SEISMIC ANALYSIS AND RETROFITTING OF RCC BUILDINGS USING DIFFERENT TECHNIQUES

A

THESIS

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision

of

Mr. Chandra Pal Gautam

(Assistant Professor)

by

Diksha Kumari

(202654)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

May - 2022

STUDENT'S DECLARATION

I hereby declare that the work presented in the thesis entitled **"Seismic Analysis And Retrofitting of RCC Buildings Using Different Techniques"** submitted by me to **Jaypee University of Information Technology, Waknaghat** in partial fulfillment of the requirement for the award of the degree of Master of technology in Civil Engineering with specialization in Structural Engineering is a record of bonafide project work carried out by me under the guidance of **Mr. Chandra Pal Gautam**. I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree in this institute or any other institute.

Diksha Kumari

202654

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

25 May, 2022

CERTIFICATE

This is to certify that the work which is being presented in the thesis entitled **"Seismic Analysis and Retrofitting of RCC Buildings Using Different Techniques"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in Structural Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Diksha Kumari (202654)** from August 2021 to May 2022 under the supervision of **Mr. Chandra Pal Gautam,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: 25 May, 2022

Mr. Chandra Pal Gautam	Dr. Ashish Kumar	External Examiner
Assistant Professor	Professor & Head of Department	
Department of Civil Engineering	Department of Civil Engineering	
JUIT, Waknaghat	JUIT, Waknaghat	

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to **"Prof. Dr. ASHISH KUMAR",** Head of Civil Department at Jaypee University of Information Technology, Waknaghat for providing me an opportunity to present thesis work on "**SEISMIC ANALYSIS AND RETROFITTING OF RCC BUILDINGS USING DIFFERENT TECHNIQUES**". This thesis bears imprints of many people. I wish to thank all the people who gave me unending support.

I express my profound thanks to my project guide **"Mr. CHANDRAPAL GAUTAM"** for his guidance and constant supervision as well as for providing necessary information regarding the project and also for his support in completing the thesis work.

My thanks and appreciation also goes to **"Dr. TANMAY GUPTA"** who have indirectly guided and helped me in completion of this thesis project.

With sincere regards,

Diksha Kumari

(202654)

ABSTRACT

The present study aims for the Seismic Retrofitting of RCC Buildings using different retrofitting techniques. In recent years, the study shows that Earthquake occurred, dangers the lives of many people, property due to the failure of the structures. This loss due to earthquake also leads to the loss of money in many cases. Sometimes failure of the structure leads to the collapse of the structure which dangers people lives. So Engineers aims to design the buildings which can bear a repairable damage but collapse should not occur. Hence, there are certain techniques by which building can sustain repairable damages which basically termed as Seismic Retrofitting. Mainly retrofitting is done for the public properties like temples, hospitals, monuments and also for the private properties which are more vulnerable to seismic forces. Seismic retrofitting is defined as the process to make existing building more resistant for earthquake forces by mean of adding some structural members or by installing certain devices which can resist the forces generated by earthquake. In the present time there are many structures which are constructed having lack in the reinforcement detailing. In many seismic prone areas people don't consider seismic forces while designing and constructing building. Retrofitting is provided to improve the construction quality and bearing capacity for external load capability.

This study deals with the usefulness of using different retrofitting techniques such as bracing, jacketing, dampers, base isolation and shear wall used in the RCC Building to make it more - stiffer. The retrofitting of building mainly results in the increase of stiffness, decreasing story drift and displacement. The work has been carried out on RCC buildings which first analyzed in ETAB's software by static analysis and dynamic analysis and then retrofitted by using different retrofitting techniques. The best suited retrofitted technique is then used in field for retrofitting purpose in the RCC buildings which gives more stiffness, less story drift and less displacement on being analyzed in ETABS's software.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATION

ADRS	Acceleration versus Displacement Response Spectrum
ASCE	American Society of Civil Engineers
CSM	Capacity Spectrum Method
DBE	Basis Earthquake
DCR	Demand and Capacity Ratio
ETABS	Extended Three Dimensional Analysis of Building System
FRP	Fiber Reinforced Polymer
HYSD	High Yield Strength Deformed bars
IS	Indian Standards
ISB	Internal Steel Bracing
ISMB	Indian Standard Medium weight Beam
MCE	Most Considered Earthquake
RCC	Reinforced Cement Concrete
SMA	Stone Mastic Asphalt
TCM	Tuned Mass Dampers
URM	Unreinforced Masonry
VED	Viscoelastic Dampers

LIST OF SYMBOLS

V_b	Design Base Shear
T_a	Fundamental Time Period
H_Z	Hertz
R	Response Reduction Factor
Z	Zone Factor
I	Importance Factor
kN	Kilo Newton
S	Scale Factor
g	Acceleration due to gravity
f_{ck}	Grade of concrete
A_c	Area of concrete
A_s	Area of steel
f_y	Grade of steel
C	Risk Coefficient

CHAPTER 1

INTRODUCTION

1.1 General

As per the research it is concluded that the shaking on the surface of the ground is due to the production of waves under the surface of the earth. These waves are known as seismic waves. There is release of certain amount of energy at the point of ruptures in the fault, this energy release is reason behind the generation of seismic waves. The amplitude of seismic waves is different at different locations and also the time taken by waves to reach at different location is different. When shaking of ground occurs the vibration or we can say shaking is mainly defined as acceleration, velocity and displacement.

The impact of earthquake can be examined by the shaking of ground at different locations on the ground surface which can be evaluated as minor, moderate and strong. The minor earthquake comes regularly, moderate earthquake comes rarely and the strong earthquakes comes very rarely.

The aim of an engineer is not to make a structure which is completely earthquake proof. The buildings which don't get small damage while earthquake costs very high and due to high cost of construction it will become uneconomical. Therefore, by considering the point of cost of construction engineers mainly focus on the design of buildings which are earthquake resistant and can bear some damages which later on gets repaired. The Buildings which resists the seismic forces appropriately doesn't lead to collapse while earthquake and due to non - collapse mechanism life of occupant of building thereby remains safe and also cost of reconstruction is saved. So, this is the basic philosophy used worldwide for construction of buildings.

1.2 Earthquake Design Philosophy

From many years, there are certain design philosophy for structures during earthquake

1. During minor earthquakes, it is prescribed that secondary structural members of buildings can have damages which can be repaired later but the primary structural members like beams, columns, slabs should not get damaged.

2. During moderate earthquakes the secondary members of the building may lead to severe damages as they can be replaced after earthquake but the primary members of the buildings which helps in carrying loads may lead to some damages due to seismic forces which can get repaired after some time.
3. During strong earthquakes, the main motive of an engineer is that how much damage it will lead due to the seismic forces but the building should not get collapsed.

It is concluded that after minor earthquakes, building will remain in complete function as damages are very rare for which repairable time and cost is very less. After moderate Earthquake shaking, functionality of building takes time as compare to the minor earthquake building repair because the secondary members needs replacement. In case of strong earthquake, building will not get collapsed so that occupant's life should be safe but the functionality of building is gone because of irreparable damages as shown in figure 1.1.

