (-X)

o For UDWal12 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP + 1.0 SP + (- 1.0) EQ(+Y)

o For UDWal13 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP + 1.0 SP+ 1.0 EQ (-Y)

o For UDWal14 : 1.3 DL + 1.0 LL + 1.3 PW + 1.3 FF + 1.0 WP + 1.0 SP + (- 1) EQ (-Y)

o For UDWal15 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (+X)

o For UDWal16 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (+X)

o For UDWal17 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (-X)

o For UDWal18 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (-X)

o For UDWal19 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (+Y)

o For UDWal20 : 0.8 DL + 0,8 PW + 0.8 FF + (-1.0) EQ (+Y)

o For UDWal21 : 0.8 DL + 0.8 PW + 0.8 FF + 1.0 EQ (-Y)

o For UDWal22 : 0.8 DL + 0.8 PW + 0.8 FF + (-1.0) EQ (-Y)

3.4.2 Dead loads

Floor space

Self-weight of slab = 5.5/12 *150 = 68.75 psf.

Floor finish commercial = 16.38 psf.

Floor finish residential = 16.38 psf.

5” Partition wall Load calculation, for Commercial = 49.46 psf.

5″ Partition wall Load calculation, for Residential = 54.2 psf.

Total dead load for 5.5-inch thickness slab, for Commercial,

= self-weight of slab + Floor finish load + partition wall load

= 68.75 + 16.38 + 49.46 = 134.59 psf

Total dead load for 5.5-inch thickness slab, for Residential,

= self-weight of slab + Floor finish load + partition wall load

= 68.75 + 16.38 + 54.2 = 139.33 psf

Ramp slab

Self-weight of ramp slab = (10/12) *150 = 125 psf.

Floor finish = 15psf.

Total dead load for 15″ thickness slab = 125 + 15 = 140 psf.

3.4.3 Live load calculation

Live load for all Ground floor space = 100.2 psf. Live load for all floor space = 41.74 psf. Live load for all stair = 100.2 psf. Live load for water tank slab (Top & Bottom) = 10 psf.

Live load for ramp (including car load) = 60 psf.

Water pressure for water tank = 343.75 psf.

3.4.4 Seismic load calculation

Height of building = 216 ft

= 65.85 m Seismic zone Coefficient (Dhaka zone) = 0.2

Special moment resisting frame, R = 6.5

Importance Coefficient for residential building, I = 1.25

Vibration time period, T = $C_t \times h^{3/4}$

= $0.049 \times 65.85^{3/4}$ = 1.13 second

Soil profile = SC

3.4.5 Wind load calculation

Height of building, H = 216 ft.

Wind pressure in Dhaka city, V_b = 147 mph

Importance coefficient, I = 1

CHAPTER 4
ANALYSIS & FINDINGS OF THE STUDY

4.1 Introduction

This chapter provides findings of the study and discussion of the obtained results as per references used. This study focuses on the responses by analyzing the effects of the lateral loads on 20 storied high-rise structures having same structure in three different Grade bars. All results are summarized in several tabular forms and presented in graphical forms in order to make comparative analyses. Also, few explanations were made based on data from ETABS. Finally, presents a comparative result to identify best structural system for a high-rise structure against lateral loadings.

4.2 Comparative discussions:

According to the main objective of this study, it is required to find out the effects of lateral loadings in different seismic zones and thereby the analysis, three 20 storied high-rise structural models for Grade bar as 40 Grade bar, 60 Grade bar, 75 Grade bar have been considered. To obtain the goal, the whole comparative study is divided into several sub topics so that a clear picture can be obtained and complete discussions are possible. Also following points are considered:

1. The both structures are divided into several grids in ETABS plan: 1~16 in horizontal grids and A~P in vertical grids.

2. Analysis's data are taken for Lateral loads to Stories; Maximum stories Displacement; Maximum stories Drifts; stories Shear, stories Overturning Moments and stories Stiffness in case of three structures.

Figures 4.1(a) ~ 4.1(i) present plan views and layouts respectively of all floors of three structures which give clear picture on the presence of columns, flat plate slab and shear walls etc. that considered in this structure.

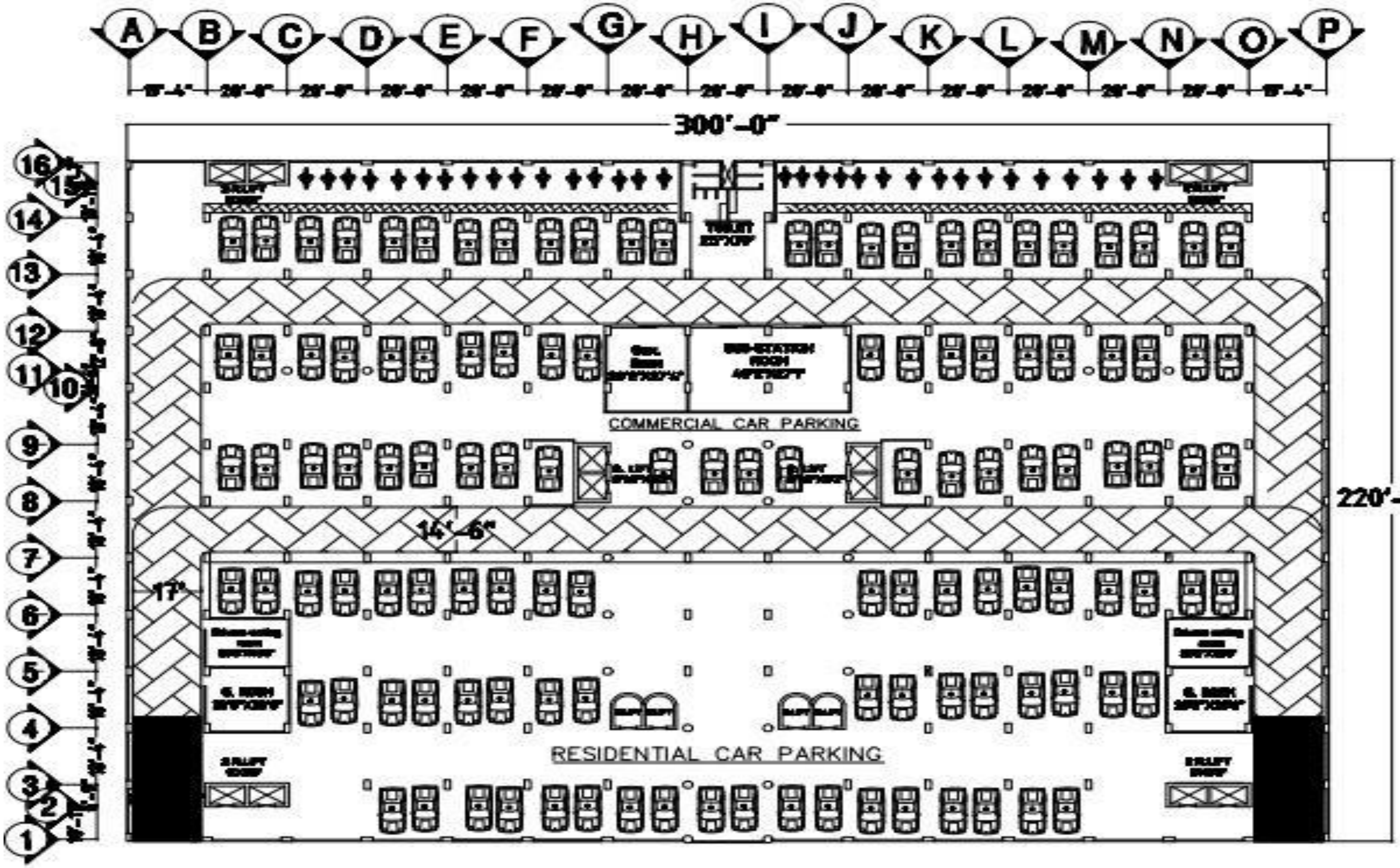


Figure 4.1(a): Basement floor plan view

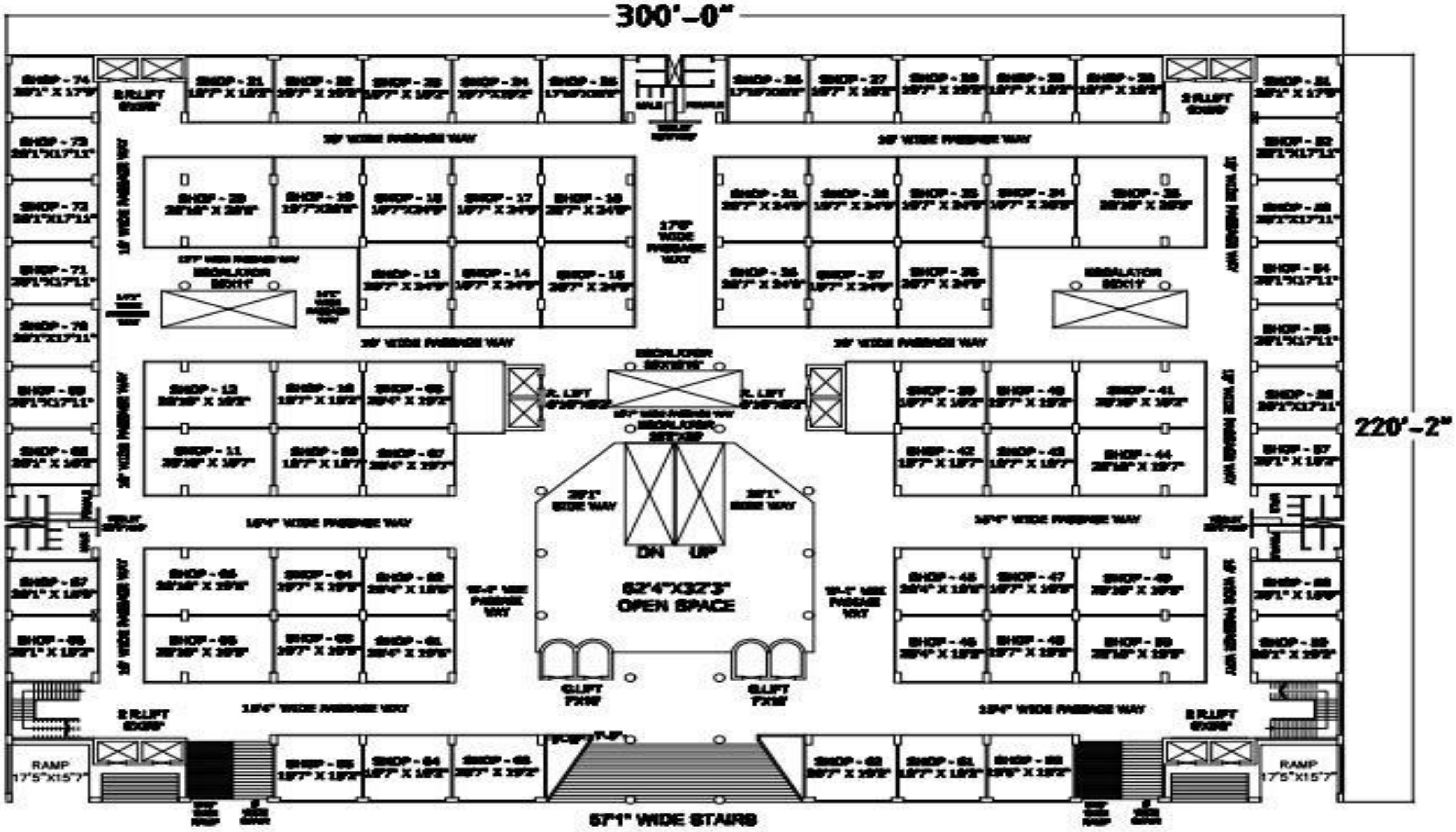


Figure 4.1(b): Ground floor plan view

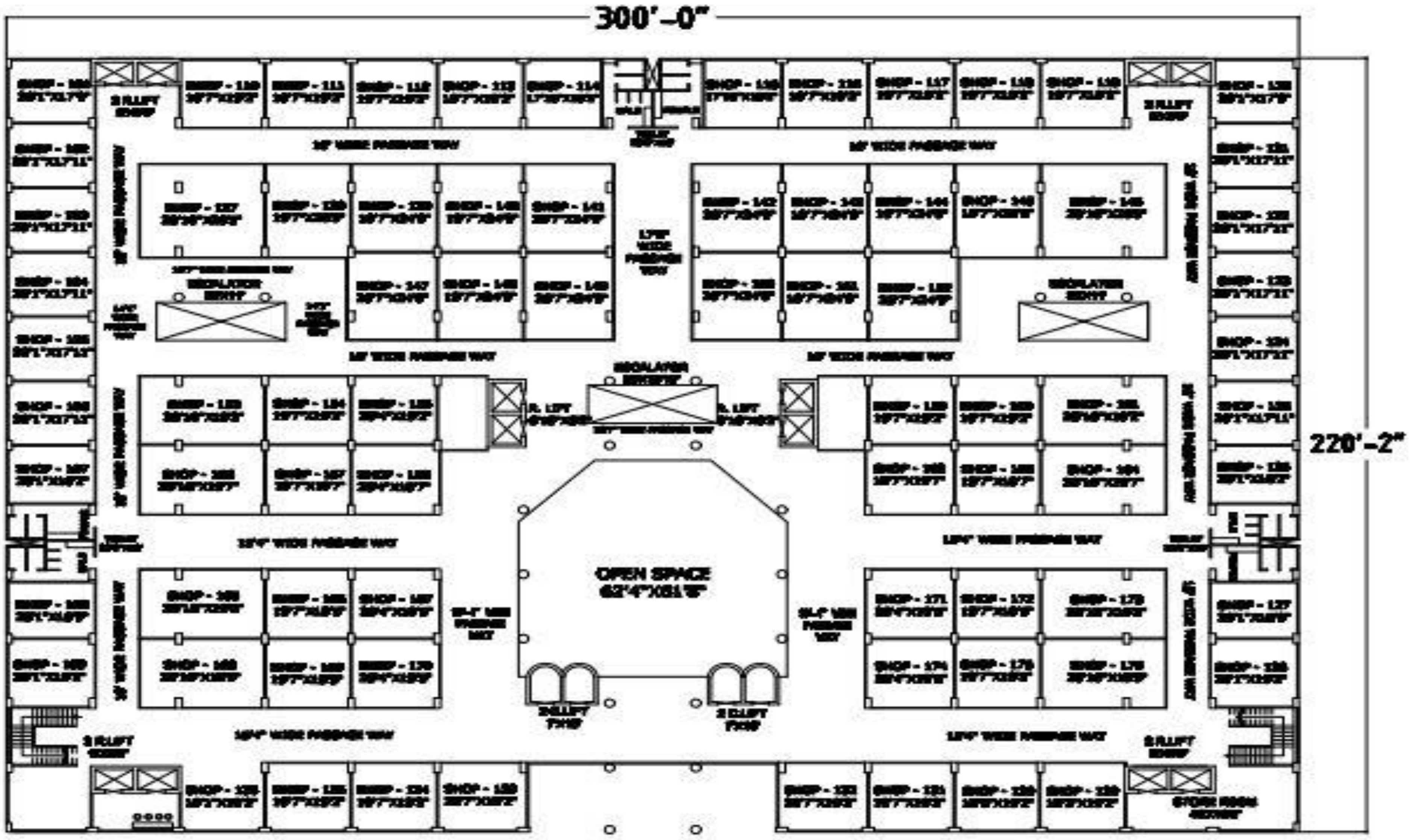


Figure 4.1(c): 1st floor plan view.