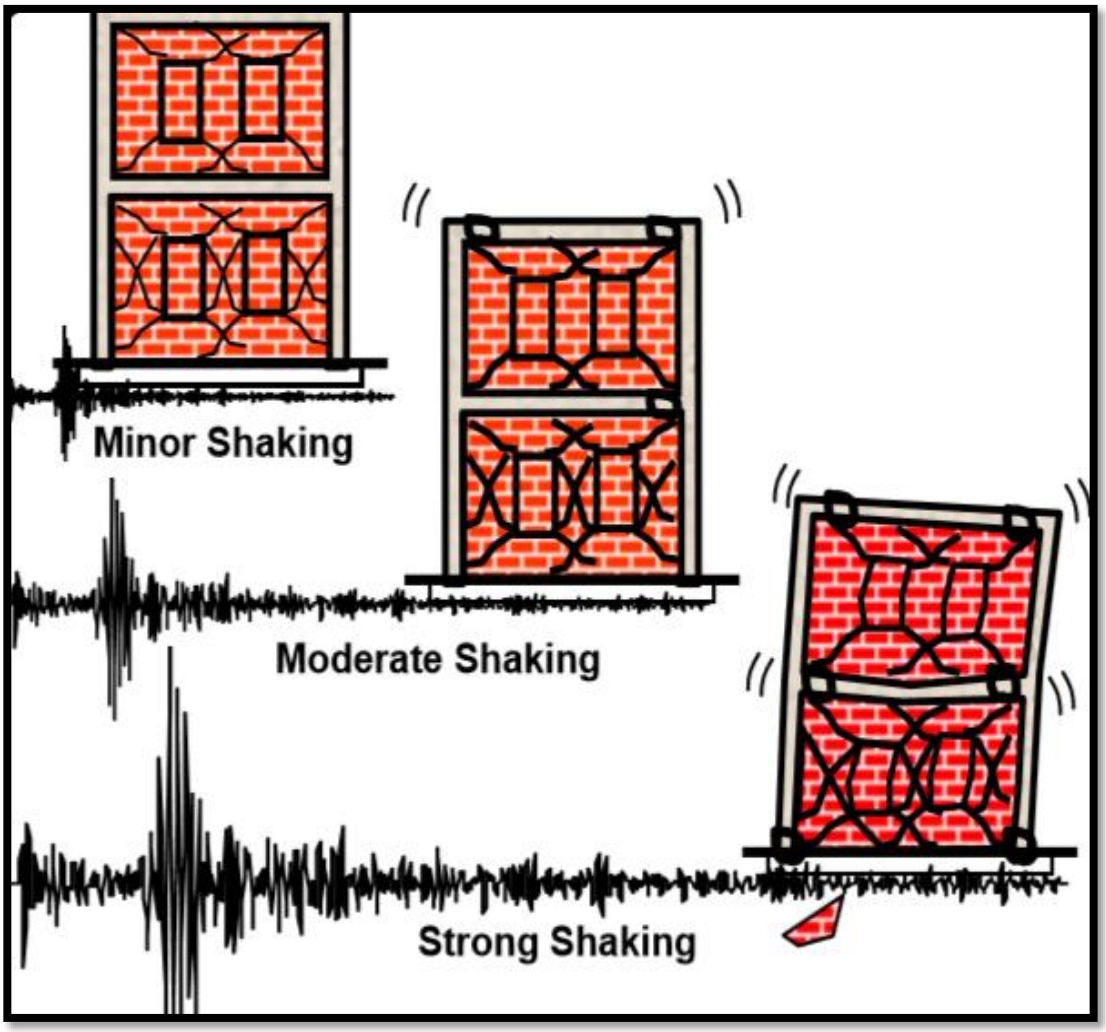


Figure 1.1: Performance objectives under different intensities of earthquake shaking

1.3 Seismic Retrofitting

1.3.1 Basic Concept Of Retrofitting

From many past earthquakes it is cleared that whenever earthquake comes it results in the loss of life of humans, animals, property. Due to earthquake sometime the structure or building will collapse. Many research has been carried out on the concepts that how we can make our structure more resistant in earthquake. After various studies a term called seismic retrofitting is introduced for making our existing structure less vulnerable towards the earthquake forces. For the process of seismic retrofitting there are various techniques which are used to make our structure more resistant toward the seismic forces. Retrofitting is provided to recover the construction quality and bearing capacity for external load capability. It is extreme significant for public sentimental properties and for the buildings which are located in the areas that are more prone to earthquake.

1. Increase in the lateral strength of the building: When their comes earthquake , seismic force acts in lateral direction which effects in shaking of ground due to which vibration occurs in building. By retrofitting structure, we can provide lateral strength to structure to withstand seismic vibrations.
2. Increase in ductility of building: Ductility means that when loads are approaching on the construction it will deflect to a certain level but after the removal of load structure will regain its original shape. So, by providing retrofitting structure can be fulfilled with sufficient ductility during seismic forces so that it cannot collapse quickly.
3. Increase in strength and ductility: There are many seismic retrofitting techniques by which structure can endure lateral forces and also deflections during earthquake.

1.3.2 Need of Retrofitting

1. Due to earthquake: During earthquake ground shakes owing to which horizontal forces acts upon the structure and building shakes which leads to cracks in structure sections, failure or settlement of building and somewhat other kind of definite damage to structure. To lessen this impact of earthquake we can use such methods which will help our building to withstand that effects of earthquake.
2. Insufficient concrete production: If concrete production if not enough it will lead to fall in strength of structure due to which structures are not that much vulnerable to bear load or may get damage also.

3. Bad execution process: It is important that how we are assigning our concrete during construction of structure as compaction is also required if we don’t compact or place concrete properly it will not gain tolerable strength. By providing retrofit we can add strength to structure.
4. Design error before & after construction: Before construction errors means not receiving proper details like not having proper survey or preparation of building plan properly and after construction includes later effects on building.
5. Due to lack of detailing: If reinforcement detailing are not proper during construction then it will lead of structure having less strength which lead to collapse of structure or having high strength which leads to uneconomical construction.

1.3.3 Objective Of Retrofitting

1. Structure unaffected: By retrofitting we can reduce the loss and damage of house.
2. Structure survivability: When the earthquake comes the main aim is that structure will safe for the purpose of leaving or exit.
3. Structure functionality: Main buildings are safe and the building is fully in service for its key application. A high level of retrofit, this approves that any vital repairs are enhancing.
4. Life Safety: One of the main objective of retrofitting is to protect lives of human beings by making structure more stable in earthquake so that there is no collapse of building on its occupants or people standing, passing by the building during earthquake.

1.3.4 Retrofitting Techniques

Retrofit scheme remarks to choices of accumulative or enhance the stability by increasing the stiffness of building. The building can also make earthquake resistant by enhancement in the ductility of structure and by increase in lateral strength of building. In simple words we can say that the process of retrofitting is a well-researched method to make buildings more stable so that they can withstand seismic forces in a very well manner. The retrofit approaches can be classified under global and local strategies. There are mainly two types of seismic retrofitting techniques named as global retrofitting technique and local retrofitting technique. The global retrofitting and local retrofitting which are discussed below as follows:

1.3.4.1 Global retrofitting techniques: This approach of retrofitting is used to offer the overall increase in the lateral strength of the building. When this technique of seismic retrofitting is used, building will not fail or collapse. There are numerous methods of global retrofitting like shear wall addition in building, infill walls, use of bracings, Mass Dampers, base isolation etc.

1. Seismic retrofitting of building by adding shear wall in the building is one of most effective method as shown in figure 1.2. This method helps in improving the resistance of the building when building will experience any kind of seismic forces. Basically shear wall helps in reducing torsion, that’s why this wall is provided for total height of structure in a symmetrical manner.

Figure 1.2: Seismic retrofitting by addition of shear wall

2. Use of steel bracings are also one of the effective way to increase the strength and stiffness of the building as shown in figure 1.3. The bracings helps to reduce the load path for the horizontal seismic forces as the load travels through the bracings to the foundation.

Figure 1.3: Seismic retrofitting by addition of bracings

3. Base Isolation: When it comes to seismic, the idea is to utilize an isolating system to keep ground motion from entering the structure. This is accomplished by the use of bearings as shown in figure 1.4. These are commonly found between the foundation and the superstructure in the basement.

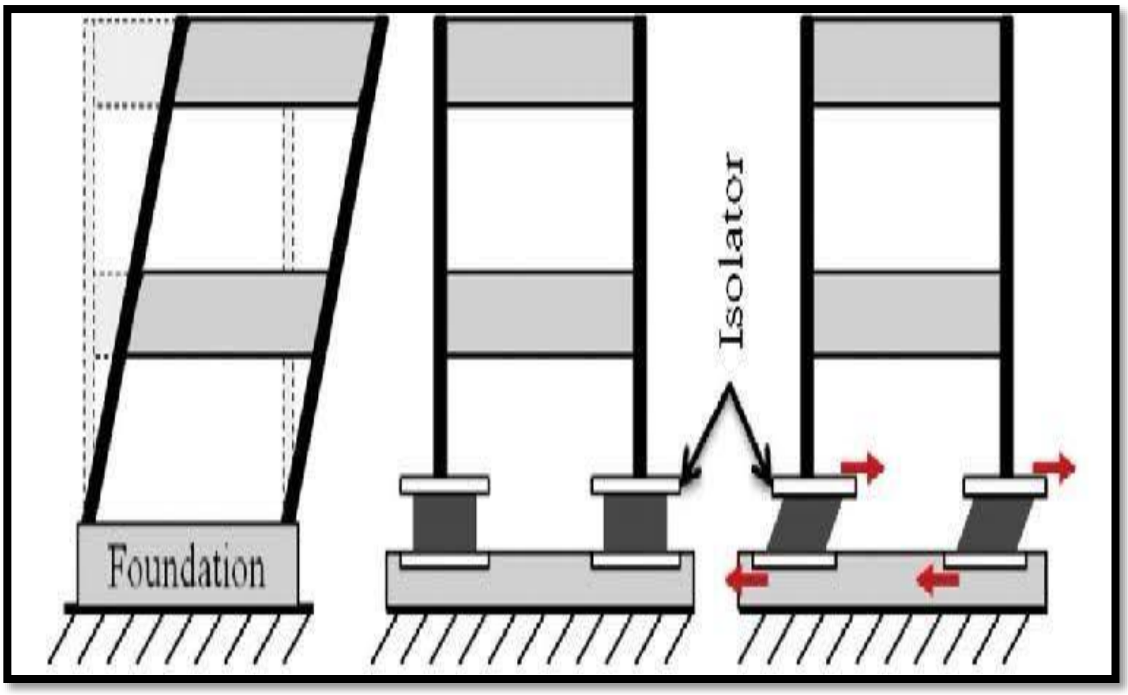
4. 

Figure 1.4: Deformation in Fixed Supported Vs Seismic Isolated Building in Earthquake

Concept of base isolation: The simple design idea shown in figure is to increase the fundamental period of the building so that the real seismic demand on the structure is less than that can safely be repelled by the structure as shown in figure 1.5. Base isolation is usually appropriate for short to intermediate rise buildings, generally up to 10-12 stories high. Superstructure features such as height, width, and stiffness are significant in defining the applicability and efficiency of seismic isolation.

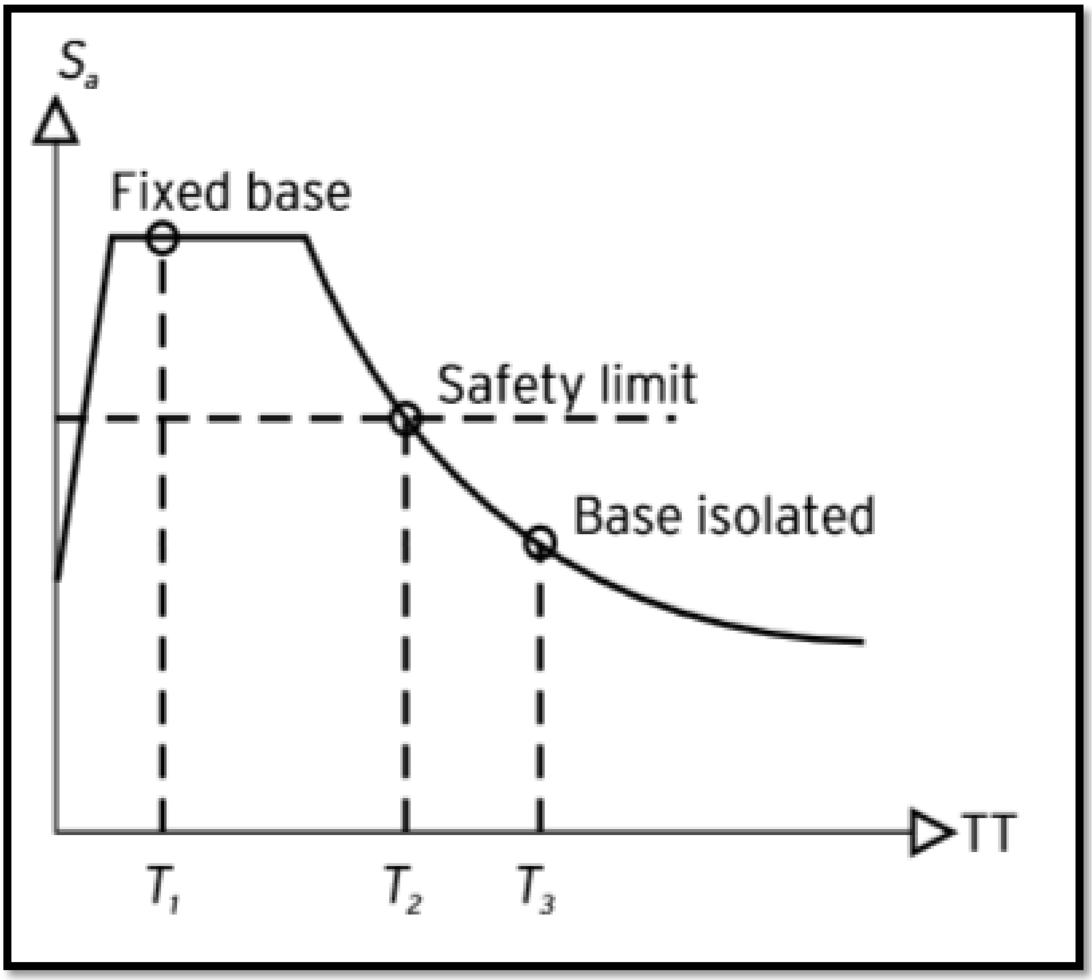


Figure 1.5: Spectral Response for a Typical Base Isolation System

5. With the evolution of technology their comes a structural component known as seismic dampers which helps in reducing displacement of the structure or building by absorbing the seismic energy generated during the shaking of ground. Viscous dampers: In this type of damper, energy is captivated by silicone based fluid transient between piston cylinder arrangements as shown in figure 1.6.

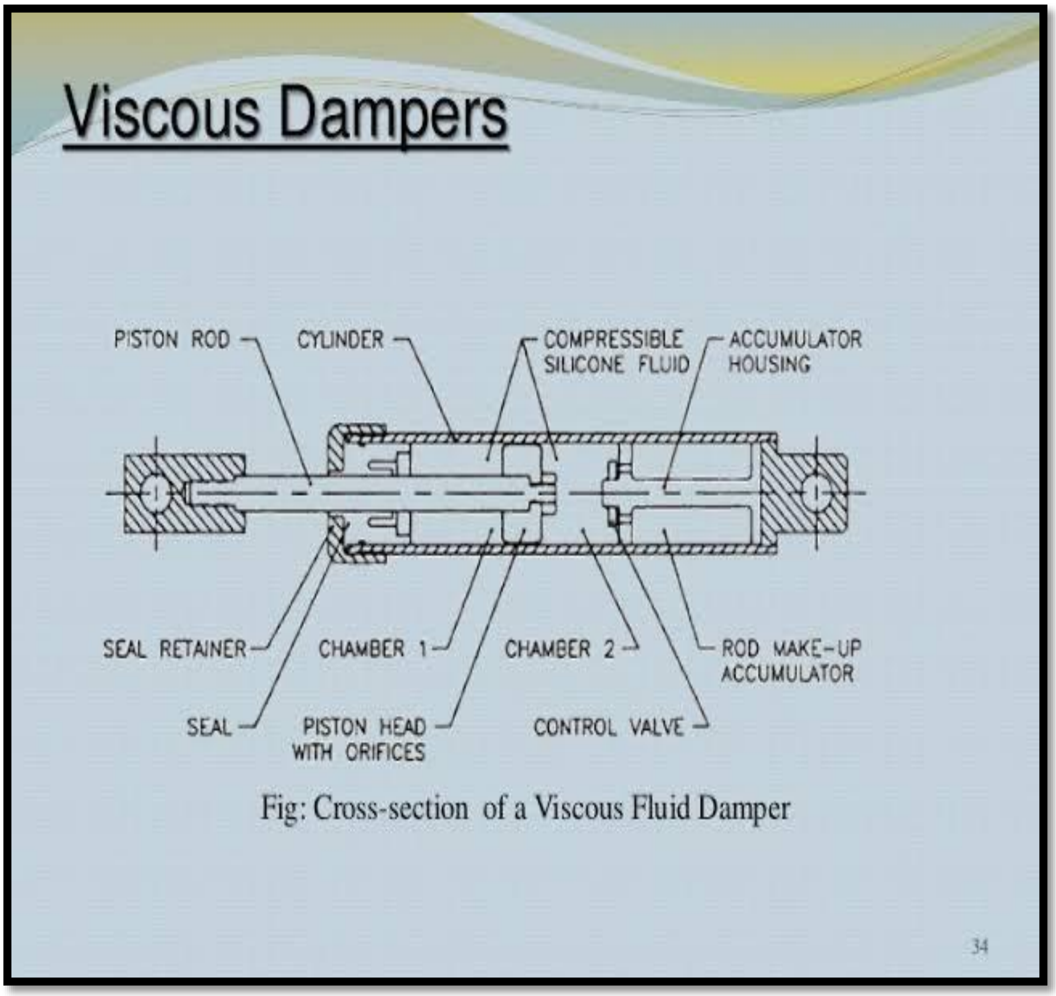


Figure 1.6: Cross section of Viscous Damper

Types of dampers: Some of the types of viscous dampers are deliberated below

i. Yielding dampers: The energy is engrossed by metallic components that yields.
ii. Friction dampers: energy is engrossed by surfaces by friction between them rubbing against each other.
iii. Tuned mass damper: This one is a device attached on the building to decrease the amplitude of mechanical vibrations.

1.3.4.2 Local retrofitting techniques: Local retrofit approaches are used to evade the collapse of the structural components. It helps in improving the performance of the building by avoiding the collapse of the structural elements.

1. Jacketing of beams and columns: It is utmost common method for enhancing the strength by strengthening of building column as shown in figure 1.7.

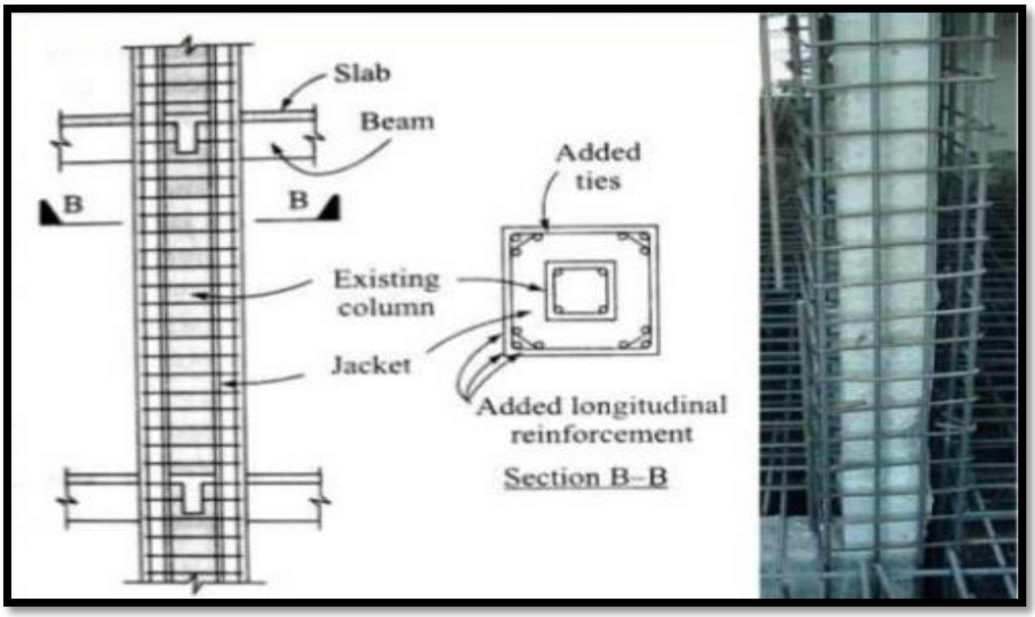


Figure 1.7: Retrofitting by Jacketing of beam and column

2. Jacketing of beams and columns by FRP: A fiber reinforced polymer is an axial strengthening system which used to increase or improve the capacity of reinforced beams. FRP upsurges the ultimate load carrying capacity of reinforced concrete members and recovers the shear capacity of reinforced concrete element. The ductility of a reinforced concrete column is increased significantly. The FRP jacketing will be used for exposed area columns as shown in figure 1.8.