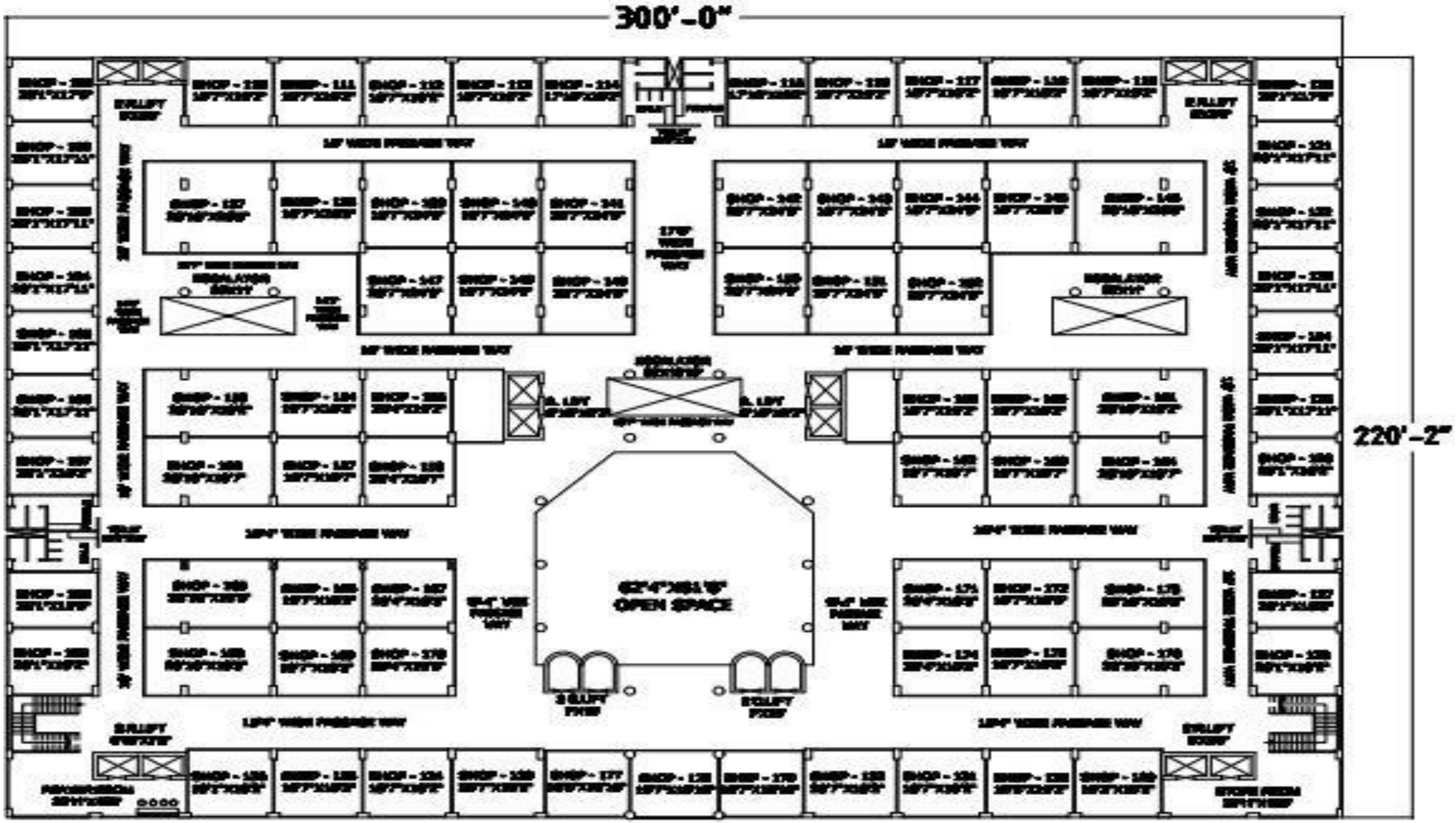


Figure 4.1(d): 2^{nd} to 4^{th} floor plan view.

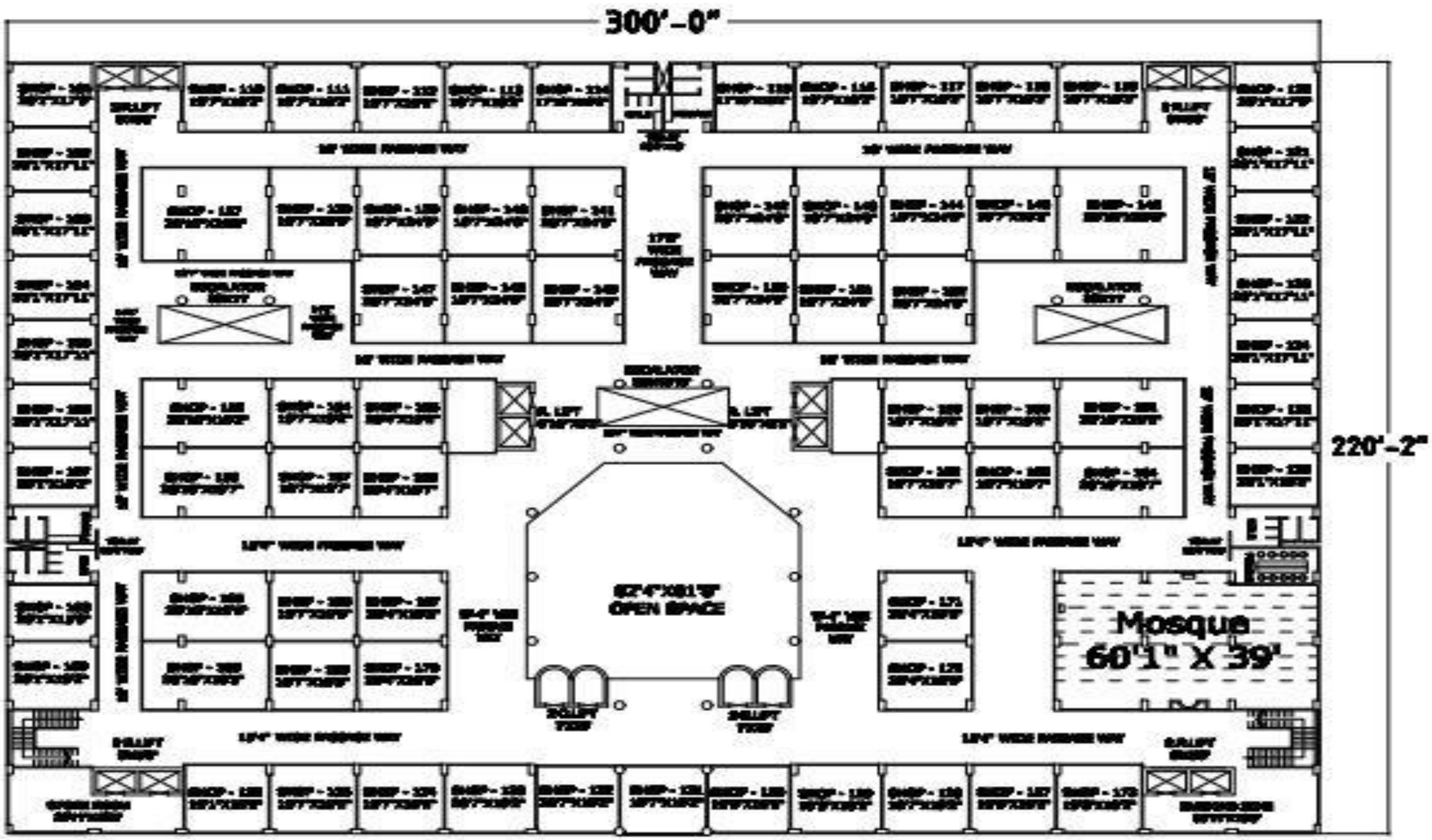


Figure 4.1(e): 5th floor plan view.

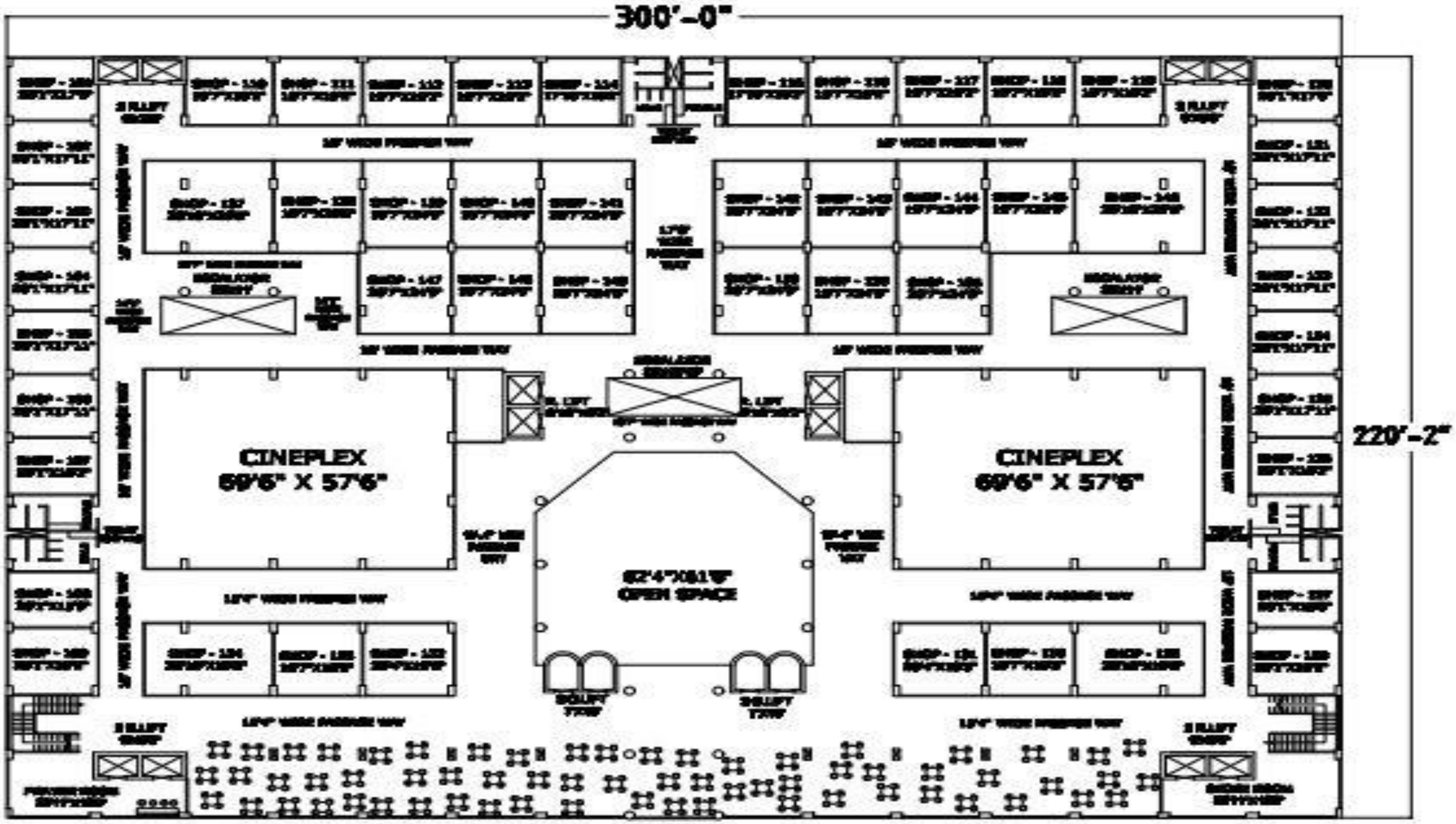


Figure 4.1(f): 6th floor plan view.

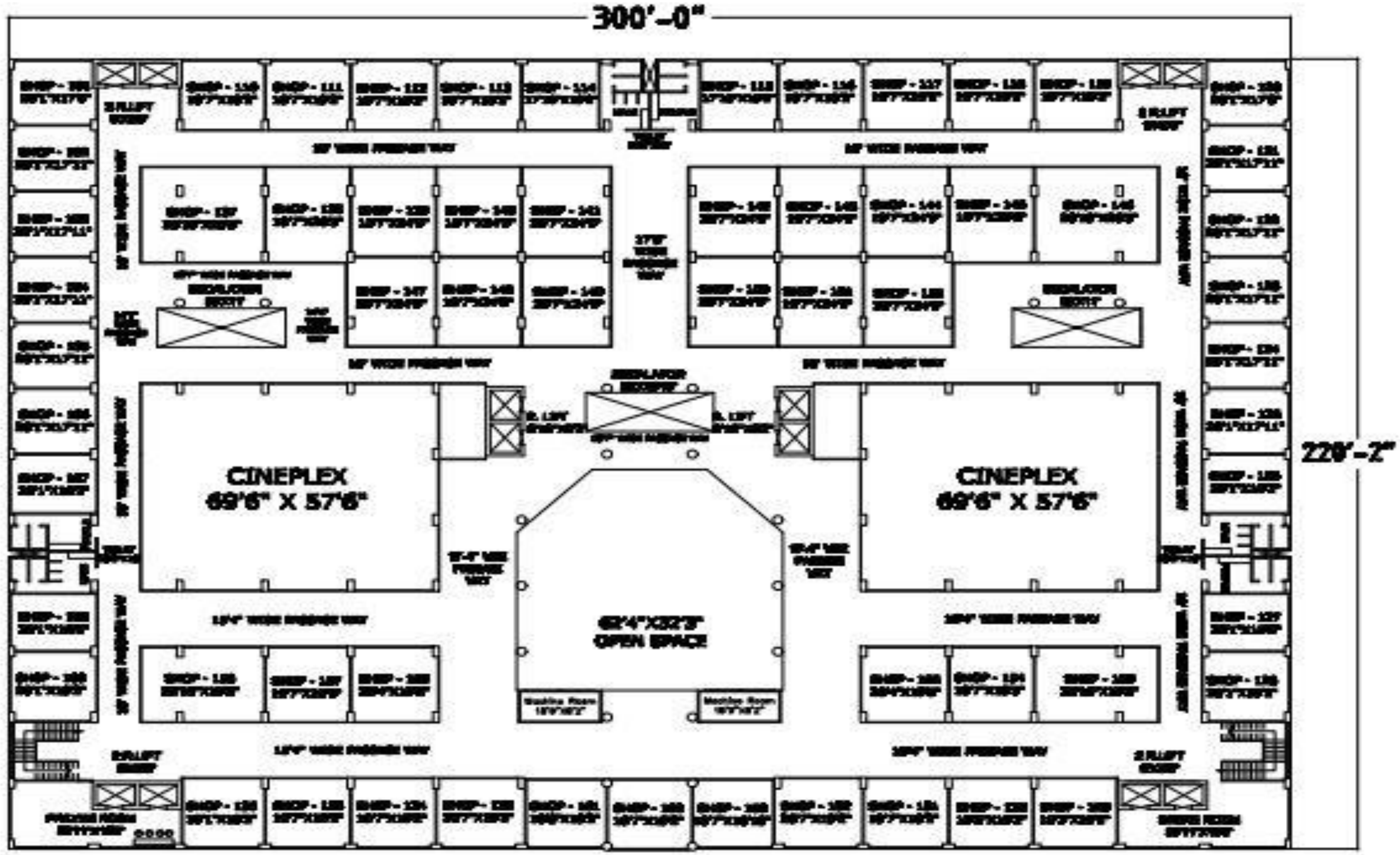


Figure 4.1(g): 7th floor plan view.

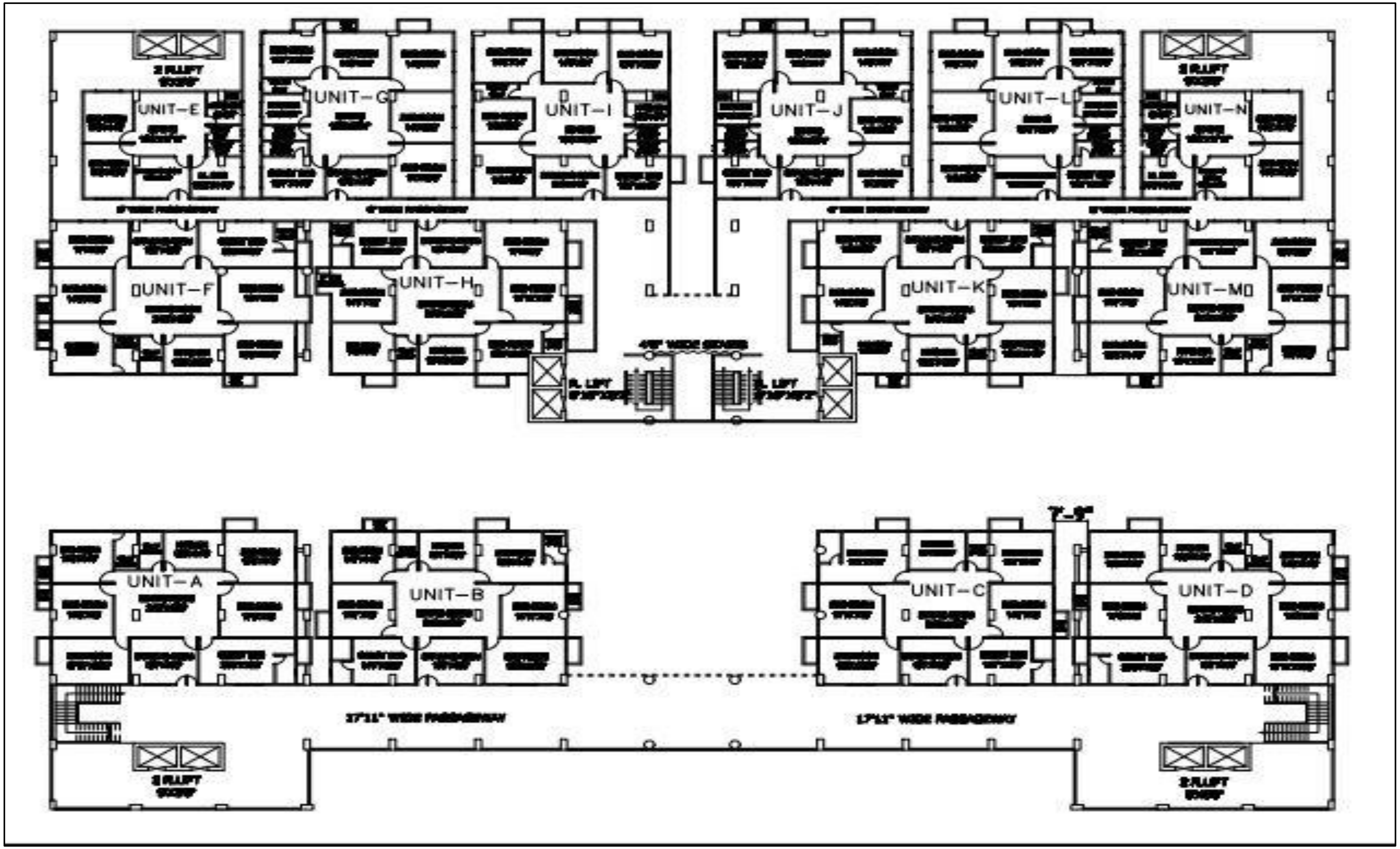


Figure 4.1(h): 8^{th} to 19^{th} Floor Plan (Residential)