Figure 1.8: Retrofitting by Composite Fibre Wrap

1.4 Thesis Organization

This project thesis consists of five chapters. The chapters are organized the proceeding side of work results.

Chapter 1 titled as **Introduction** which deals with the introduction about seismic retrofitting, Research objective of the study, Scope of the study and what is the methodology used for the project work.

Chapter 2 titled as **Literature Review** which deals with the literature review comprises of the review work which is analyzed by the studies carried out on seismic retrofitting of building by using ETABS software on the RCC Buildings.

Chapter 3 titled as **Methodology** which deals with the basic concepts used for analysis of the building and the elaborated procedure of the seismic analysis and retrofitting of RCC buildings using different techniques.

Chapter 4 titled as **Analytical Results** which deals with the analytical results in terms of story response plots for buildings. This Chapter comprises of the results compilation obtained before and after seismic retrofitting of buildings in ETABS 18.

Chapter 5 titled as **Conclusion** which further deals with the concluded results after the results compilation and suggestion is made that which retrofitting techniques is best suited for particular type of building.

CHAPTER 2

LITERATURE REVIEW

2.1 General

From the past earthquakes it is accounted that earthquakes will lead to lot of destruction in the society. The studies shows that during the earthquake there are many structure which doesn't perform well or we can say that their response to the seismic forces was not good due to which there may be sudden collapse of the structure occurs during the earthquake. The literature also concludes that even the structures that are designed with the basic Codal provisions also lead to failure or damage during earthquake. The reason behind this damage is, not considering the seismic forces while design of the building. So, researchers concluded that we can protect our structure at an economical value compare to reconstruction by doing seismic retrofitting of existing structure. The literature gives an overview of the seismic retrofitting of the buildings that are modelled and analyzed using ETABS by static and dynamic analysis. After analysis one should be able to find seismic vulnerability of the building and later the components that are more vulnerable to the earthquake was retrofitted by using various seismic retrofitting techniques.

2.2 Studies on Seismic Retrofitting

Geetha M, Chaitra D M (2021)[1] In this study, G+6 storey in Zone II is analyzed using linear static method in ETABS on different soil condition & the retrofitting techniques like jacketing of column with steel and concrete, use of braces are taken into consideration. Column failure was observed when additional floors were added. After the analysis of the structure it is observed that the building shows maximum story response plots i.e. displacement, drift and shear at soft soil as compare to medium and hard soil. Retrofitting methods improves the strength and load carrying capacity of the structure. Consequence of which storey displacement, storey drifts are reduced. As the study uses jacketing and bracing techniques, it is observed that bracing gives better results in reducing the story response plots as compare to jacketing.

Kafeel Hussain Ganaie, Birendra Kumar Bohara et.al. (2021)[2], In this study, G+3 soft irregular building is modelled and analyzed by using Response Spectrum & Pushover analysis in ETABS software. After the analysis building is retrofitted by using steel bracing. As according to the short load path the seismic force travels through the braces to the foundation which helps in increasing the strength of the structure. The bracing helps to reduce maximum story displacement and story drift. Bracings also helps to make structure more stable by increasing the stiffness of structure. Bracing helps to avoid soft story failures.

Valeti Immanial, R. Sai Teja (2018)[3], In this study, G+10 storey is analyzed using Response spectrum method in ETABS. Building was shifted from zone 2 to zone 3. As the building is shifted to the area or zone which is more prone to the seismic forces due to which the cross section provided for the primary or structural members is not appropriate to take modified seismic zone force which requires retrofitting of columns by FRP, Steel, Concrete jacketing. It was concluded that time period, displacement and drift of the structure reduces more in FRP due to which FRP jacketing model is more- stiffer than other two. So, at last study concluded that the technique that is best suited for this case is FRP as compare to RCC, steel jacketing and column jacketing.

Yaman Hoodaa, Pradeep K. Goyalb (2021)[4], In this study a hospital building located in the North – Eastern Region Zone IV was analyzed in ETABS 19 using Pushover Analysis & Retrofitted for fragile structural members by using bracing of dissimilar units of variable dimensions i.e. circular rod sections, angle sections and channel sections. It was determined that, from all the variable sections considered, circular rod sections of 10 mm diameter displays the best result. Also, for similar section measured ISA 150 x 100 x 10 mm demonstrations the extreme reduction in the displacement – storey relationship.

B M Varsha1, Dr. M D Vijayananda (2018)[5], In this study, residential four storey building in Zone II and soil Type-II was renewed to commercial building which results in upsurge of live load in existing building & analysis is approved out with extra live loads on slab under linear static analysis technique using ETABS 2016 software. The load increment in the existing four storey building, the beams and columns of the building got deteriorate. RC seismic retrofitting technique was used to improve the strength of beams and column and likewise the shear deformation of the joint panel will be reduced considerably after retrofitting.

Amjad Al-Mudhafer (2021)[6], In this study, inter-frame walls of deficient two-story building was designed using ETABS and retrofitting of columns of half inter-frame was completed by brick wall, concrete and FRP jacketing using nonlinear elastic analysis by ABAQUS Software. It was determined that presence of retrofitting of short shafts using steel jacket and FRP leads to 3-40% escalation in concrete bending framework in the section of shear strength and earthquake resistance. It was similarly observed that presence of the brick wall contributes to the strength of the column as it engrosses and damps part of the loads enforced on the columns as a consequence of which brick walls decreases the risks of damages to the columns due to unexpected loads on them.

Theint Theint Thu Soe, San Yu Khaing (2014)[7], In this study, twelve storey RCC structure was promoted from zone 2 to zone 3 due to higher seismic risks. The structure was designed by using ETABS and the retrofitting of fragile columns and beams in shear, flexural and confinement respectively by means of externally bonded FRP reinforcement the on ''Sika Curbodur Composite Strengthening Systems of FRP Analysis Software''. Strengthening of beams in shear and columns in confinement was completed by using Sika warp Hex 230C (carbon fiber type) & strengthening of beams in flexural using Carbodur S512 and Carbodur S1012. Now least thickness of FRP with the less number of layers was used as increasing stiffness, it is easier for debonding to happen.

Nima Sthapit, Nisha Sthapit (2021)[8], In this study, a house located at Purano-Nikap-13, Kathmandu was analyzed in ETABS using pushover analysis which displays that few columns got weaken & retrofitted by concrete and steel jacketing via epoxy resins. It was concluded that after retrofitting the drift reduced by 61% and 53%, displacement reduced by 62% and 52% in x and y direction. Through pushover analysis, it was originate out that the capacity of building was upgraded to 86% and total drift of building was 2%.

A. Malhotra, D. Carson, P. Gopal, et.al. (2004)[9], In this study, St. Vincent Hospital consist of five blocks of 5-storey RCC structure was retrofitted by using non - linear time history dynamic analyses in ETABS. Retrofitting by concrete shear walls or rigid steel bracing were not considered appropriate for this hospital as improvements with these approaches would have required costly and time consuming. Pall Friction dampers with suitable stiffness were used as they were efficient. It was concluded that dampers dissipate a major portion of the seismic energy in friction and structure experiences reduced displacements and member forces.

S. Shamshad Begum, G. Vani (2016)[10], In this study, 20 floors building was analyzed in Zone 2 and Zone 3 on altered soil condition with columns, columns with viscous dampers. The outcome has been associated using tables & graph to find out the utmost optimized solution. It was concluded that deflection was reduced by providing Viscous dampers. The stiffness of structure was also better by providing dampers. By using Viscoelastic Dampers 50% of displacement can be reduced.

B.Naresh, J.Omprakash (2018)[11], In this study, it is taken into account that result of lateral loads increases with increase in height of building due to these lateral loads, moments on steel components will be precise high. Now residential building with 20 floors is analyzed with columns, columns with viscous dampers to reduce this amplified moment. It was concluded that at top storey 50% displacement is reduced when the dampers are provided at each elevation. By providing the dampers the stiffness of the building is increased and storey shear is decreased with increase in height of structure.

Eben .C. Thomas (2015)[12], In this study, a soft storey structure is analyzed by using dynamic analysis was approved out by considering various time history analysis by using ETABS software. Seismic response of soft storey buildings fitted with Viscoelastic dampers (VED) having numerous damper configurations viz. single diagonal bracing, chevron bracing and double diagonal bracing considering varying damping coefficients has been considered. It was concluded that use of dampers reduces the displacement upto 70% & also reduce decrease in displacement by providing with damper configuration on both inner and outer bays. VED are easy to install and maintenance free. Therefore can be used as retrofitted technique.

P. Nawrotzki, T. Popp et.al. (2012)[13], In this study, structure Palatul Victoria in Bucharest, Romania was retrofitted by use of Tuned Mass Dampers (TCM). A model investigation and numerical investigation was also applied. This conclusion had been made that Tuned Mass Dampers results in a major seismic reaction decline in relations of induced acceleration and displacement intensities as well as of internal stresses and support reactions.

E. Roy, P. Ghose et.al. (2018)[14], In this study, two investigative models have been created i.e. existing building in ETABS 2015 & SMA retrofitted building in SeismoStruct 2018. Nitinol (Nickel titanium) is used as SMA material for retrofitting of columns. DCR values of the retrofitted columns were less than 1.0 which means that those columns can endure the existing loads. It was concluded that responses of RC columns are considerably reduced after retrofitting it by SMA material.

A. K. Kadu, Pawar Tanishk Shantanu et.al. (2019)[15], In this study, the Raja Dinkar Kelkar Museum in Pune was analyzed using ETABS and retrofitted by using Base isolation. The structure framing is included of URM bearing wall system with stone masonry foundations. It was determined that base isolation resist the reduced seismic forces deprived of the requirement for improvement. From Cost Benefit Ratio it was also determined that base isolation for an older structure saves extra cost, damages, deaths and injuries during an earthquake & base isolated buildings faces minor to no damage during earthquake.

Suman Verma, Manish Sakhlecha et.al. (2020)[16], In this study, an imaginary case study was analyzed using ETABS by Linear analysis using Time History Analysis having (G+8) storied MRF structure in Zone V. It was determined that base isolated structure demonstrated an abundant lesser fundamental frequency than fixed base structure & also high energy in ground motion at the advanced frequencies does not get spread to the building as this reduced frequency is abundant lesser than frequency of ground motion. It was also determined that structures whose period lies around 1.0s need additional lateral resistance, which can be delivered using other passive and semi active control like dampers and bracings so base isolation technique is appropriate for low and medium rise structures.

Anant Vats, Ankit Kumar Singh et.al. (2019)[17], The key purpose of this study, is to plan new as well as old buildings by retrofitting by base isolation methods, here isolator used was lead rubber base isolator and the structure was investigated in ETABS using Time History analysis. It was determined that by means of base isolation storey shear, base shear, storey drift was reduced which makes building stable and safe against seismic forces. Too, displacement and mode periods were increased which makes structure flexible and stable against earthquake.

K. Senthil, SK. Gupta et.al. (2017)[18], In this study, six storey reinforced concrete frames was analyzed in ETABS by finite element analysis. Retrofitting was essential due to insufficient reinforcements when seismic zone ever-changing from zone 3 to 5. Methods used were shear wall, X bracing and jacketing. It was determined that the lateral displacement, storey drift of the frame without shear wall upsurge upto 65% as associated to the frame with shear wall. Likewise, lateral displacement and storey drift of the frame without bracing increase upto 90% as compare to with bracing. Shear wall was found to be 46% and 91% pricier compared to X steel bracing and jacketing.

Anirudhha Banhatti, Ganesh Kumbhar (2016)[19], Equivalent Static Analysis and Response Spectrum Analysis were used to investigate open ground story and floating columns in ETABS. Retrofitting was completed with lateral bracings, shear walls, and increasing column size in the soft ground floor, as well as their combinations, to reduce stiffness irregularity and discontinuity in the load path. Shear wall retrofit is the most effective way to retrofit a soft story while also lowering the overall structure's displacement.

Fauzan, F A Ismail et.al. (2019)[20], In this study, due to destruction of the structural elements of Andalas University Dental Hospital structure retrofitting was essential. Now considered shear wall and concrete jacketing technique for analysis in ETABS. It was determined that shear wall was more active to decrease the internal forces and displacement of the structure & is more inexpensive.

2.3 Literature Review Summary

1. Seismic retrofitting is an appropriate skill for safeguard of a variety of structures.
2. Retrofitting procedure like jacketing, shear wall & bracing improves the story response plot of structure as a result of which storey displacement, storey drifts are reduced.
3. Dampers are easy to fix and maintenance free & similarly they offer suitable stiffness to structure.
4. By means of base isolation we can create structure which face minor to no damage during earthquake.
5. Optimization methods are required to know the utmost effective retrofit for a specific structure.

6. Appropriate design codes are required to be available as a code of practice for professionals linked to this field.

CHAPTER 3

METHODOLOGY

3.1 Research Objective

The work is carried out conclude the effect of different retrofitting techniques on a reinforced concrete moment resisting frame by modelling of RCC structures in ETABS. The basic objectives of the study are:

1. To analyse seismic performance of the structure according to the design generated by ETABS.
2. To analyse the story response plots of retrofitted buildings with different seismic retrofitting techniques.
3. To make comparison of the story response plots between retrofitted and not retrofitted buildings i.e. storey displacement, storey drift, story shear, story stiffness for the different seismic retrofitting techniques.
4. To find the best method of retrofitting among the used techniques.

3.2 Scope of Study

1. This study deals with the two RCC Structures, one is G+19 storey building and another one is G+3 Building subjected to earthquake forces.
2. Both the structures are analyzed by the Static analysis i.e. linear static analysis (Equivalent static analysis) & nonlinear static Analysis (Pushover Analysis) method using ETABS software version 18.
3. The weak members of the building firstly identified and retrofitted with different retrofitting techniques i.e. Bracings, Seismic dampers, Jacketing.
4. The performances of the existing buildings are improved by different retrofitting technique based on ETABS version 18 results.
5. To suggest effective or best retrofitting technique for buildings which helps in better results during the experience of earthquake forces.

3.3 Methodology of Study

The first stage of the methodology comprises the study of the buildings i.e. study of plan of buildings and the data given for its modelling. The Building is then modelled and analyzed using ETABS 18 software. After the analysis the buildings are then designed by using Design Spectrum Method. With the completion of the design process next step is to evaluate the performance of the building which can be done by using Pushover analysis. With the help of pushover analysis it is identified that where the plastic hinges formation occurs first due to the experience of seismic forces. Since the identification of weak members or regions is done buildings are then retrofitted by using different seismic retrofitting techniques. The phase I methodology is shown in figure 3.1.

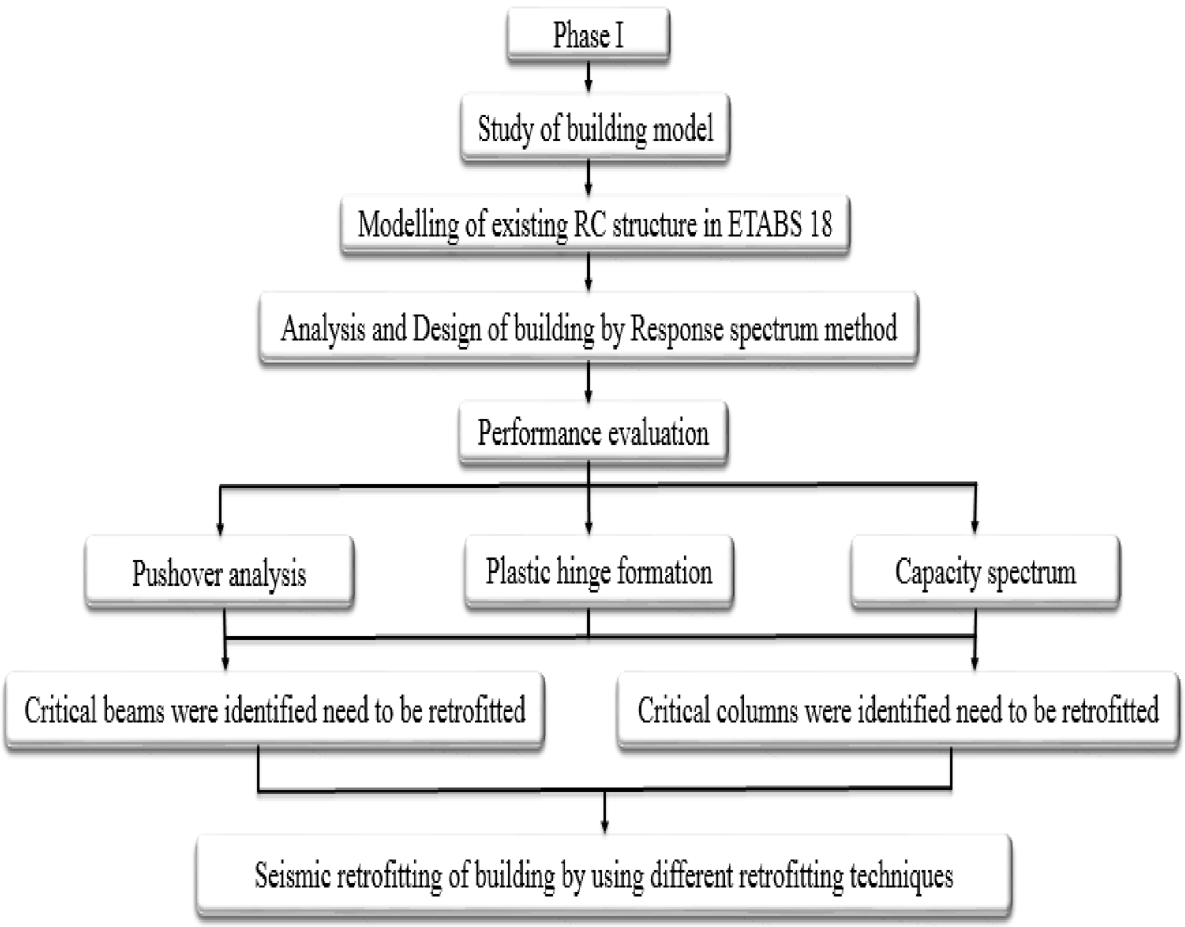


Figure 3.1: Methodology (phase 1)

The stage II starts with the analysis of buildings after retrofitting. So, the results for both cases i.e. retrofitted and without retrofitted buildings are obtained by using ETABS 18, the next step is to make comparison between the story response plots of the buildings. After comparing the story response plots of the buildings the best retrofitted technique is suggested for particular type of building. The second phase of the methodology is shown in figure 3.2.