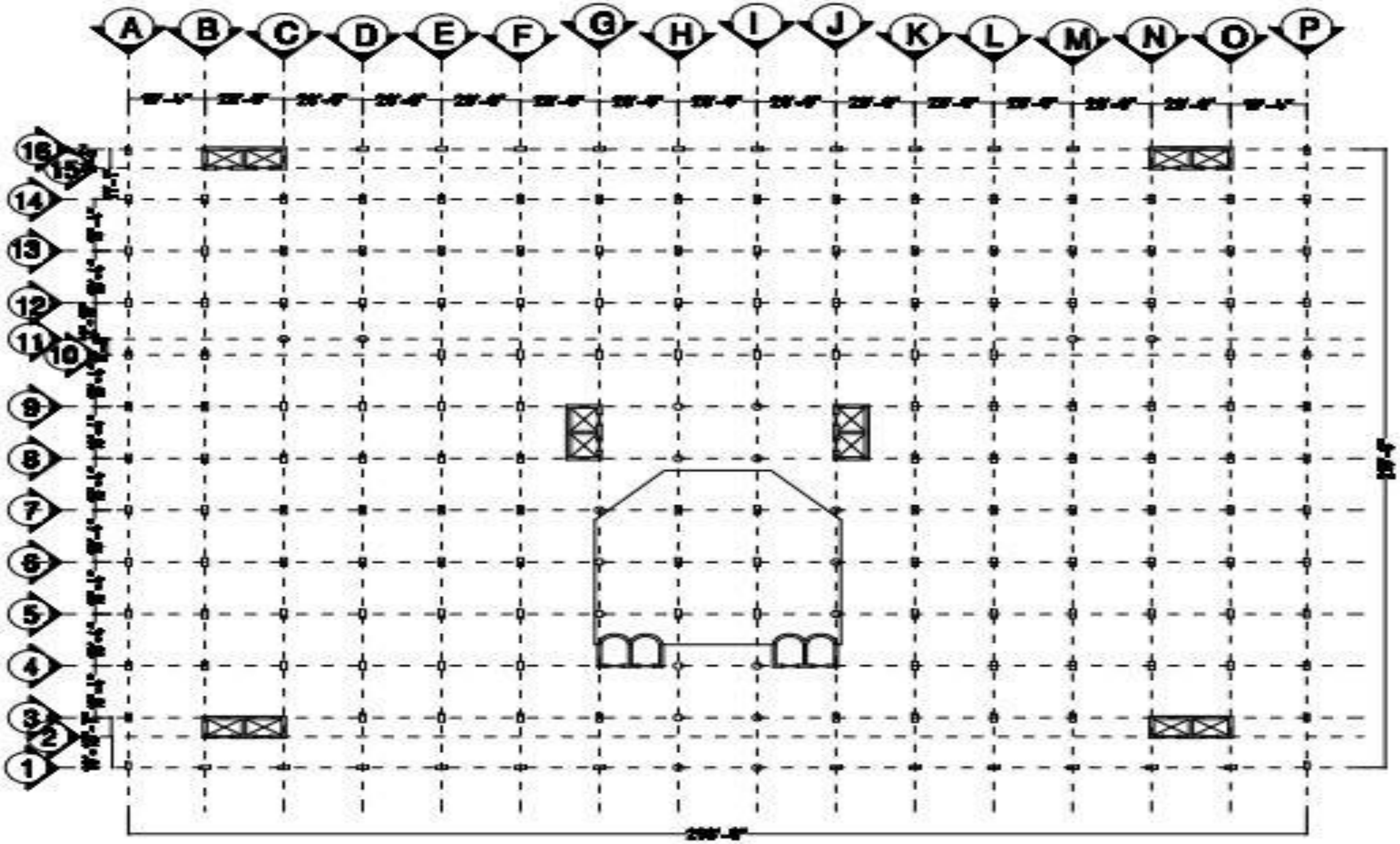


Figure 4.1(i): Column layout

4.2.1 Comparison based on Different Influencing Factors

This section will present the differences among the responses of 40 Grade bar, 60 Grade bar and 75 Grade bar - Structure towards lateral loadings in terms of the following factors:

- Auto Lateral Loads to Stories
- Maximum Story Displacement
- Maximum Story Drifts
- Story Shears
- Story Overturning Moments
- Story Stiffness
- Base Reactions

Comparative analysis was done by ETABS. The global X-axis and Y-axis of the model are similar of the building. The global X-axis and Y-axis of the models are shown in Figure 4.2.

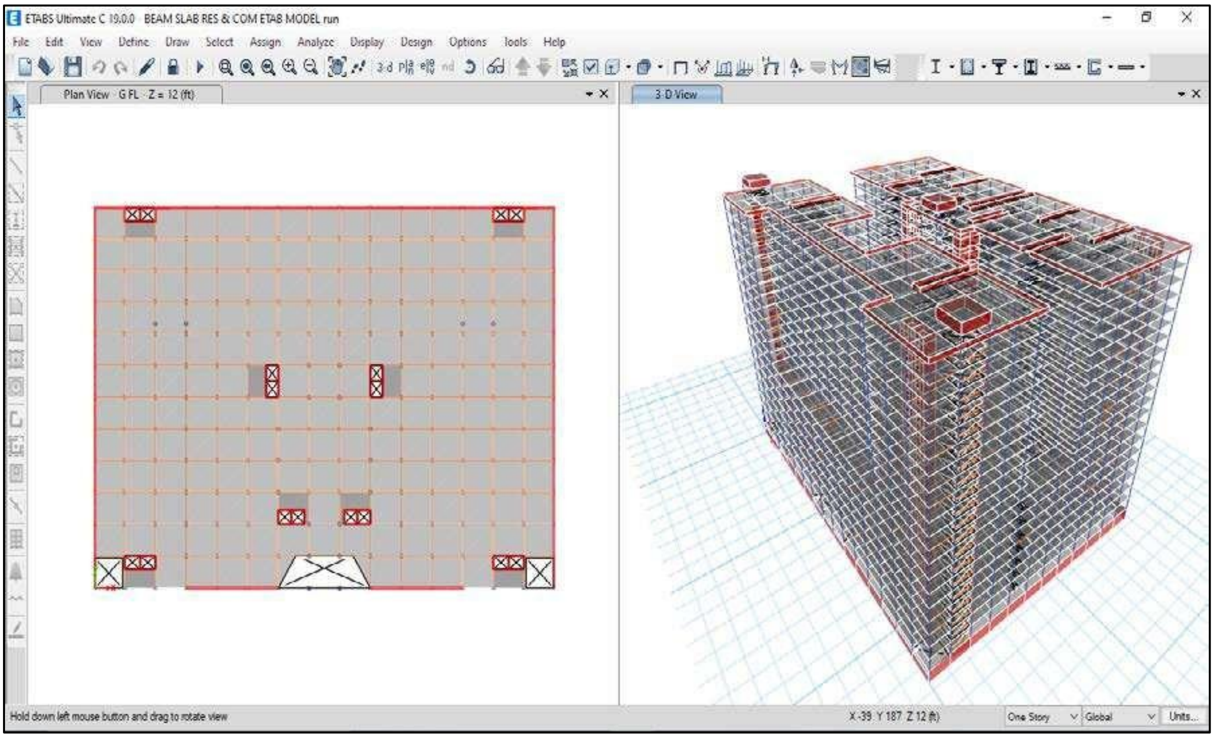


Figure 4.2: Global X & Y Direction of ETABS Model

To illustrate the different phase of response curves due to lateral loadings in both X & Y direction, and to set comparison these responses, the whole discussion is going to focus on the effects of wind and earthquake separately.

A. Response due to Earthquake Loads in Global +ve directions

1] Lateral loads resisted by the Stories:

Figures 4.3 (a ~b) illustrated below provide information about the response for lateral loads to stories. Here the horizontal axis represents lateral force in kips and the vertical axis represents the stories of the building.

From figure it is clearly seen that, 40 Grade bar, 60 Grade bar & 75 Grade bar has to resist equal earthquake loads. It shows that the value of EQ force increases gradually from Ground Floor to Roof floor.

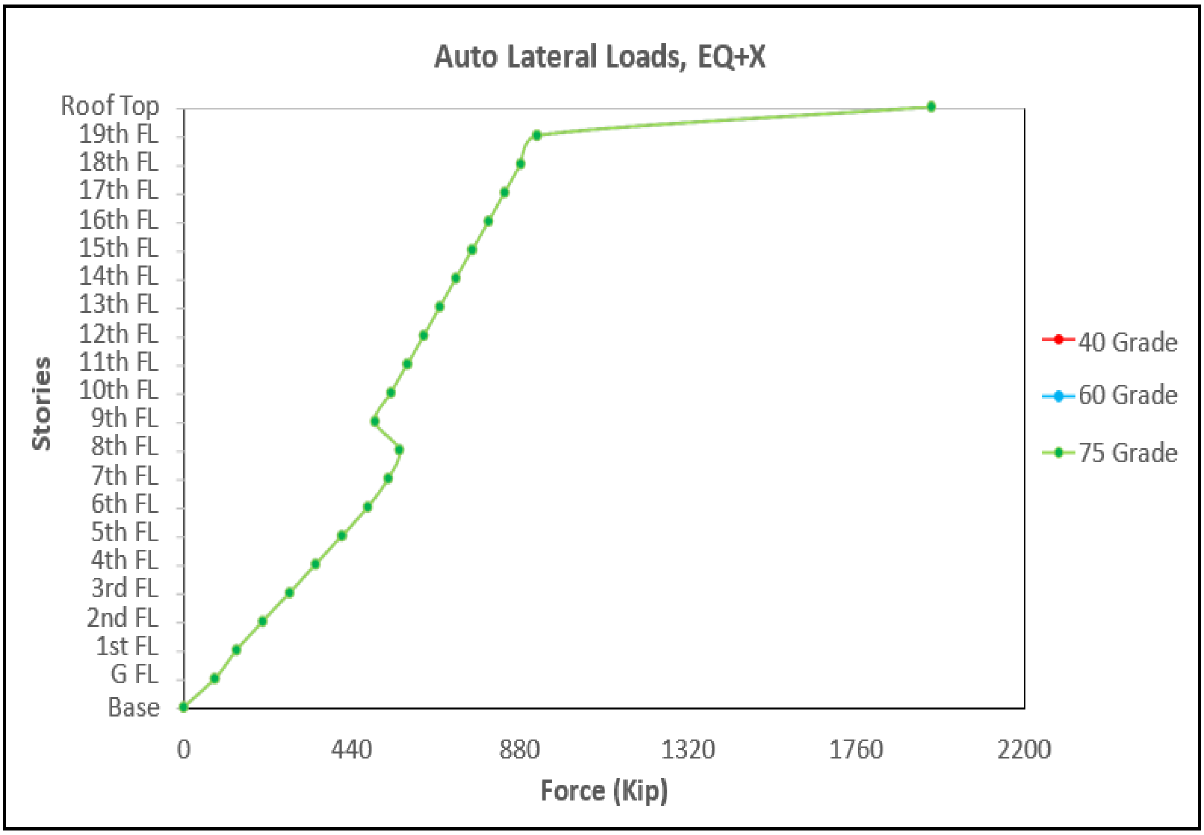


Figure 4.3a: Auto Lateral Load due to Earthquake in +ve (X) Direction

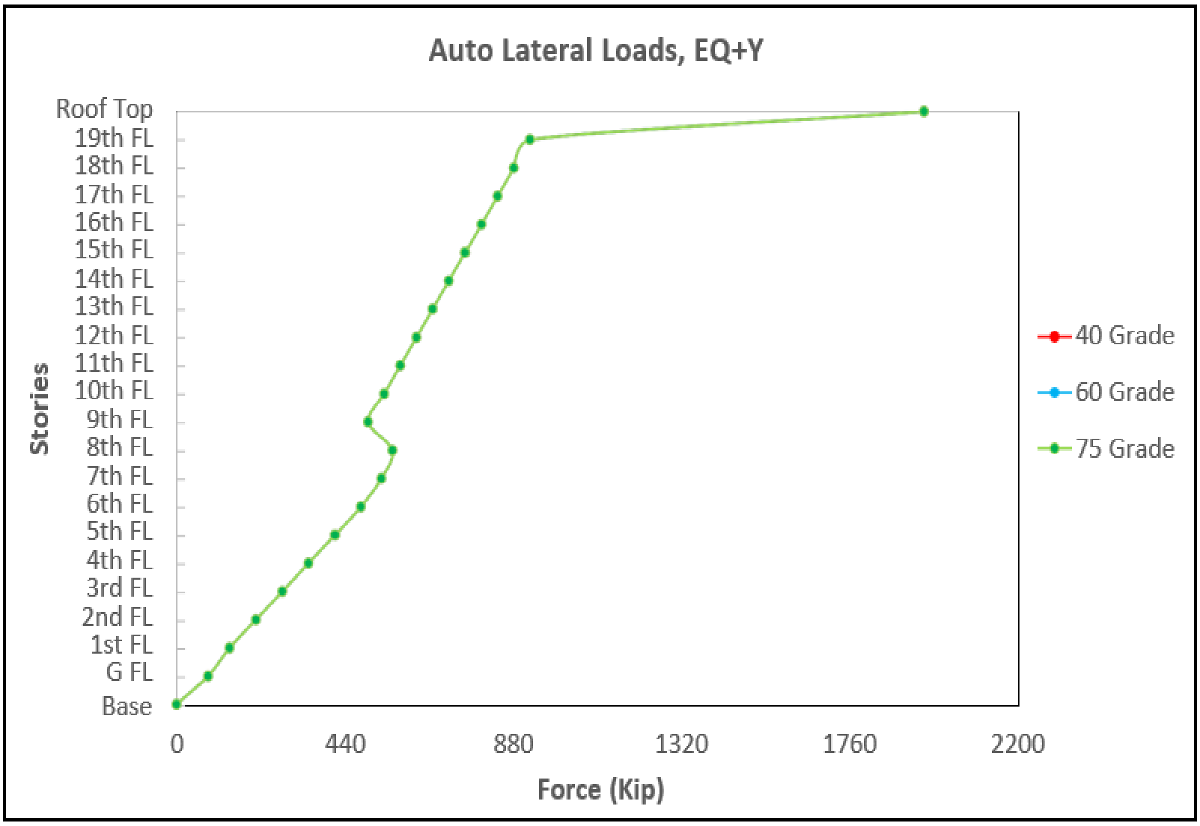


Figure 4.3b: Auto Lateral Load due to Earthquake in +ve(Y) Direction

2] Maximum Story Displacement:

Figure 4.4 illustrated below provides information about the response for maximum story displacement. Here the horizontal axis represents displacement in inch and the vertical axis represents the stories of the building.

From figure it is clearly seen that 60 Grade bar resists more story displacement compared to 40 Grade bar and 75 Grade bar. There is no significant difference between 40 Grade bar and 75 Grade bar in respect of displacement. It shows that the story displacement starts from base with zero value and increases at top (due to impact of Lateral load).