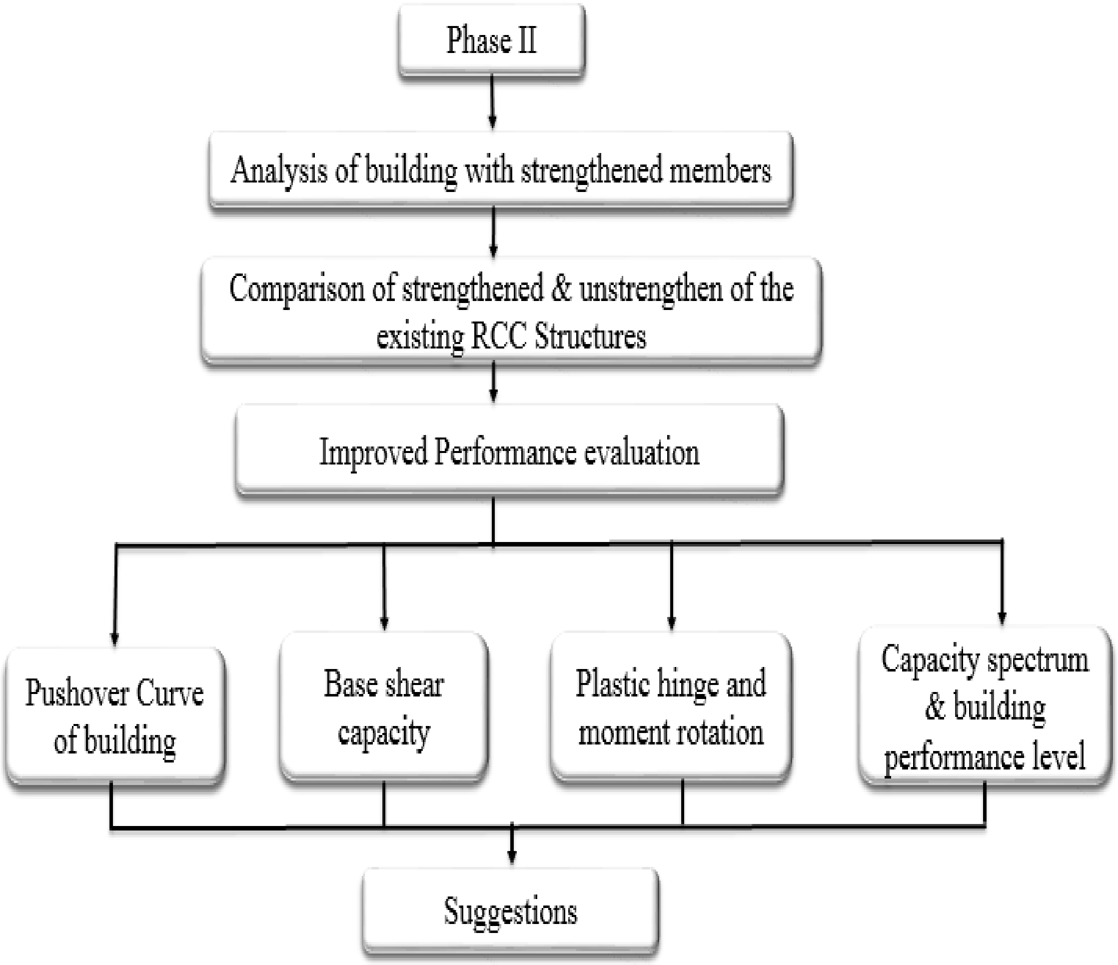


Figure 3.2: Methodology (phase II)

3.4 Method of analysis used in this Study

The analysis method used in this study is equivalent static method or linear static method to compute the story response plots of the buildings and pushover analysis to determine the hinge formation and buildings performance evaluation in various stages in buildings structural members i.e. beams and columns.

3.4.1 Equivalent Static Method of analysis

In the equivalent static method, the building response is noted by the series of forces acting on the building and gives the various mode shapes as the response of the building. The response of the building is noted by the plots of the building after the design response spectrum.

3.4.2 Pushover Analysis

Since the approach is very straightforward and analyses post elastic behaviour, nonlinear static analysis, also known as pushover analysis, has become the favored analysis for design and seismic performance evaluation purposes. However, because the approach incorporates various approximations and simplifications for the prediction of seismic demand.

The non-linear static process, often known as push over analysis, is a straightforward method for calculating post-elastic strength capacity. This process entails distributing a predetermined lateral load pattern at overall height of the structure. The deformation point of the building is reached due to the increase of forces in the lateral direction with the displacement control. As the displacement and loads are increasing, a significant reduction in the lateral displacement is observed.

3.4.2.1 Nonlinear Plastic Hinge Properties

This necessitates the construction of a force-deformation curve for important sections of beams and columns utilizing the FEMA 356 criteria (2000). The flexure force deformation curves are derived from reinforcing details and allocated to all beams and columns. The section designer was used to analyse the nonlinear properties of beams and columns, which were then allocated to the computer model in ETABS 18. At both ends of the beams, flexural default hinges (M3) and shear hinges (V2) were allocated. All of the columns' upper and lower ends have interacting (P-M2-M3) hinges. Figure 3.2 shows the relationship between the lateral force on a structure and the lateral deformation of the structure's roof. This curve is known as the 'push over' curve. The pushover curve, as shown in Figure 3.3, can be used to determine the performance point and position of hinges at various stages. The force deflection behaviour of the hinge is defined by five points designated A, B, C, D, and E. From point A to point B Elastic state is there, From point B to point IO the state of below immediate occupancy, from point IO to point LS there is a stage between immediate occupancy and life safety, from point LS to point CP the stage is between life safety and collapse prevention, from point CP to point C the stage is between collapse prevention and ultimate capacity, from point C to point D the stage is between ultimate capacity and residual strength, from point D to point E the stage is between residual strength and collapse, and greater than point E stage is collapse.

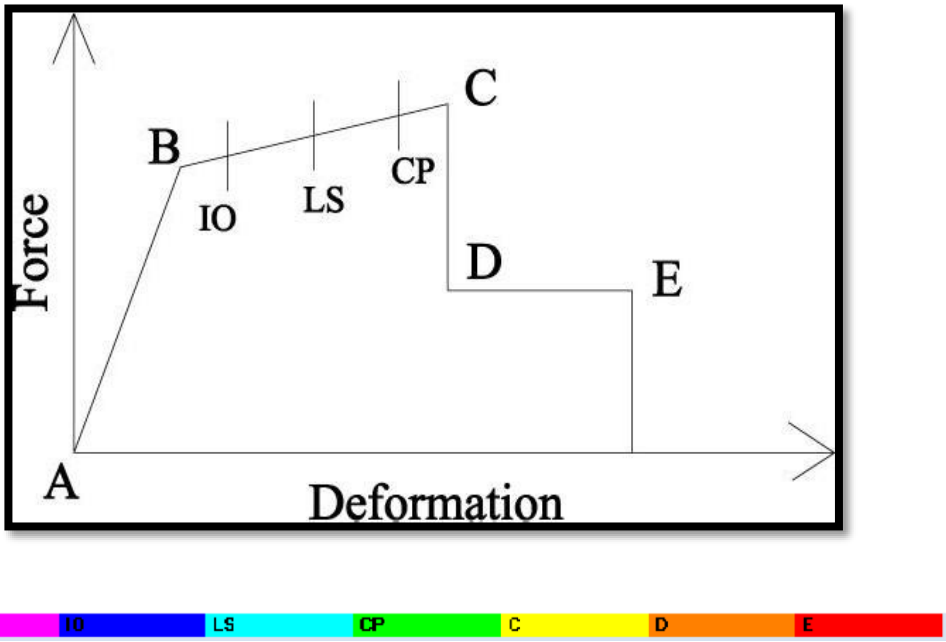


Figure 3.3: Different Stages of Plastic Hinge [ATC 40 (1996)]

3.5 Modelling, Analysis & Retrofitting of G+3 Building

3.5.1 Details of the G+3 Building

The four-story RCC structure was under consideration. The building is designed using the Indian standard seismic code IS 1893 (part 1):2016. The yield strength of reinforced rebar is 415 MPa in this investigation, and the concrete grade is 25 MPa. The steel bracings have a yield strength of 250 MPa. The response reduction factor is 5, and the study is conducted in zone V. In this building has 5 number if bays and 3 number of bays in the direction of x and y respectively. The distance between the one bay to another bay is given as 5m. The Height of first story is 4 meters and the height of above three stories are taken as 3 meters which results in the structure vertically uneven. Figure 3.3 shows the plan and elevation view. The thickness of 120mm is given for reinforced concrete Slab. The Live load is given as 3KN/m2. The appropriate size for is 250X300 mm, and the cross-section of the columns is 300mmX300mm.