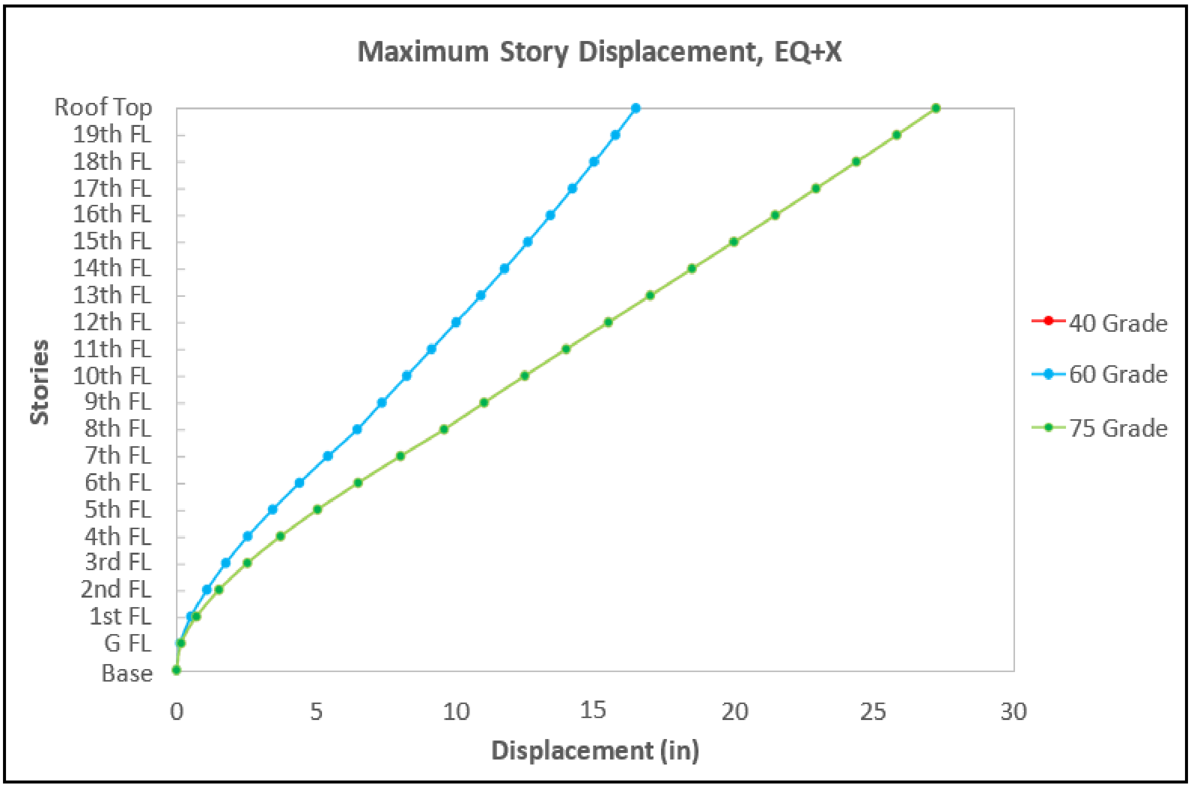


Figure 4.4a: Maximum Story Displacement due to Earthquake in +ve (X) Direction

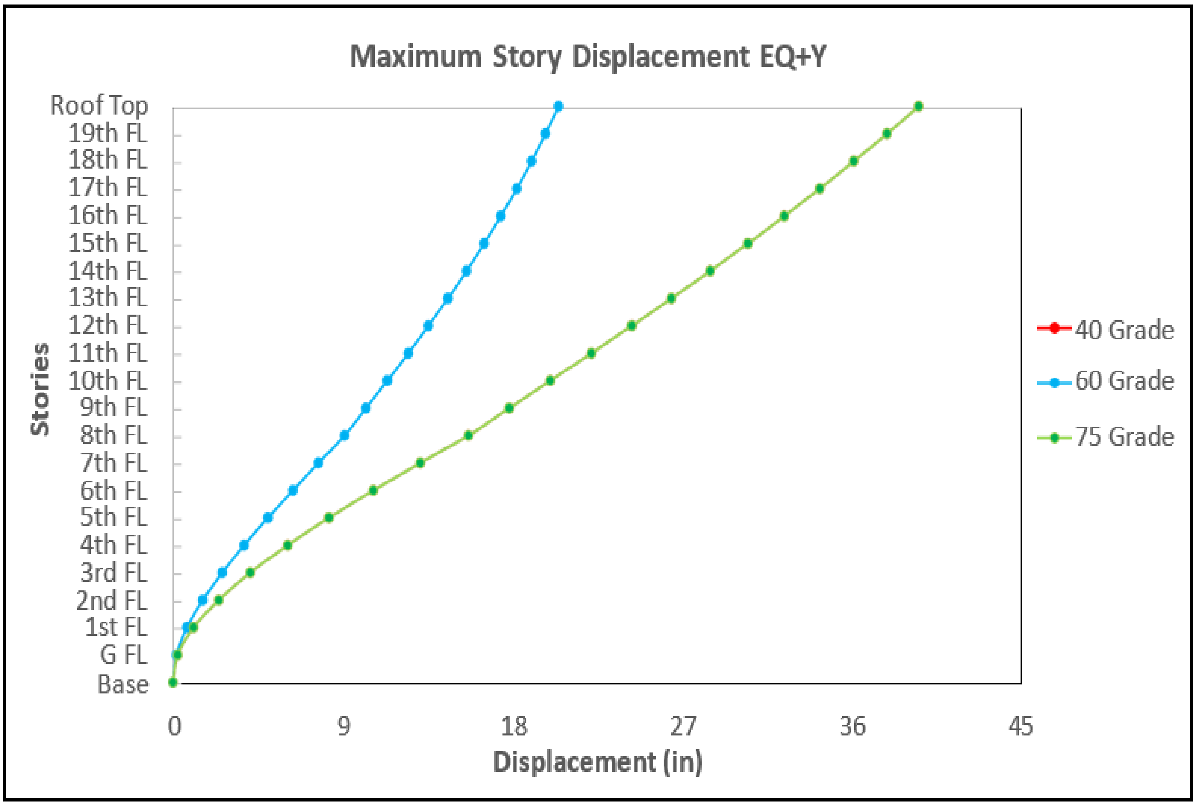


Figure 4.4b: Maximum Story Displacement due to Earthquake in +ve (Y) Direction

3] Maximum Story Drifts:

Figures 4.5(a ~b) illustrated below provide information about the response maximum story drifts. Here the horizontal axis represents drifts and the vertical axis represents the number of the stories of the building.

In both X and Y axes, drift scenario of, 40 Grade bar and 75 Grade bar are similar and the value is higher than 60 Grade. Due to higher earthquake loads in 40 Grade bar and 75 Grade bar shows higher drift in stories compared to other models.

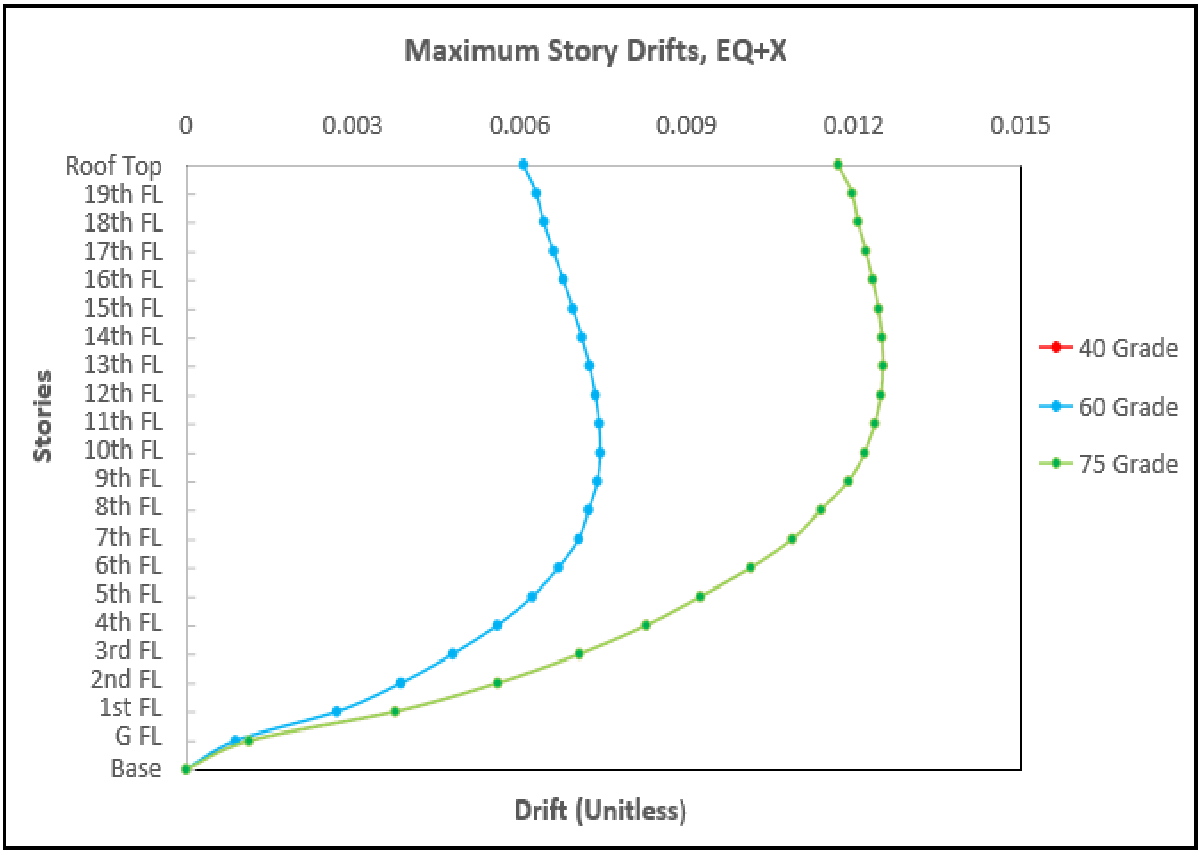


Figure 4.5a: Maximum Story Drift due to Earthquake in +ve(X) Direction

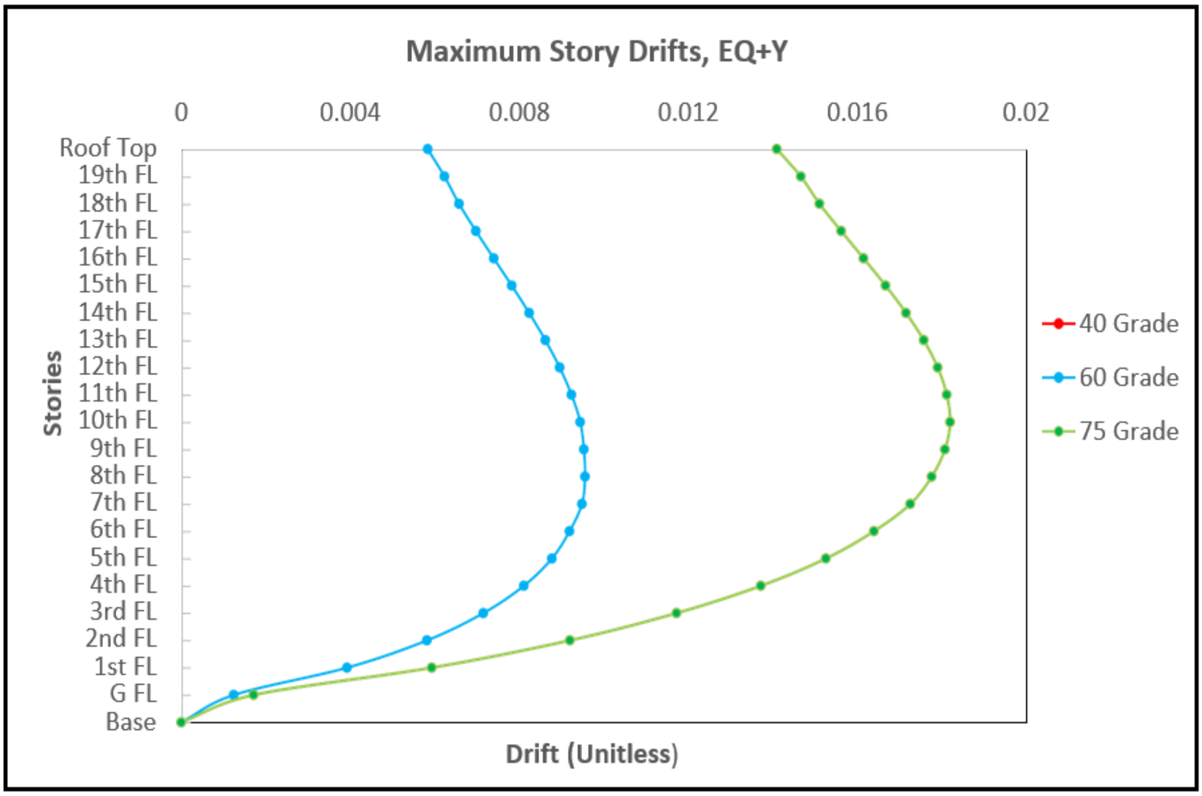
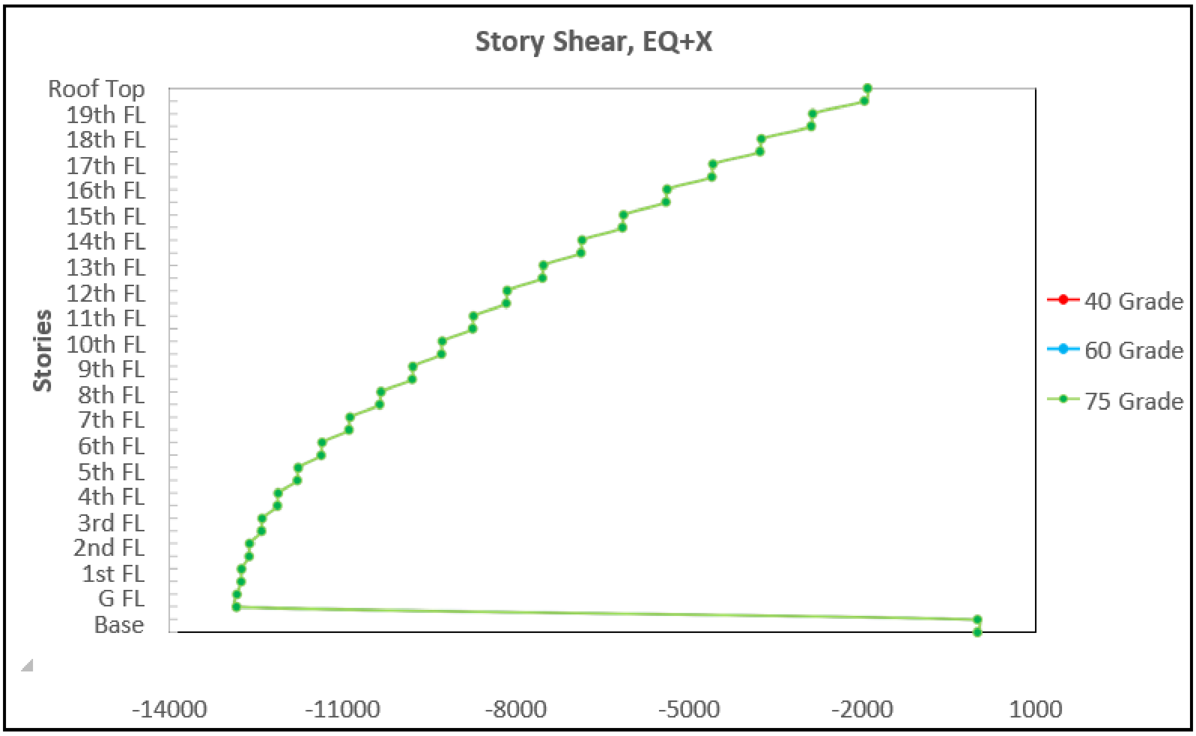


Figure 4.5b: Maximum Story Drift due to Earthquake in +ve(Y) Direction

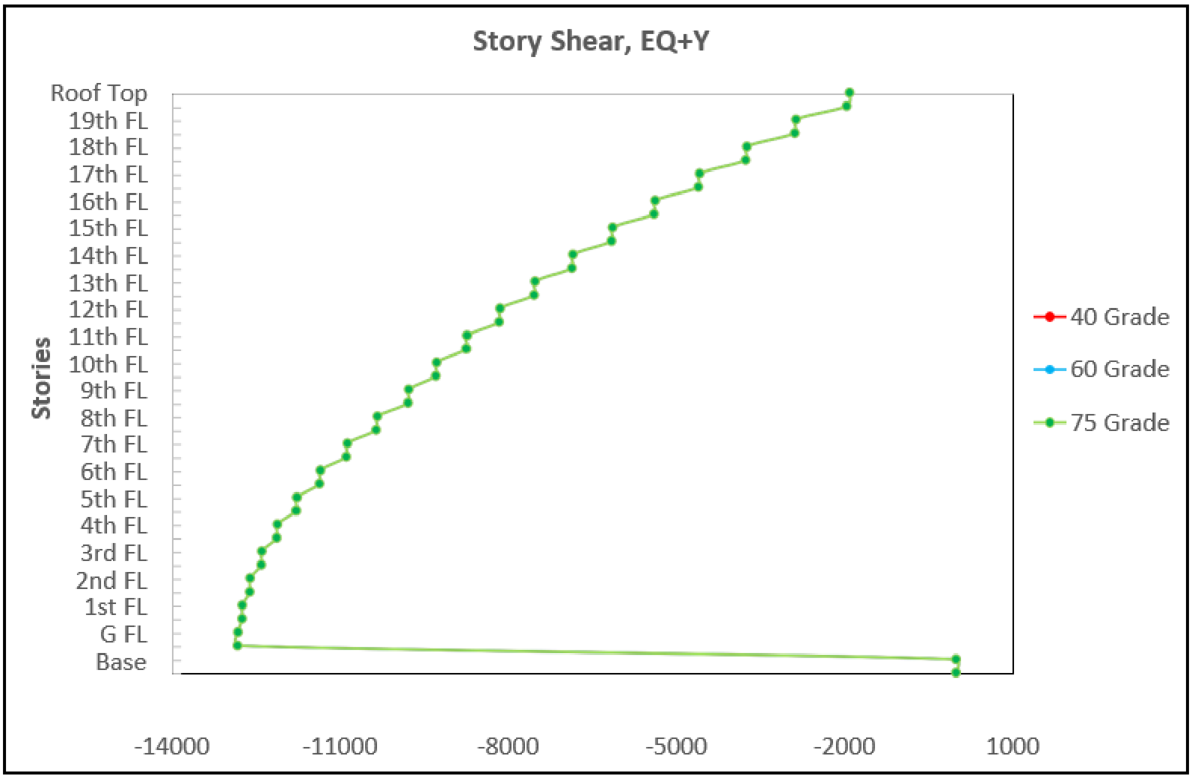
4] Story Shears:

Figures 4.6(a ~b) illustrated below provide information about the response for story shears. Here the horizontal axis represents story shear in kips and the vertical axis represents the stories of the building.

From figure it is clearly seen that, response curves are equal in all Grade bar in both EQ+Y and EQ+X directions. It shows that the story shear resisting capacity is higher at base due to strong basement. Shear resisting capacity is decreasing from bottom to top. (Due to lateral load impact).



Force (kip)
Figure 4.6a: Story Shear due to Earthquake in +ve(X) Direction

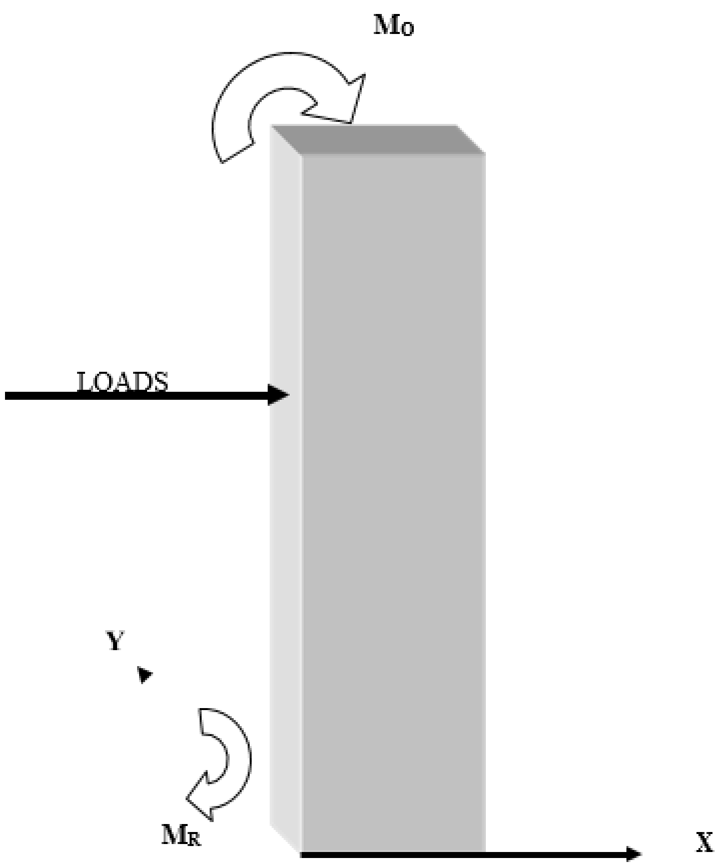


Force (kip)
Figure 4.6b: Story Shear due to Earthquake in +ve(Y) Direction

5] Resisting Story Overturning Moments [M_R]:

Figures 4.7(a~b) illustrated below provide information about the response for story overturning moments. Here the horizontal axis represents overturning moments in kip-ft and the vertical axis represents the stories of the building.

From figure it is clearly seen that, curve starts from base with its peak value and sharply goes down to 19th story in both EQX and EQY. It is noted here that due to lateral loads in X-direction, the whole structure will resist its overturn with respect to Y-axis and creates a resisting overturning moment MR with respect to Y-axis as shown in figure below. Similar case can be explained for loads in Y-direction. However, it is shown that all reinforcement bar can resist equal overturning moment of the structure.



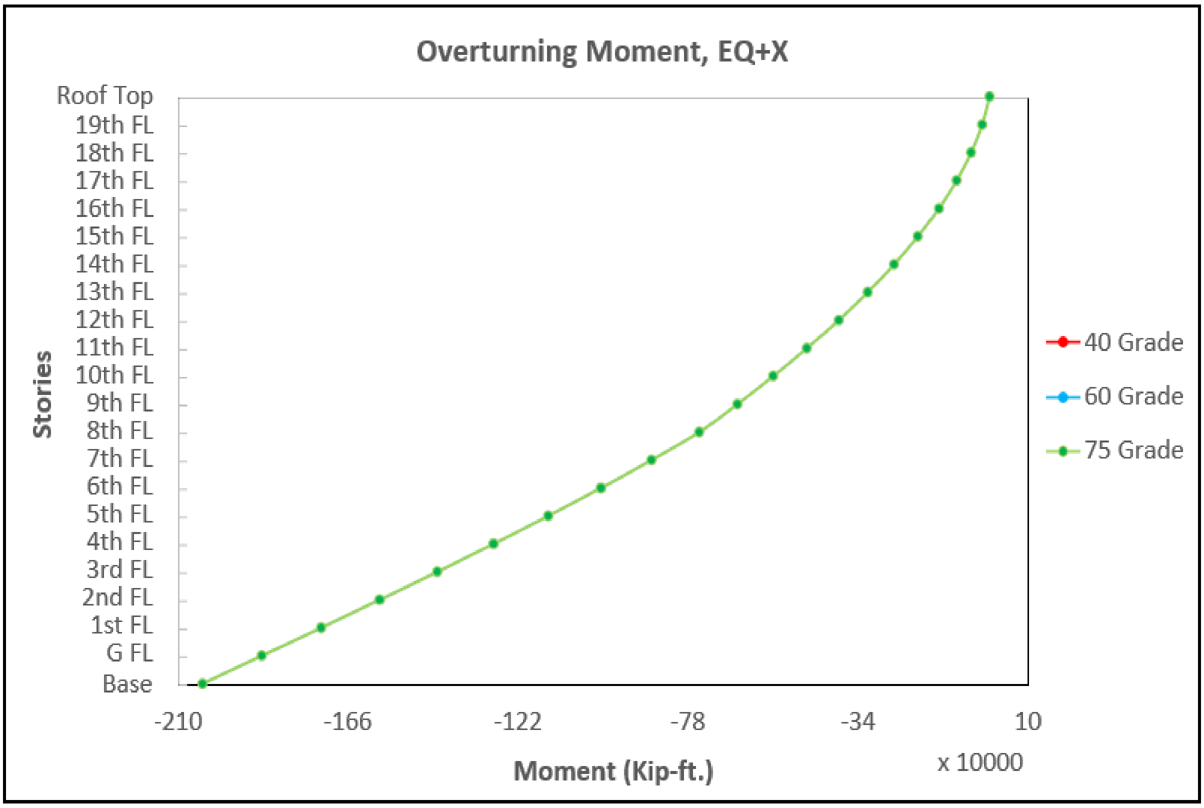


Figure 4.7a: Overturning Moment due to Earthquake in +ve(X) Direction

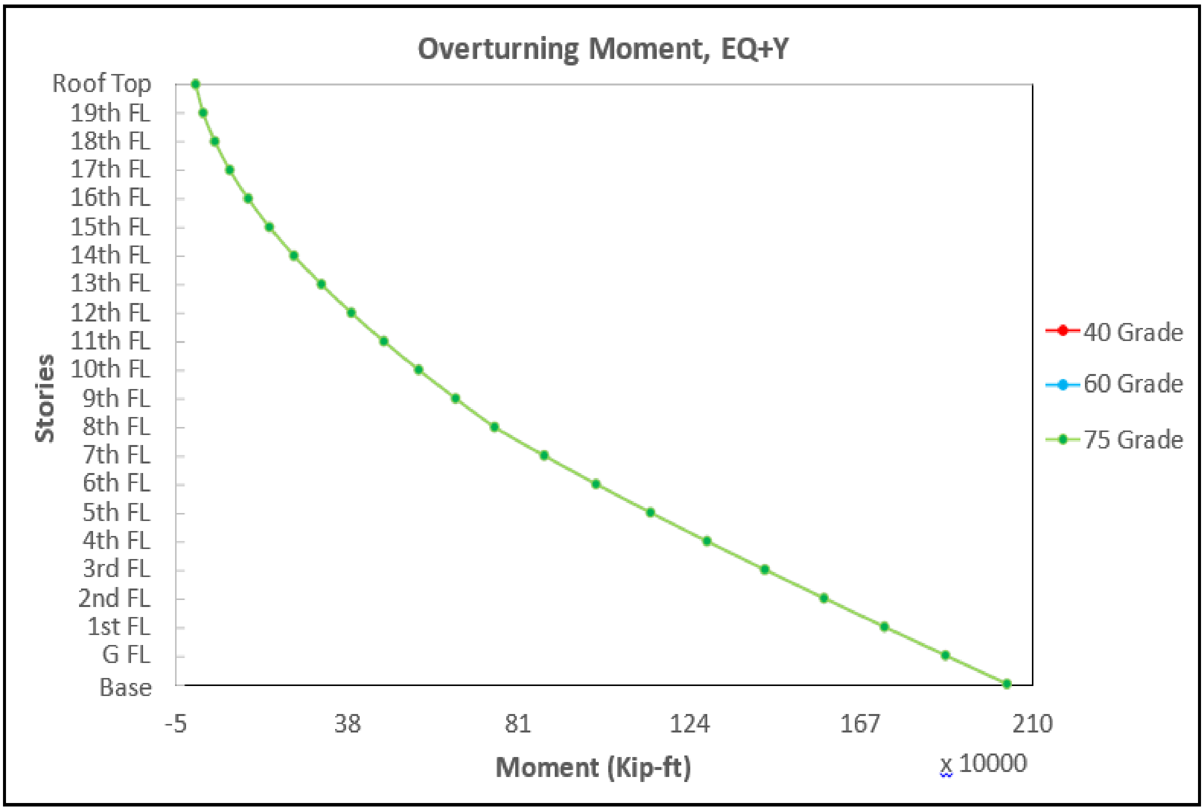


Figure 4.7b: Overturning Moment due to Earthquake in +ve(Y) Direction

6] Story Stiffness:

Figures 4.8(a~b) illustrated below provide information about the response for story stiffness. Here the horizontal axis represents story stiffness in kip-inch and the vertical axis represents the stories of the building.

From figure it is clearly seen that, 60 Grade bar more stiffer compared to 40 Grade bar and 75 Grade bar. The displacement of 40 Grade bar and 75 Grade bar is equal. It shows that story stiffness value is maximum at ground floor due to presence of boundary wall and ramp and stiffness value decreases at first floor because of discontinuity of them.

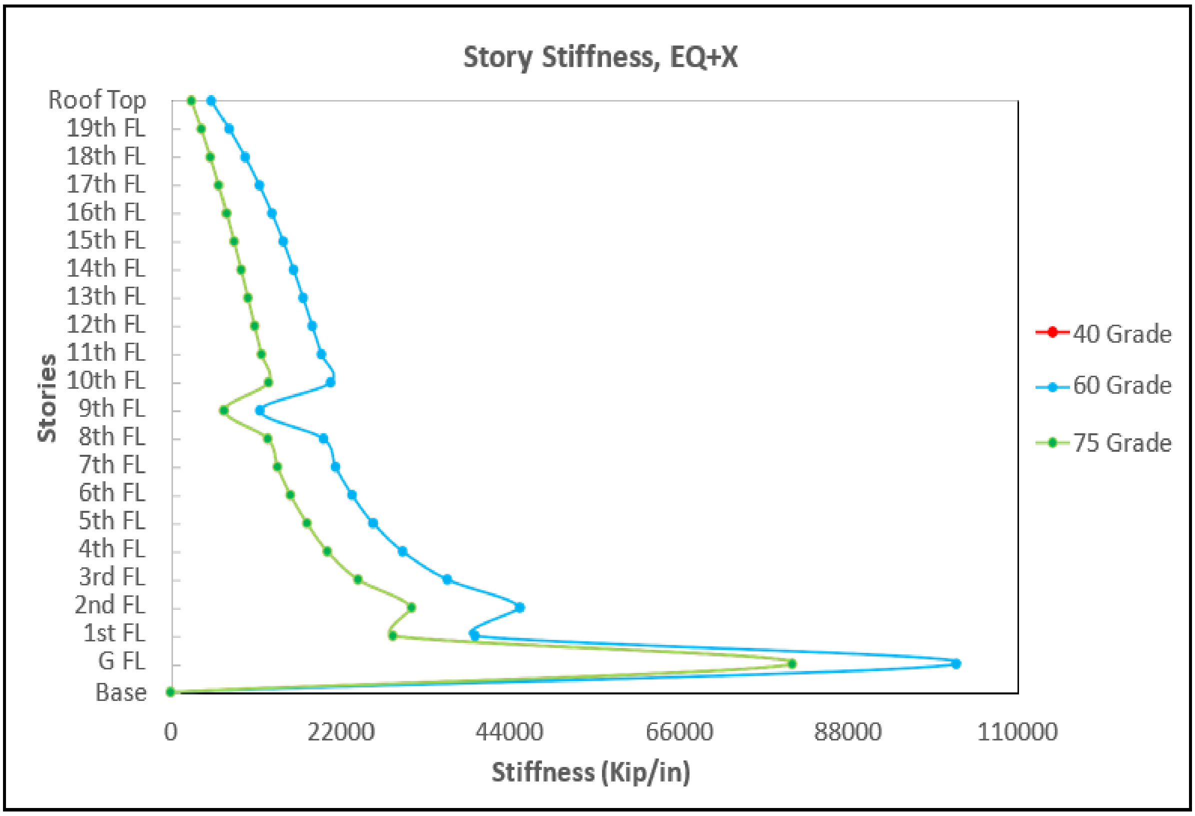


Figure 4.8a: Story Stiffness due to Earthquake in +ve(X) Direction

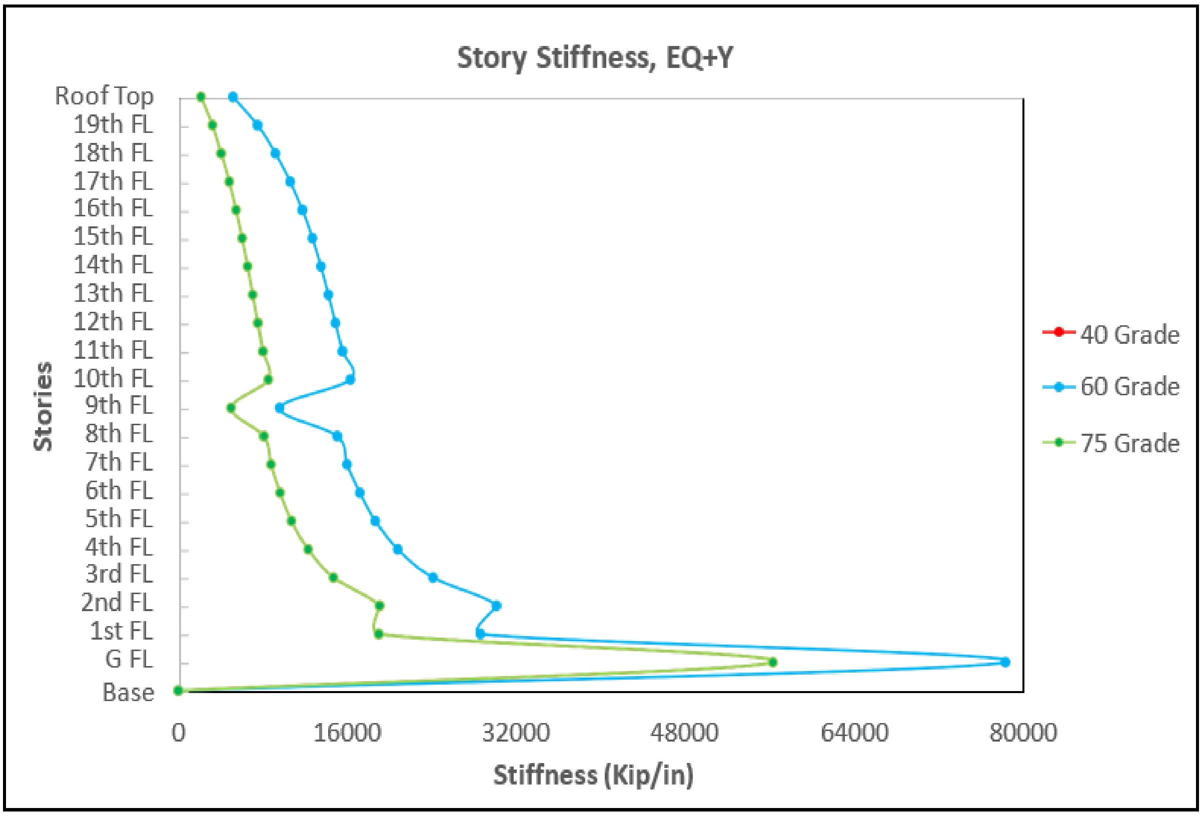


Figure 4.8b: Story Stiffness due to Earthquake in +ve(Y) Direction

Table 4.1: Summary Table (EARTHQUAKE)

Topic	EQ+X			EQ+Y		
	40 Grade	60 Grade	75 Grade	40 Grade	60 Grade	75 Grade
Maximum Auto lateral load to stories (kip) at Rooftop	1955.70	1955.70	1955.70	1955.70	1955.70	1955.70
Maximum Story Displacement (inch) at Rooftop	27.22	16.45	27.22	39.64	20.50	39.64
Maximum Story Drifts	0.0126 (13th Floor)	0.0075 (10th Floor)	0.0126 (13th Floor)	0.0182 (10th Floor)	0.0096 (8th Floor)	0.0182 (10th Floor)
Maximum Story Shears (kip) at GF	-1903.01	-1903.01	-1903.01	-1903.01	-1903.01	-1903.01
Maximum Story Overturning Moments (k-ft.) at Basement	-2035390	-2035390	-2035390	2035352.2	2035352.2	2035352.2
Maximum Story Stiffness (k/in) at GF	80701.55	102010	80701.55	56274.89	78263.3	56274.89

B. **<u>Response due to Wind Loads in Global X and Y directions</u>**

1] Lateral loads resisted by the Stories:

Figures 4.9(a ~b) illustrated below provide information about the response for lateral loads to stories. Here the horizontal axis represents lateral force in kips and the vertical axis represents the stories of the building.