1. The plan and 3D view of building as shown in the figure 3.4.

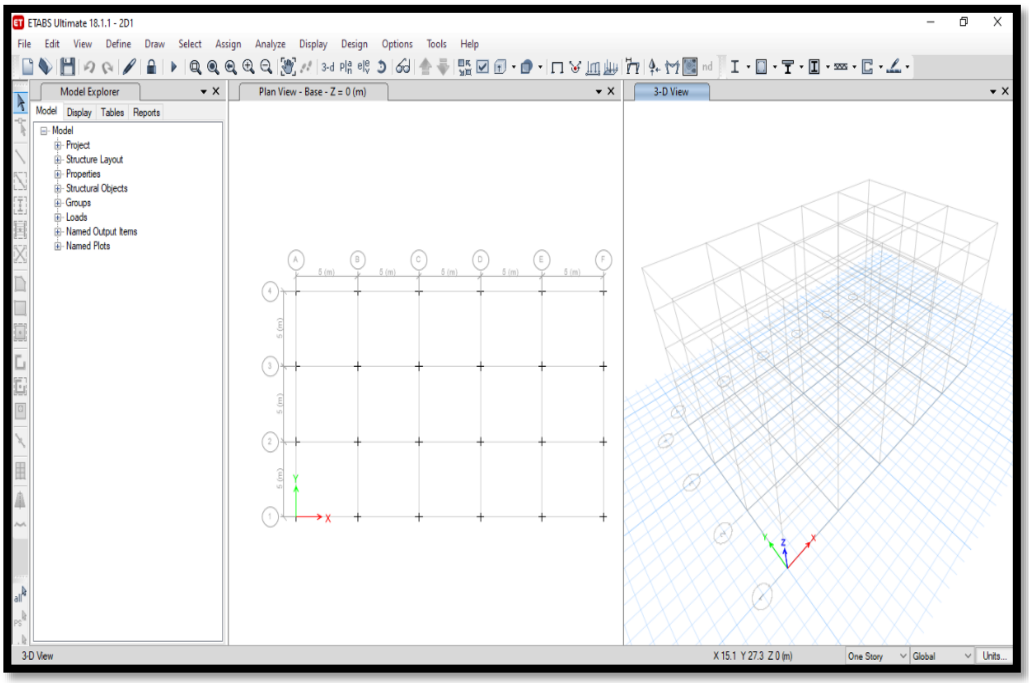


Figure 3.4: Plan and 3D configuration of building for G+3 Building

2. Go on Define > material property, add new material property dialogue box is opened. Select grade of concrete as M25, grade of rebar as HYSD 415 and Mild 250 as shown in figure 3.5.

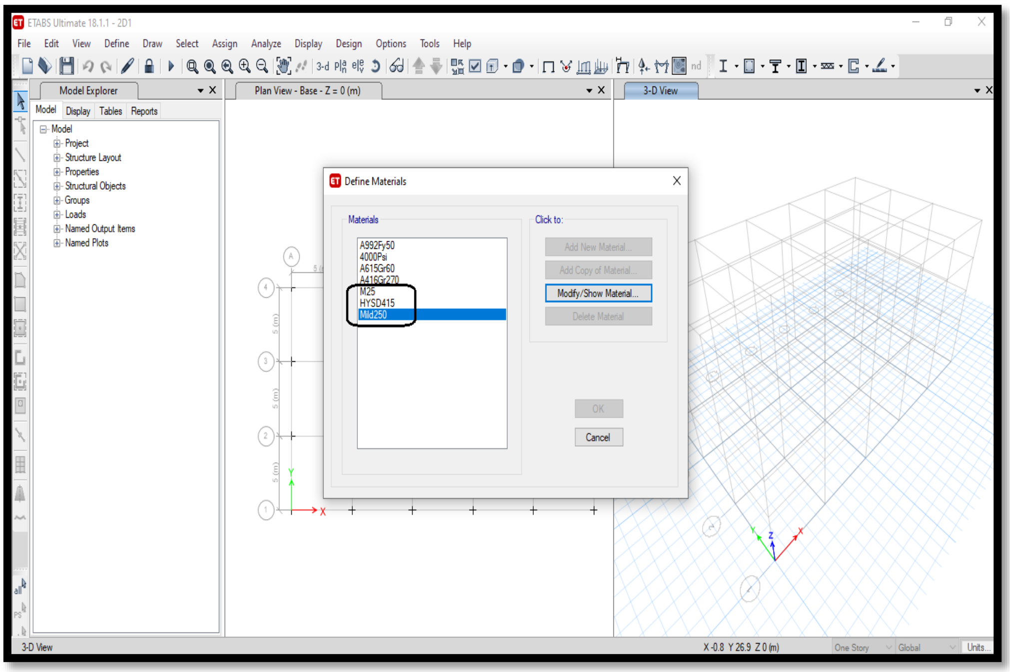


Figure 3.5: Defined material and section property for G+3 Building

3. Go to Define > Section property > Frame sections and Slab sections. A frame property and slab property dialogue box is opened and by clicking on add new property define the beam size of 350*350mm, column size of 450*450mm and slab thickness of 120mm for building as shown in figure 3.6.

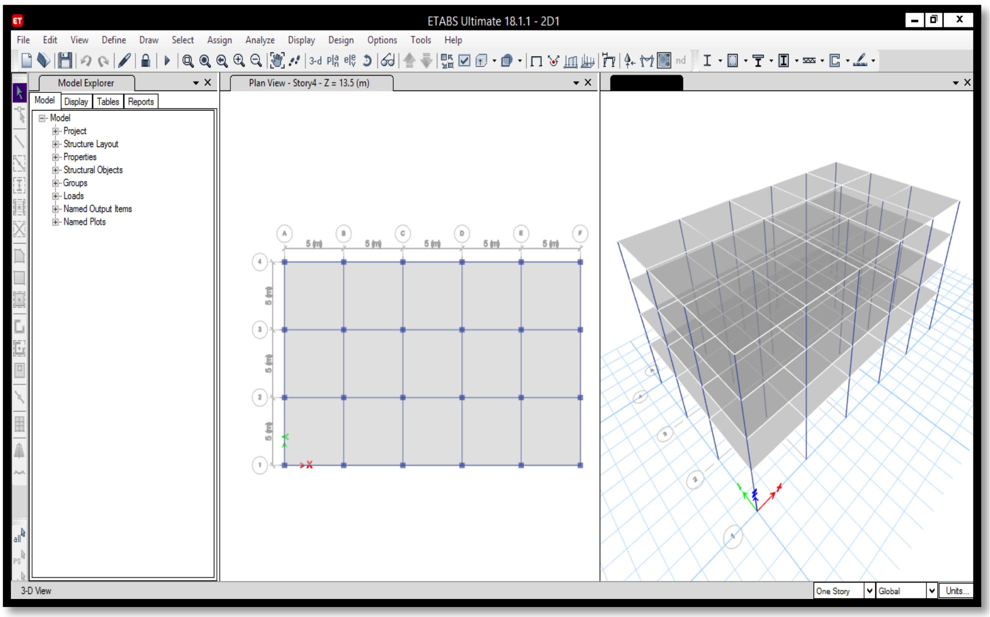


Figure 3.6: Assigned section property for G+3 Building

4. Go to Define > Load patterns. A define load patterns dialogue box is opened. By clicking on add new load define dead, live, wind and earthquake load as shown in figure 3.7.

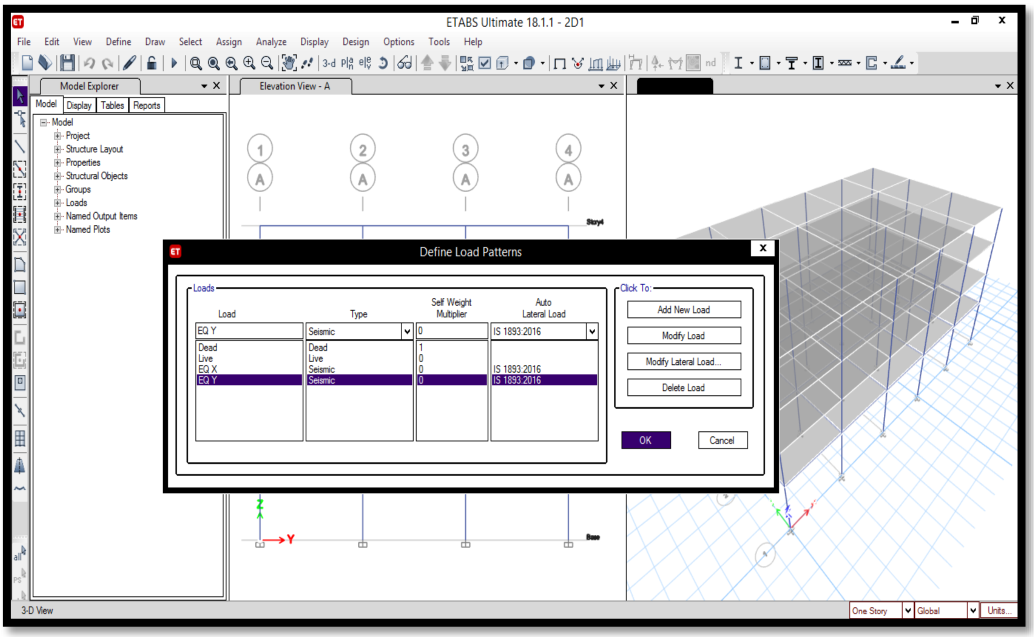


Figure 3.7: Load pattern for G+3 Building

5. For self-weight added weight is 1Kn in joint load assignments, after applying the self-weight of building the joint loads are shown in figure 3.8.