From figure it is clearly seen that, 40 Grade bar, 60 Grade bar & 75 Grade bar has to resist equal earthquake loads. It shows that the value of EQ force increases gradually from Ground Floor to Roof floor.

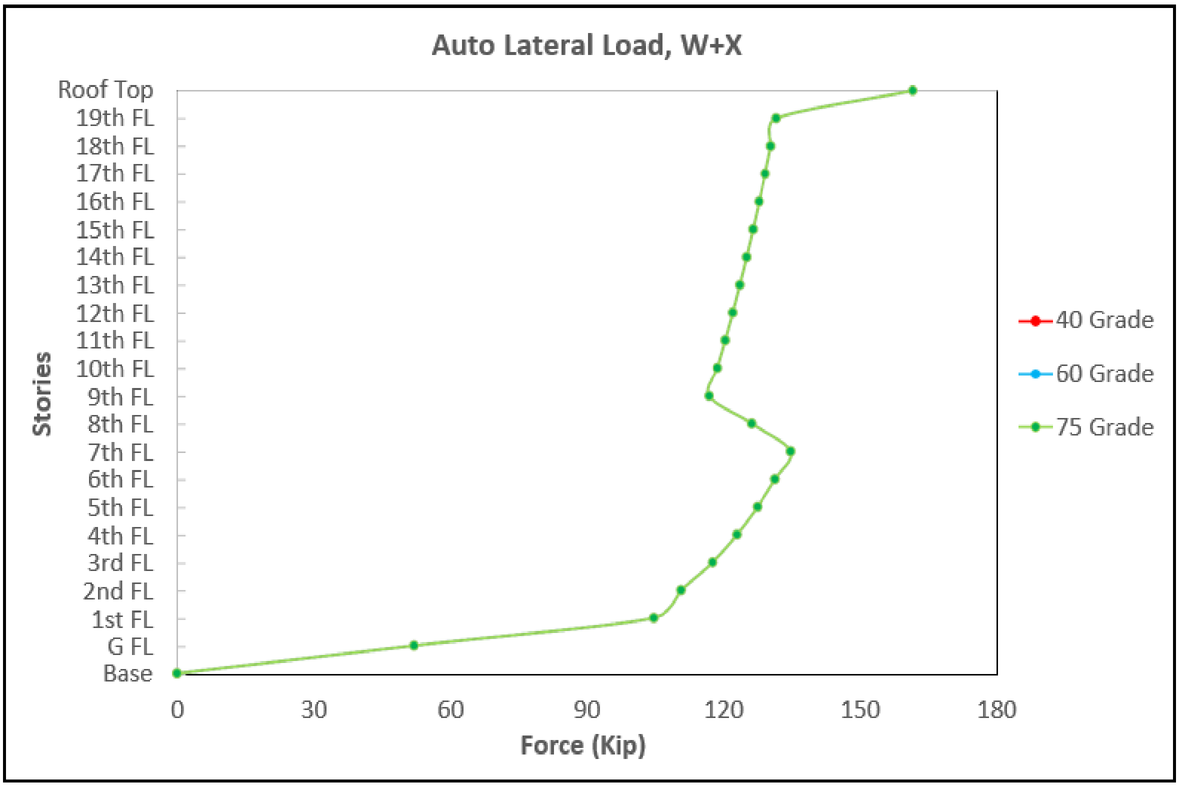


Figure 4.9a: Auto Lateral Load due to Wind in X Direction

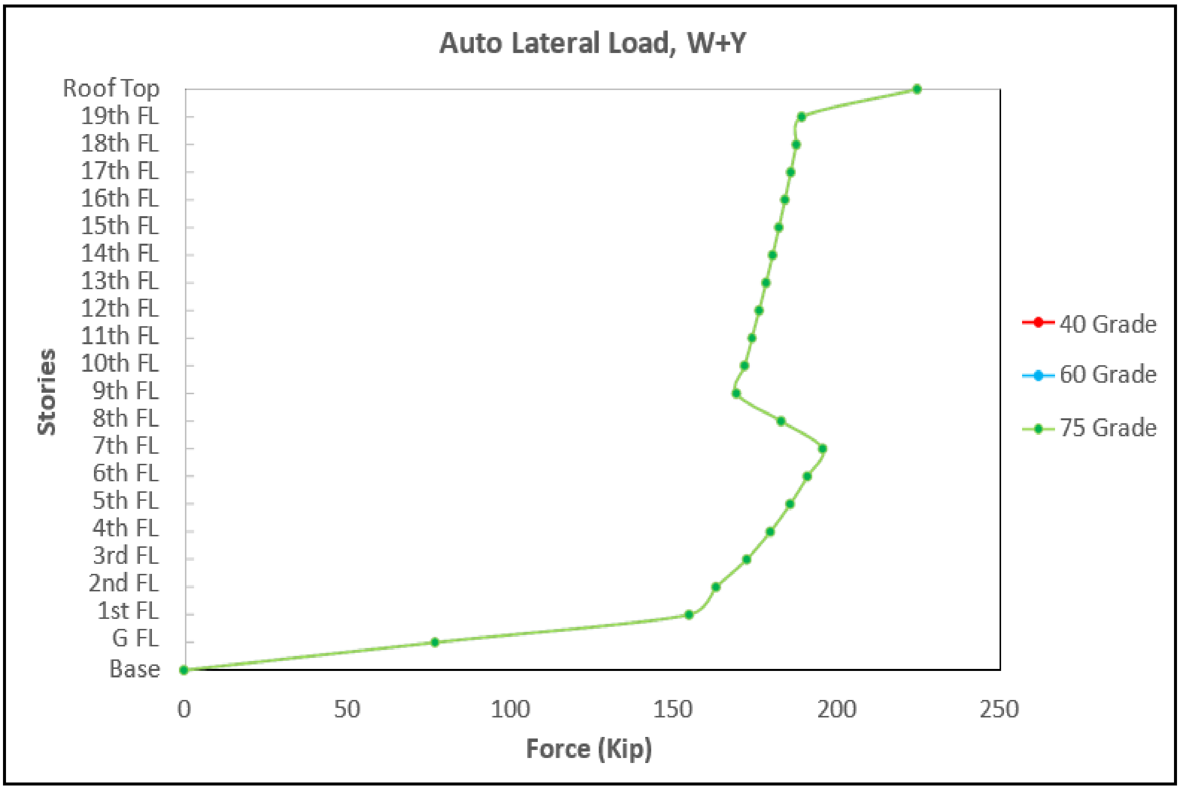


Figure 4.9b: Auto Lateral Load due to Wind in Y Direction

2] Maximum Story Displacement:

Figures 4.10(a ~b) illustrated below provide information about the response for maximum story displacement. Here the horizontal axis represents displacement in inch and the vertical axis represents the stories of the building.

It shows that the story displacement starts from base with zero value. From bars, the value of story displacement increases from bottom to top (due to impact of Lateral load). Due to higher wind speed in selected areas of 40 Grade bar and 75 Grade bar compared to that of 60 Grade bar, lateral top story displacement as well as other stories show higher value than that of 60 Grade bar in X -directions. The displacement of 40 Grade bar and 75 Grade bar is equal. In X -directions 40 Grade bar resists more story displacement compared to 60 Grade bat and 75 Grade bar.

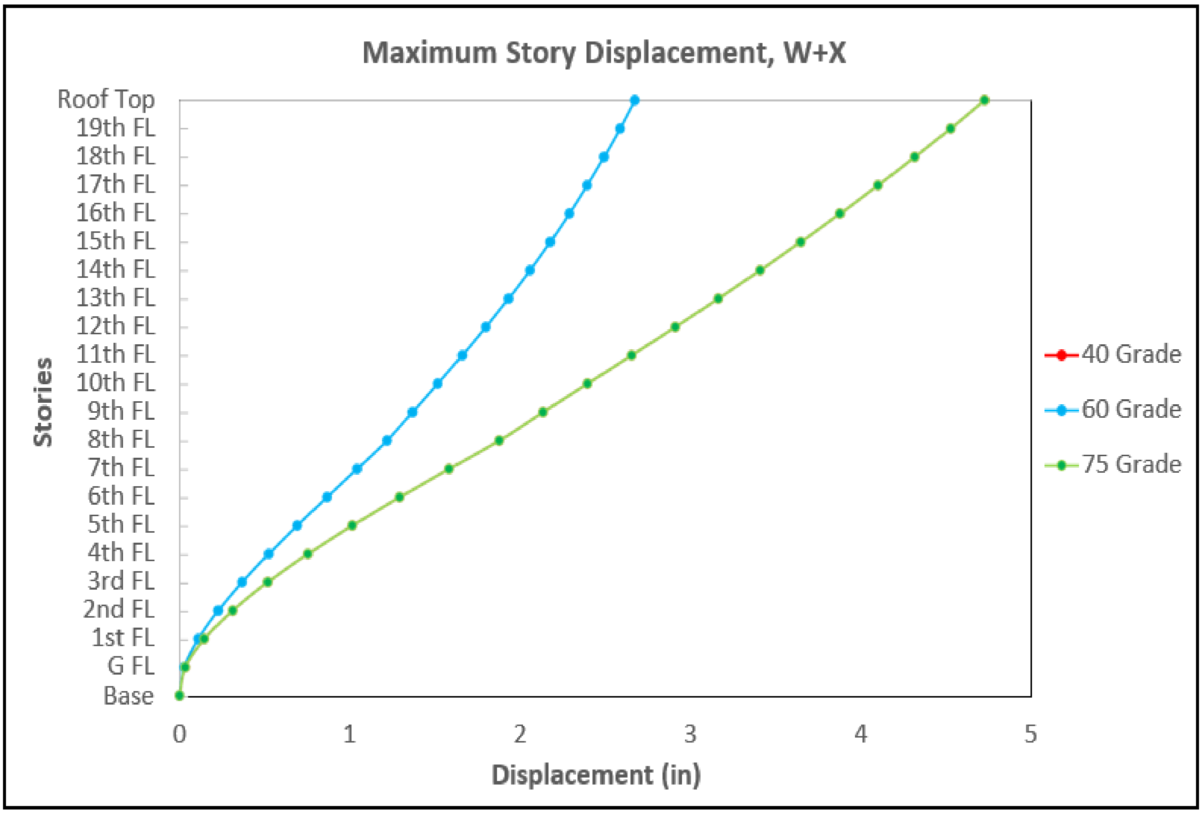


Figure 4.10a: Maximum Story Displacement due to Wind in X Direction

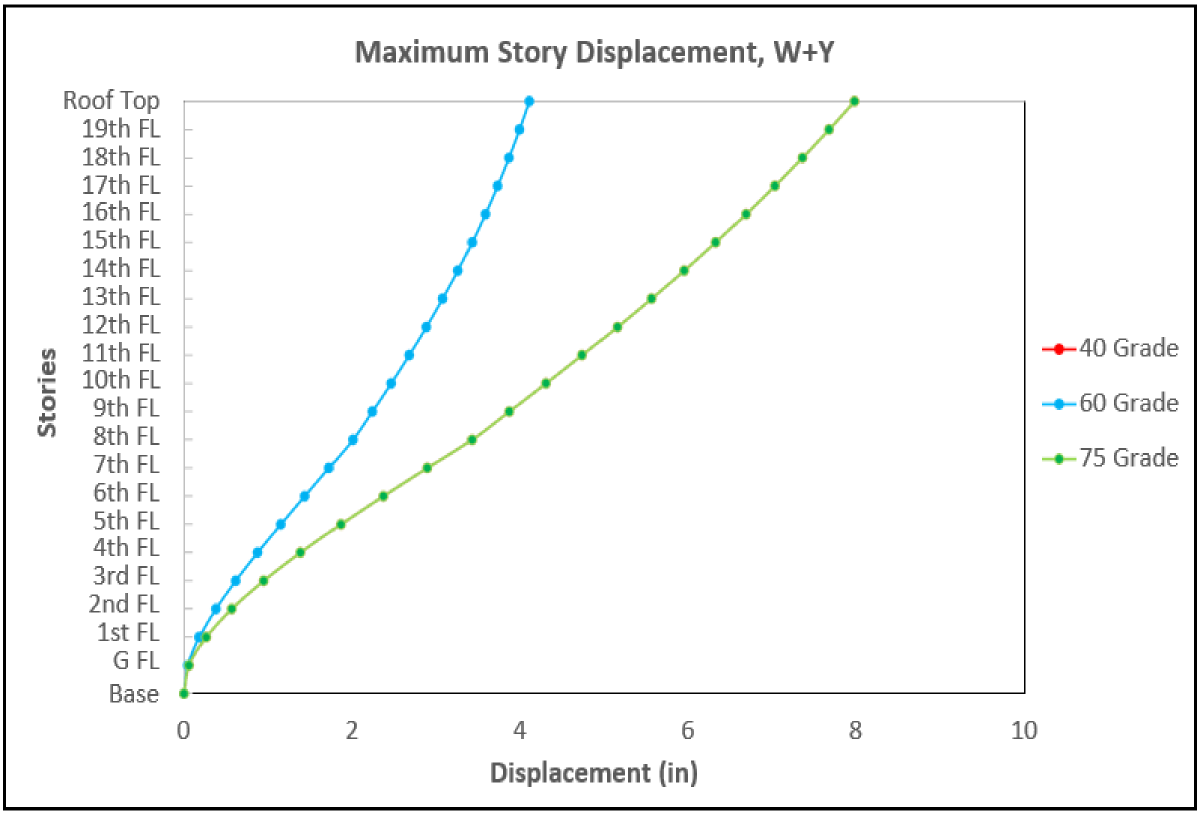


Figure 4.10b: Maximum Story Displacement due to Wind in Y Direction

3] Maximum Story Drifts:

Figures 4.11(a~b) illustrated below provide information about the response maximum story drifts. Here the horizontal axis represents drifts and the vertical axis represents the number of the stories of the building.

Story drift is the relative story displacement between two consecutive upper or lower stories and hence it is unit less. Its value increases if displacement between two consecutive stories become higher and vice versa. Due to higher wind speed in selected areas of 40 Grade bar and 60 Grade bar compared to that of 60 Grade bar, lateral top story displacement as well as other stories show higher value than that of 60 Grade bar in both X and Y-directions. The results of story drift in 40 Grade bar and 60 Grade bar.

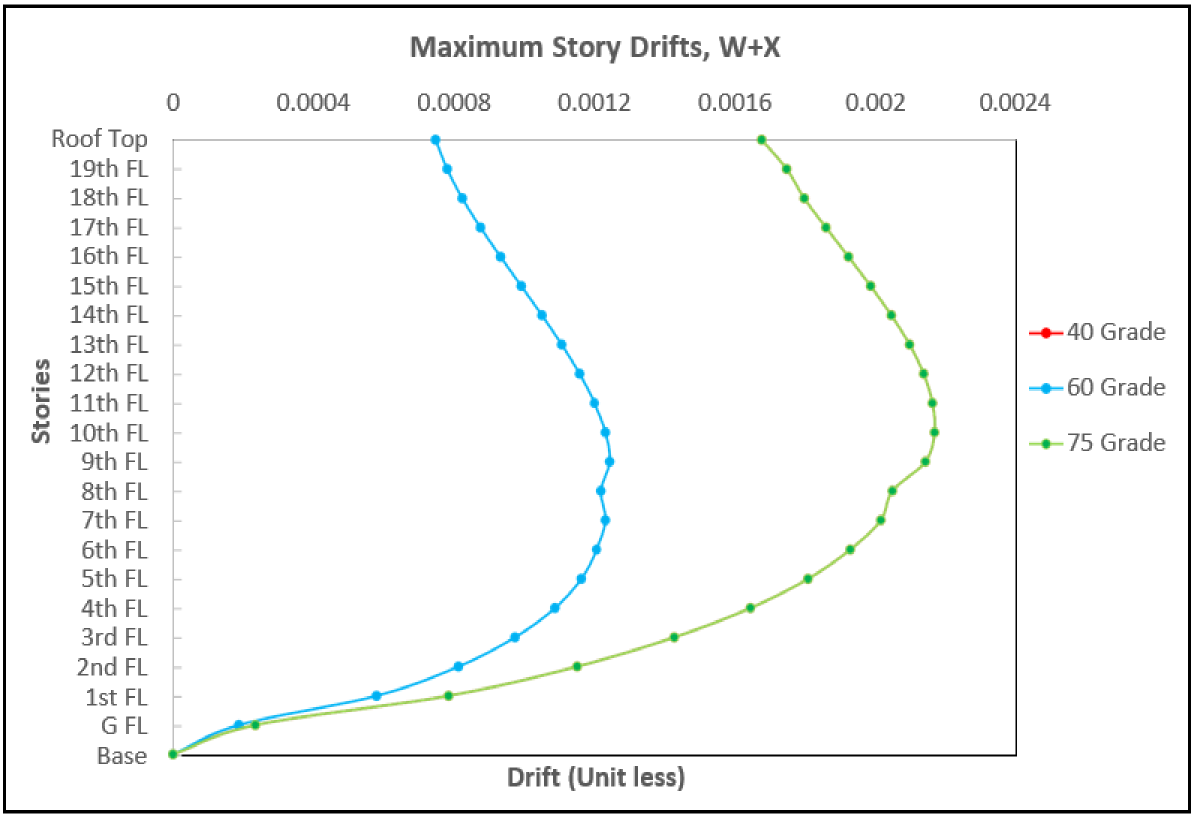


Figure 4.11a: Maximum Story Drift due to Wind in X Direction

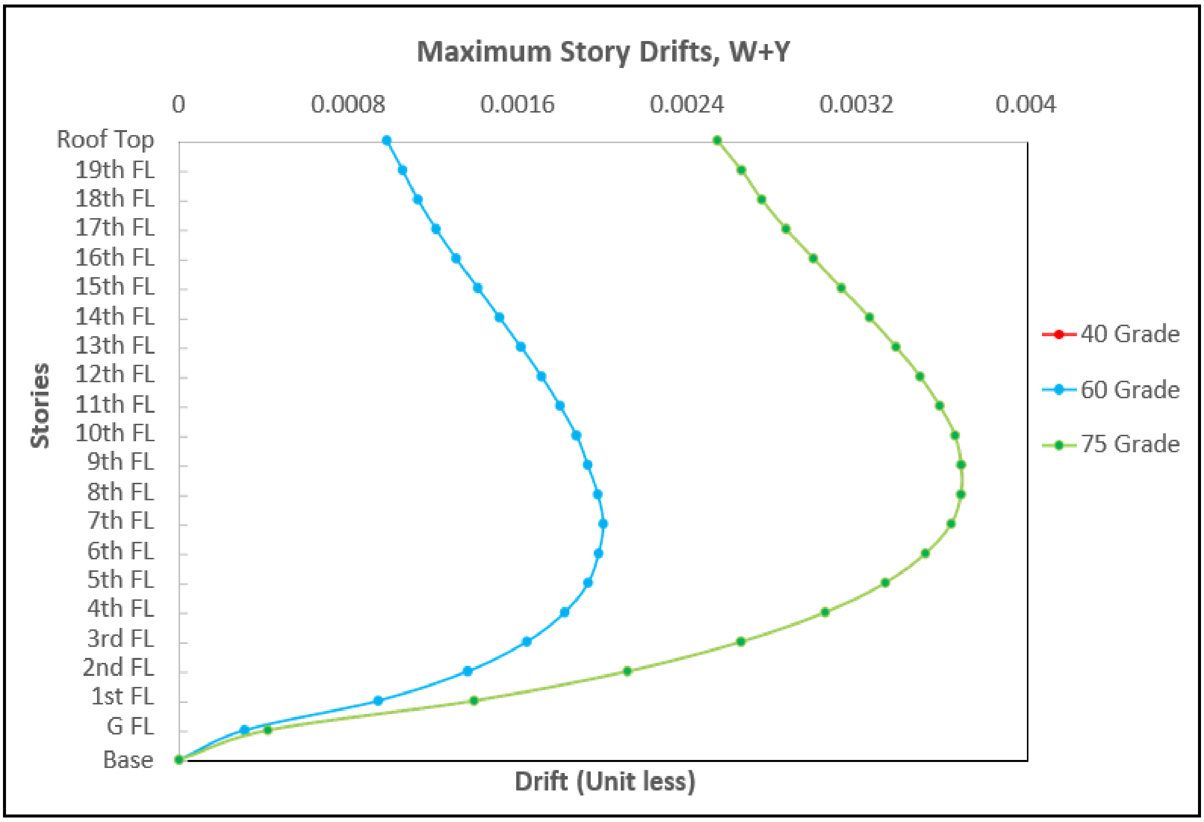


Figure 4.11b: Maximum Story Drift due to Wind in Y Direction

4] Story Shears:

Figures 4.12(a~b) illustrated below provide information about the response for story shears. Here the horizontal axis represents story shear in kips and the vertical axis represents the stories of the building.

It shows that the story shear resisting capacity is higher at base due to strong basement. Shear resisting capacity is decreasing from bottom to top (due to lateral load impact) and its value negative against given load. From figure it is clearly seen that, response curves are equal in all Grade bar in both EQ+Y and EQ+X directions.

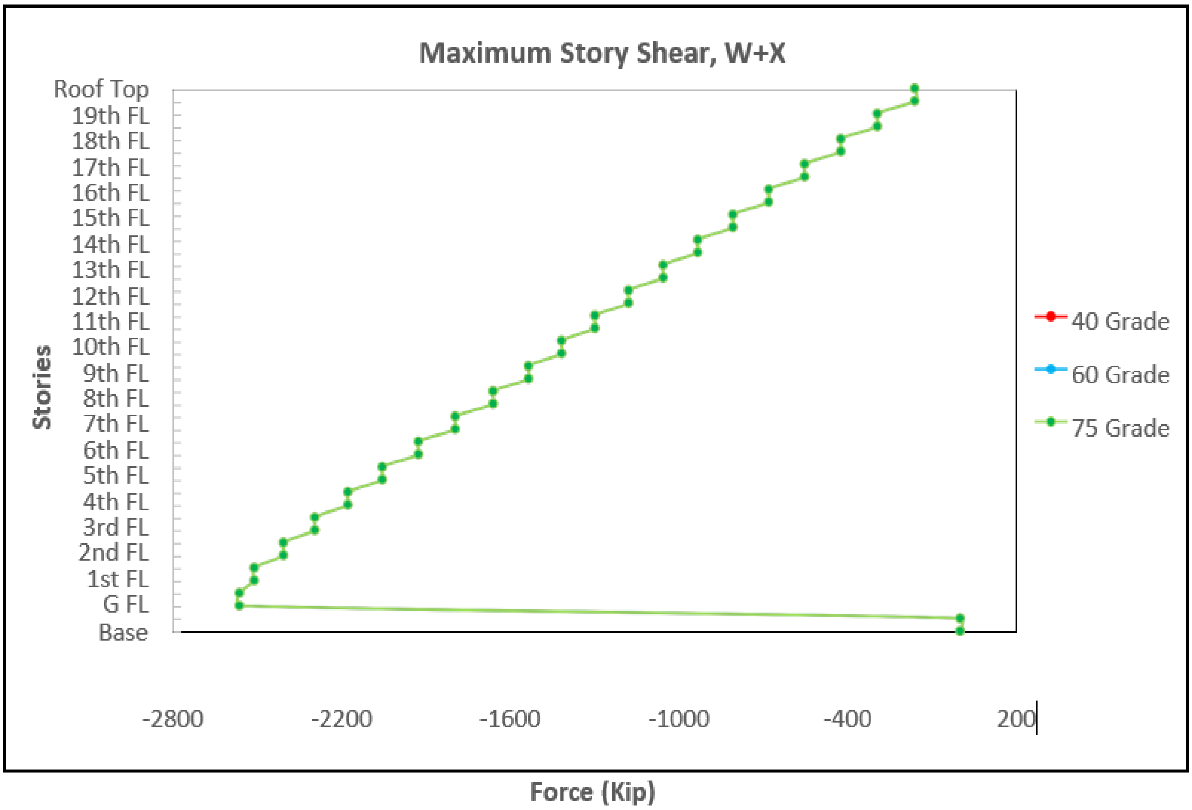


Figure 4.12a: Story Shear due to Wind in X Direction

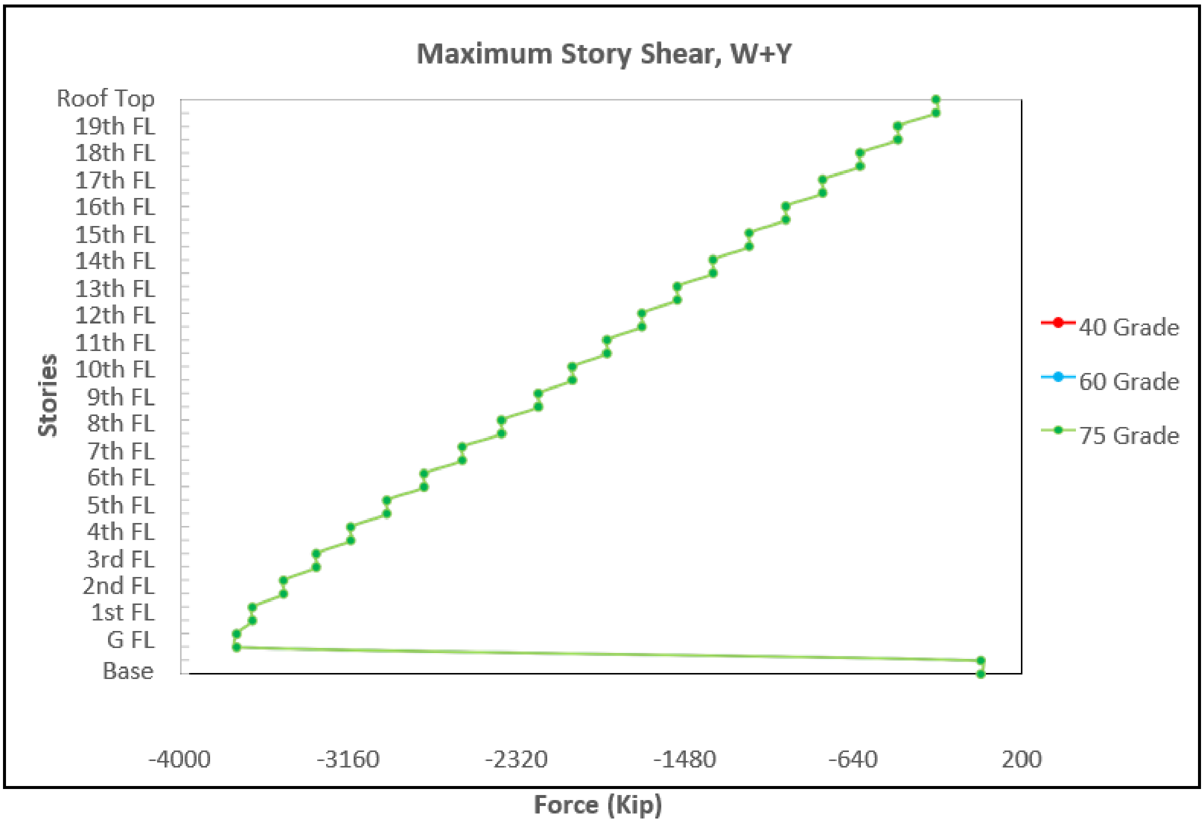
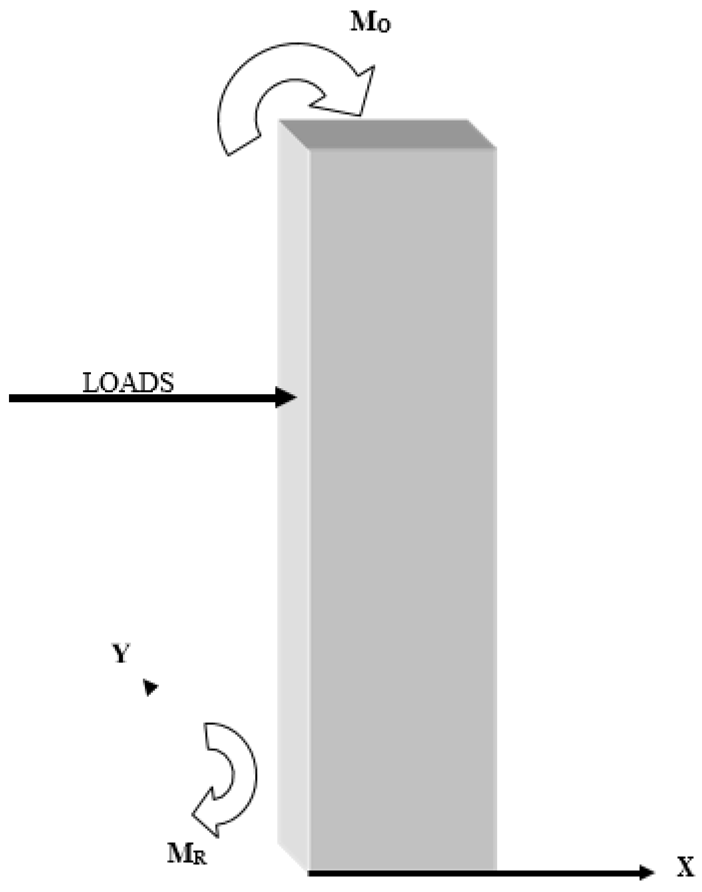


Figure 4.12b: Story Shear due to Wind in Y Direction

5] Resisting Story Overturning Moments [M_R]:

Figures 4.13(a~b) illustrated below provide information about the response for story overturning moments. Here the horizontal axis represents overturning moments in kip-ft and the vertical axis represents the stories of the building.

From figure it is clearly seen that, curve starts from base with its peak value and sharply goes down to 19th story in both EQX and EQY. It is noted here that due to lateral loads in X-direction, the whole structure will resist its overturn with respect to Y-axis and creates a resisting overturning moment M_R with respect to Y-axis as shown in figure below. Similar case can be explained for loads in Y-direction. However, it is shown that all reinforcement bars can resist equal overturning moment of the structure.



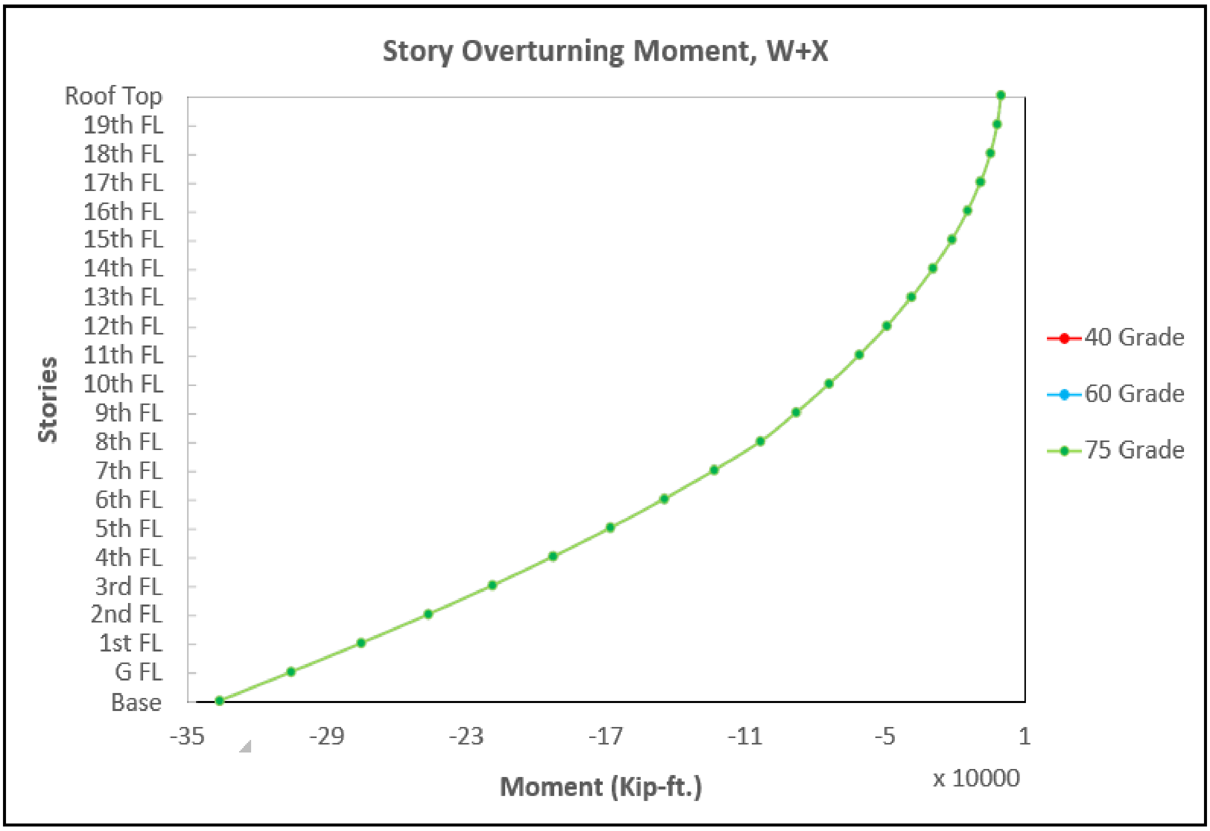


Figure 4.13a: Story Overturning Moment due to Wind in X Direction

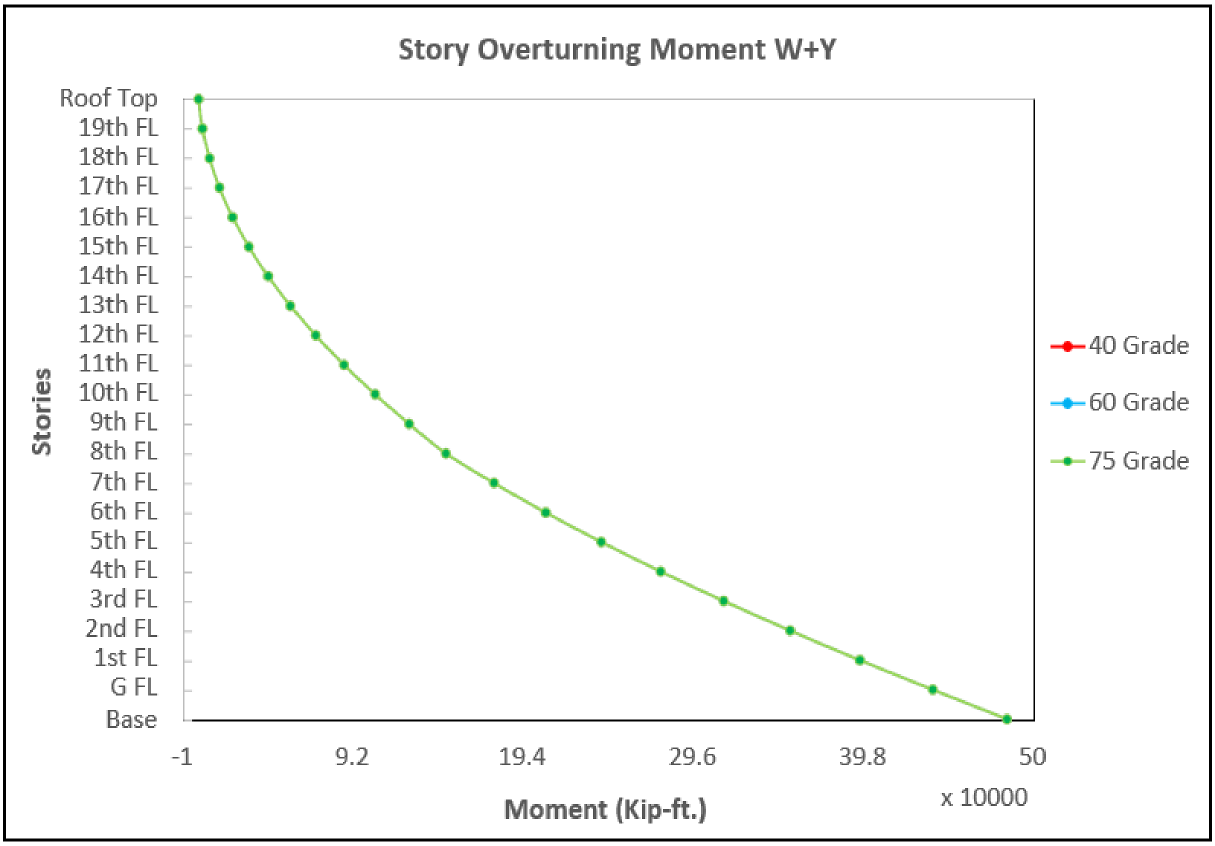


Figure 4.13b: Story Overturning Moment due to Wind in Y Direction

6] Story Stiffness:

Figures 4.14(a ~b) illustrated below provide information about the response for story stiffness. Here the horizontal axis represents story stiffness in kip-inch and the vertical axis represents the stories of the building.

From figure it is clearly seen that, 60 Grade bar stiffer compared to 40 Grade bar and 75 Grade bar. The displacement of 40 Grade bar and 75 Grade bar is equal. It shows that story stiffness value is maximum at ground floor due to presence of boundary wall and ramp and stiffness value decreases at first floor because of discontinuity of them.

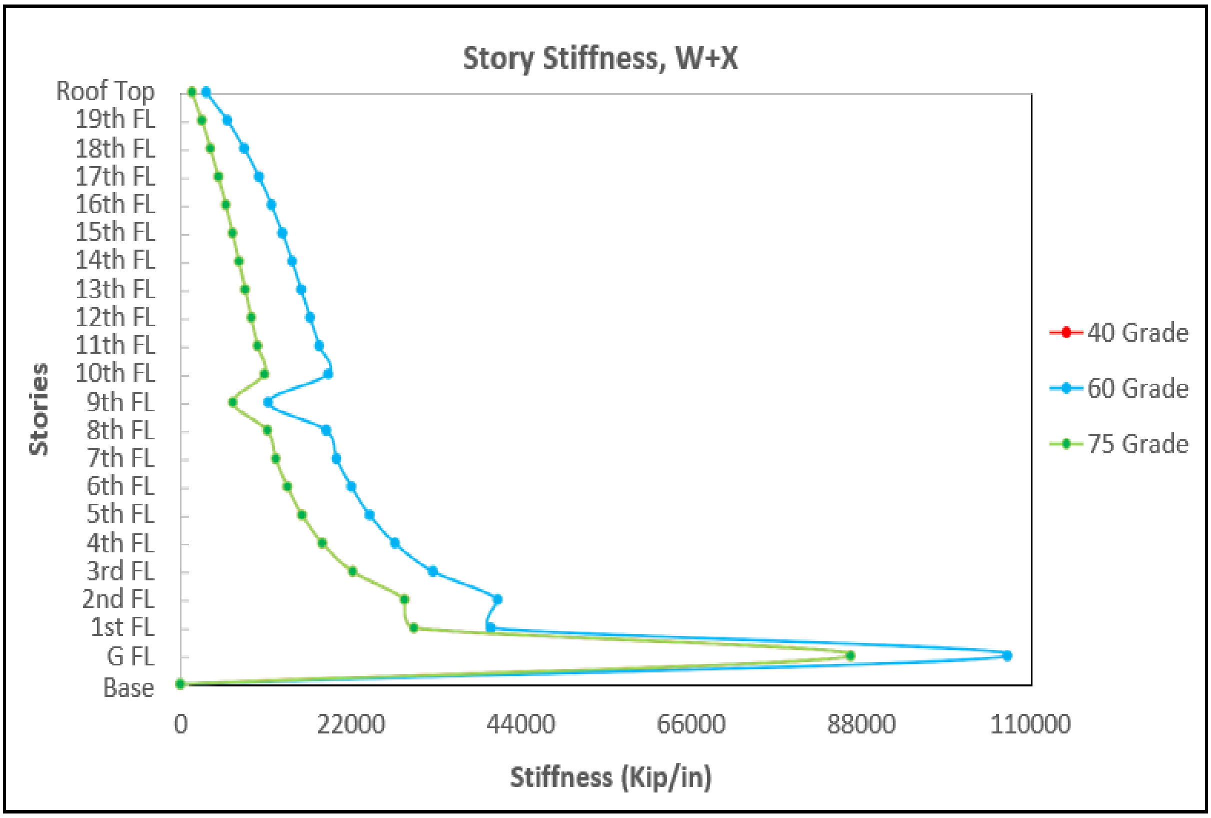


Figure 4.14a: Story Stiffness due to Wind in X Direction

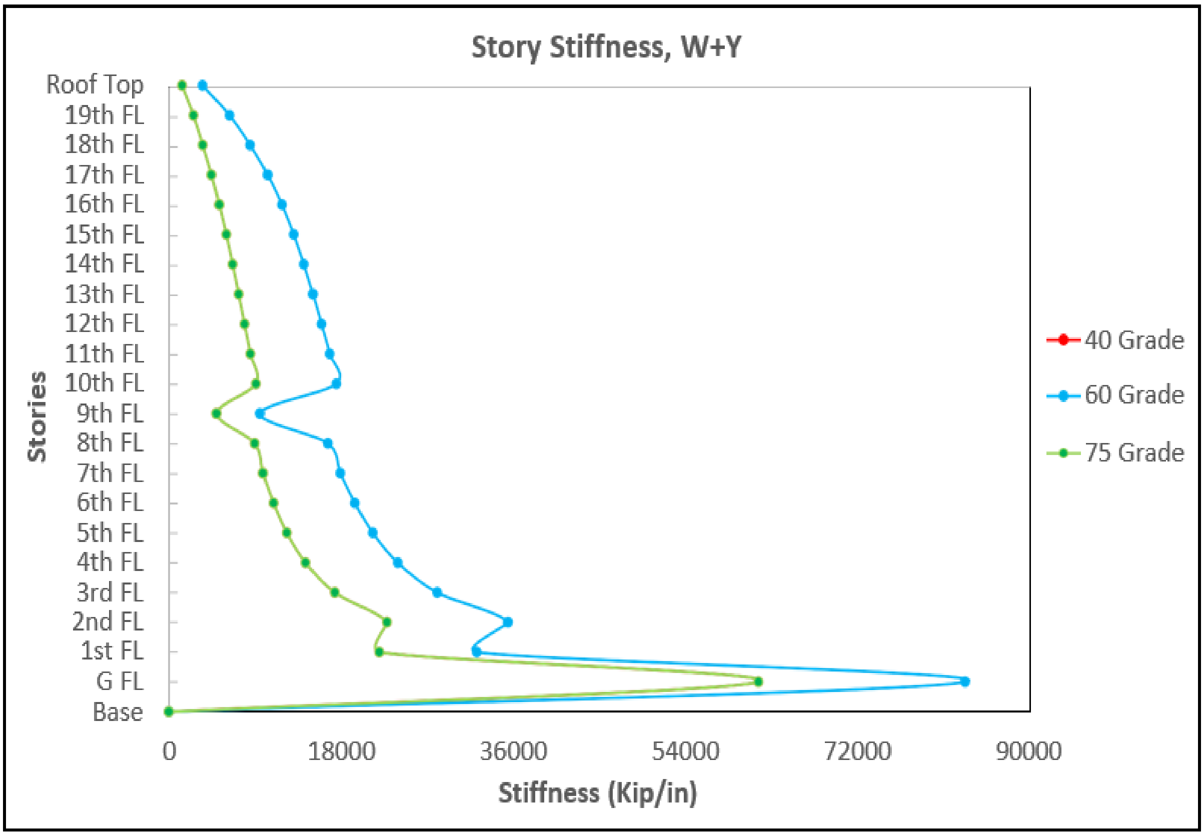


Figure 4.14b: Story Stiffness due to Wind in Y Direction

Table 4.2: Summary Table (WIND)

Topic	WIND X			WIND Y		
	40 Grade	60 Grade	75 Grade	40 Grade	60 Grade	75 Grade
Maximum Auto lateral load to stories (kip) at 14th Floor	161.53	161.53	161.53	224.99	224.99	224.99
Maximum story displacement (inch) at Rooftop	4.73	2.68	4.73	8	4.11	8
Maximum story drifts	0.0022 (10th Floor)	0.0013 (9th Floor)	0.0022 (10th Floor)	0.0037 (9th Floor)	0.0020 (8th Floor)	0.0037 (9th Floor)
Maximum Story Shears (kip) at GF	-161.53	-161.53	-161.53	-225	-225	-225
Maximum Story Overturning Moments (k-ft.) at Basement	-335762.29	-335762.37	-335762.29	484124.33	484124.42	484124.33
Maximum Story stiffness (k/in) at GF	86697.29	106986	86697.29	61684.3	83330.5	61684.3

4.2.2. Comparison based on Base Reactions, Forces

Load Case	F_x (Kip)			F_y (Kip)			F_z (Kip)		
	40 Grade	**60 Grade**	**75 Grade**	**40 Grade**	**60 Grade**	**75 Grade**	**40 Grade**	**60 Grade**	**75 Grade**
EQ+X	-12837.25	-12837.26	-12837.25	0	0	0	0	0	0
EQ+Y	0	0	0	-12837	-12837.11	-12837	0	0	0
Wind X	0	0	0	1960.65	2611.9	2611.88	0	0	0
Wind Y	2560.42	2560.42	2560.42	-1116.19	0	0	0	0	0

4.2.3. Comparison based on Base Reactions, Moments

Load Case	M_x (Kip-ft)			M_y (Kip-ft)			M_z (Kip-ft)		
	40 Grade	**60 Grade**	**75 Grade**	**40 Grade**	**60 Grade**	**75 Grade**	**40 Grade**	**60 Grade**	**75 Grade**
EQ+X	0	0	0	-2035390	-2035391	-2035390	1655926.5	1655926.6	1655926.5
EQ+Y	2035352.2	2035370.27	2035352.22	0	0	0	-2098754	-24725.98	-2098754
Wind X	484124.33	484128.42	484124.33	0	0	0	600874.83	600877.66	600874.83
Wind Y	484124.33	484128.42	484124.33	335762.29	335762.37	335762.29	845.91	843.9	845.91

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Based on EQ [Table 4.1]

▶ There are no significant differences among 40, 60 and 75 Grade in case of Maximum Auto lateral load to stories, Maximum Story Shears and maximum story overturning moments in both (EQ X) and (EQ Y).

▶ 40 and 75 grade shows similar Story displacement and 39.5% higher (EQ X) than 60 Grade bar. 40 and 75 grade shows similar Story displacement and 48.3% higher (EQ Y) than 60 Grade bar.

▶ 40 and 75 grade shows similar Story drifts and 40% higher (EQ X) than 60 Grade bar. 40 and 75 grade shows similar Story drifts and 47.3% higher (EQ Y) than 60 Grade bar.

▶ 40 and 75 grade shows similar Story stiffness but shows 20.9% lower (EQ X) compare to 60 Grade bar. 40 and 75 grade shows similar Story stiffness and 28.1% lower (EQ Y) compare to 60 Grade bar.

Based on Wind [Table 4.2]

▶ There are no significant differences among 40, 60 and 75 Grade in case of Maximum Auto lateral load to stories, Maximum Story Shears and maximum story overturning moments in both (WIND X) and (WIND Y).

▶ 40 and 75 grade shows similar Story displacement and 43.3% higher (WIND X) than 60 Grade bar. 40 and 75 grade shows similar Story displacement and 48.6% higher (WIND Y) than 60 Grade bar.

▶ 40 and 75 grade shows similar Story drifts and 40.9% higher (WIND X) than 60 Grade bar. 40 and 75 grade shows similar Story drifts and 40.9% higher (WIND Y) than 60 Grade bar.

40 and 75 grade shows similar Story stiffness but shows 19% lower (WIND X) compare to 60 Grade bar. 40 and 75 grade shows similar Story stiffness but shows 26% lower (WIND Y) than 60 Grade bar.

5.2 Recommendations

Based on the objectives, scopes and limitations of the study (stated in Chapter I), few recommendations can be proposed for further studies:

✦ This study was conducted based on 20 storied beam column floor system, further analyses considering other floor system such as flat plate or flat slab floor system can be considered to see the change in lateral load, maximum story displacement, maximum story drifts, story shears, overturning moments, story stiffness in different building elements.

✦ This study can be further conducted based different zone requirement in structures for different reinforcement Grade to identify the economic issues.

✦ Further Footing design should be considered.

REFERENCES

1. "*Design of Concrete Structures*", 13th Edition, Nilson A. H., Darwin D. and Dolan, **C.** W.; McGraw-Hill Publishing Company Ltd, New Delhi, India, 2006.
2. "*Seismic Design of Buildings and Bridges*", Williams A.; Oxford University press, New York, 2003.
3. "*Tall Building Structures*", Smith B.S. and Coull A.; John Wiley & Sons, Inc., New York, 1991.
4. "*High Rise Building Structures*", Schueller, Wolfgang; John Wiley & Sons, Inc., New York, USA.
5. "*Reinforced Concrete Fundamentals*", Ferguson P. M., Breen J. E. and Jirsa J. O.; 5th Edition, John Wiley & Sons, Inc., New York, 1987.
6. "*Reinforced Concrete Design*", 3rd Edition, Everard N. J.; SCHAUM'S outlines, Tata McGraw-Hill Publishing Company Ltd, New Delhi, India, 2004.
7. "*Bangladesh National Building Code*", 1st Edition, City Art Press, Dhaka, Bangladesh, 2006.
8. "*American Concrete Institute Building Design Code*", *ACI,* New York, USA, 2019.
9. *"Reinforcing bar specifications-Update on ASTM requirements", David P. Gustafson,* Concrete Reinforcing Steel Institute, Publication # C810819, The Aberdeen Group.
10. "*Use of 500 Grade Steel in the Design of Reinforced Concrete Slab*", Prof. M. Shafiul Bari, Ph.D, Department of Civil Engineering, BUET.
11. *High-Strength Reinforcing Bars- a Technical note",* Engineering: ETN-M-8-16, Concrete Reinforcing Steel Institute.
12. *"Study on Grade 75 & 60 Reinforcement in RC Design",* Noor, M. A, and Ahmed, A.U, Department of Civil Engineering, BUET, BSRM Seminar, 12 April 2008.
13. "*Types and Grades of Steel Reinforcement*" Fasi Ur Rahman, 2016
14. "*MATETIALS GRADES*" ENGR. ALI ALVI, 2013