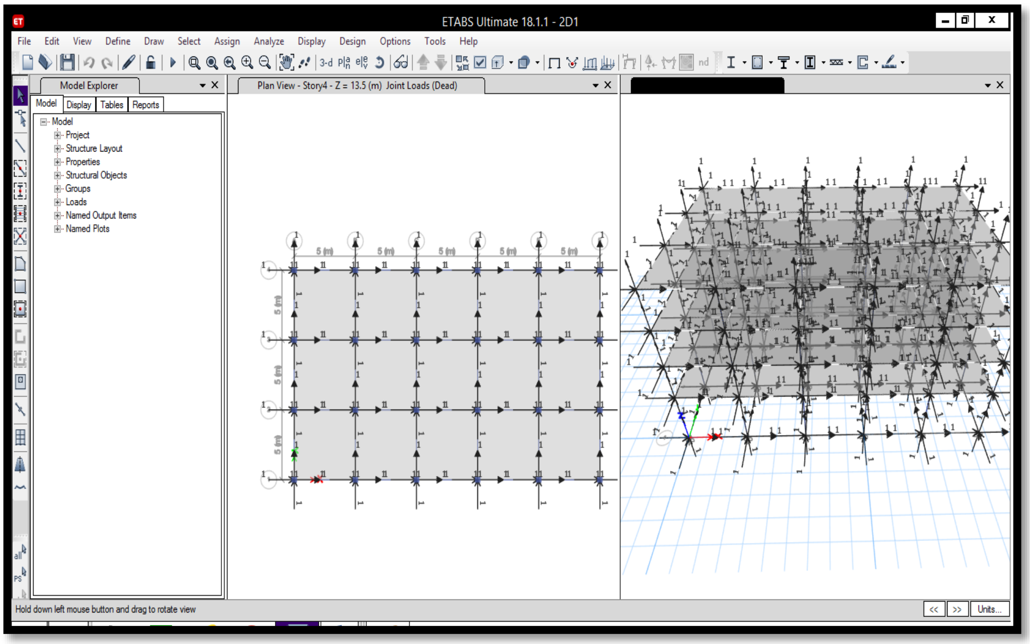


Figure 3.8: Assigned self weight load for G+3 Building

6. The slab dead load is calculated by multiplying the thickness of slab with density of concrete i.e. 120*25 = 3kn/m2, added floor finish load of 1.5Kn/M2. After assigning dead load on slabs the loads are as shown in figure 3.9.

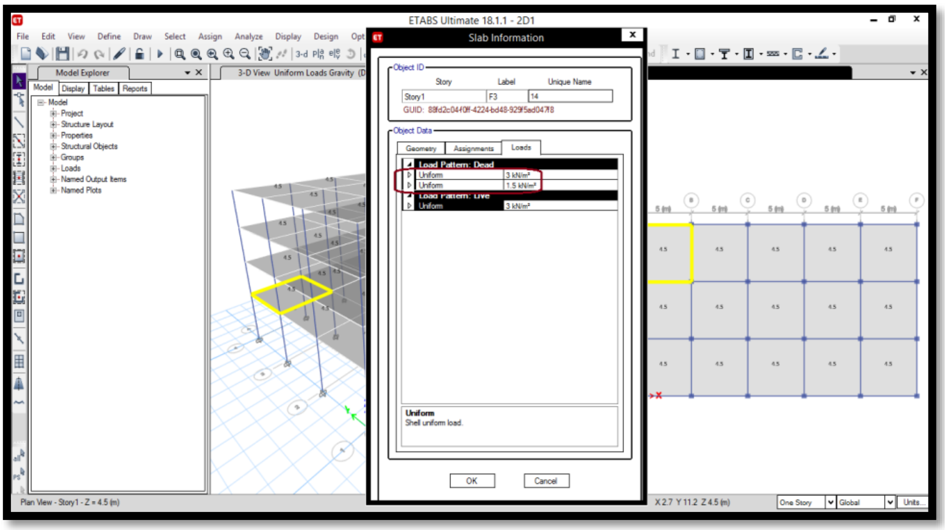


Figure 3.9: Total Dead slab load assigned for G+3 Building

7. The wall Dead load is calculated by multiplying thickness of brick wall with unit weight of brick masonry and with floor height i.e. 0.21*19*3 = 12kn/m for story 2 to story 4 and

wall load is calculated by multiplying thickness of brick wall with unit weight of brick masonry and with floor height i.e. 0.21*19*4.5 = 17.955kn/m for story 1. After assigning wall load on beams the loads are is shown in the figure 3.10 and figure 3.11.

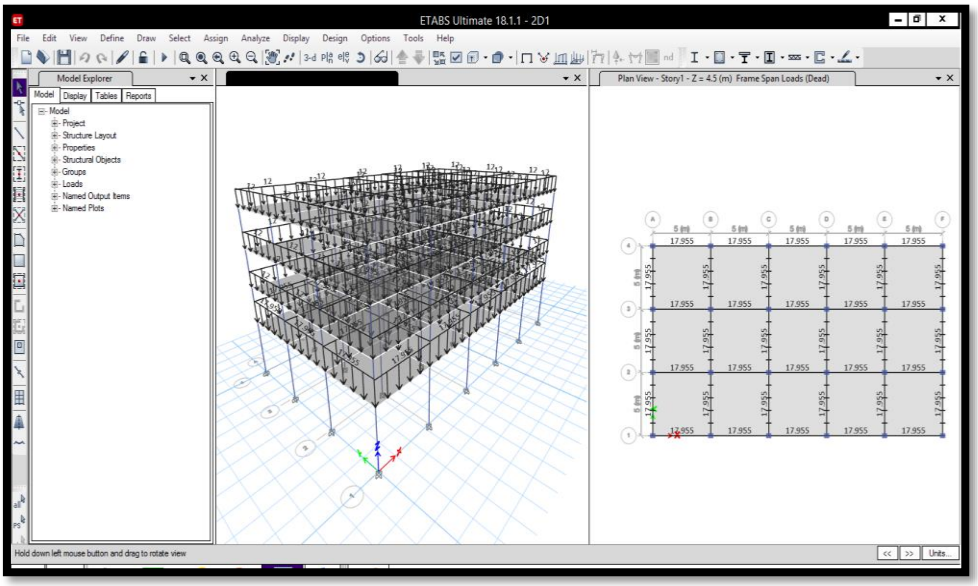


Figure 3.10: Assigned wall load on beams for story 1 of G+3 Building

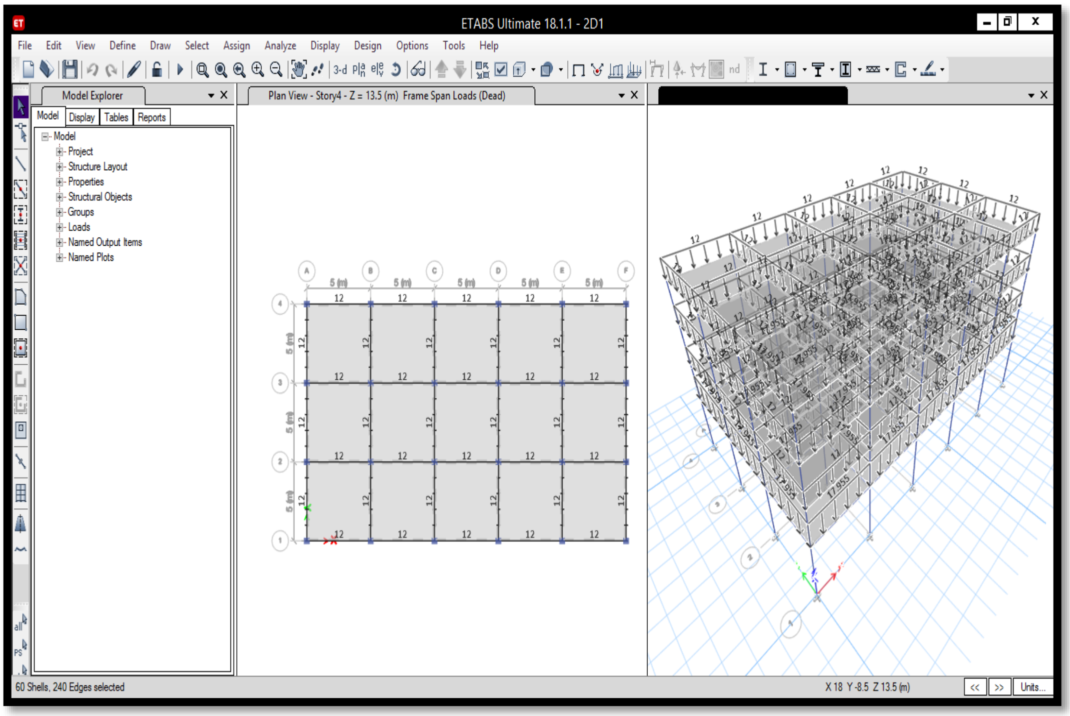


Figure 3.11: Assigned wall load on beams for upper stories of G+3 Building

8. Added live load of 3Kn/M2 for all story. After assigning live load on slabs for all story the assigned loads are as shown in figure 3.12.

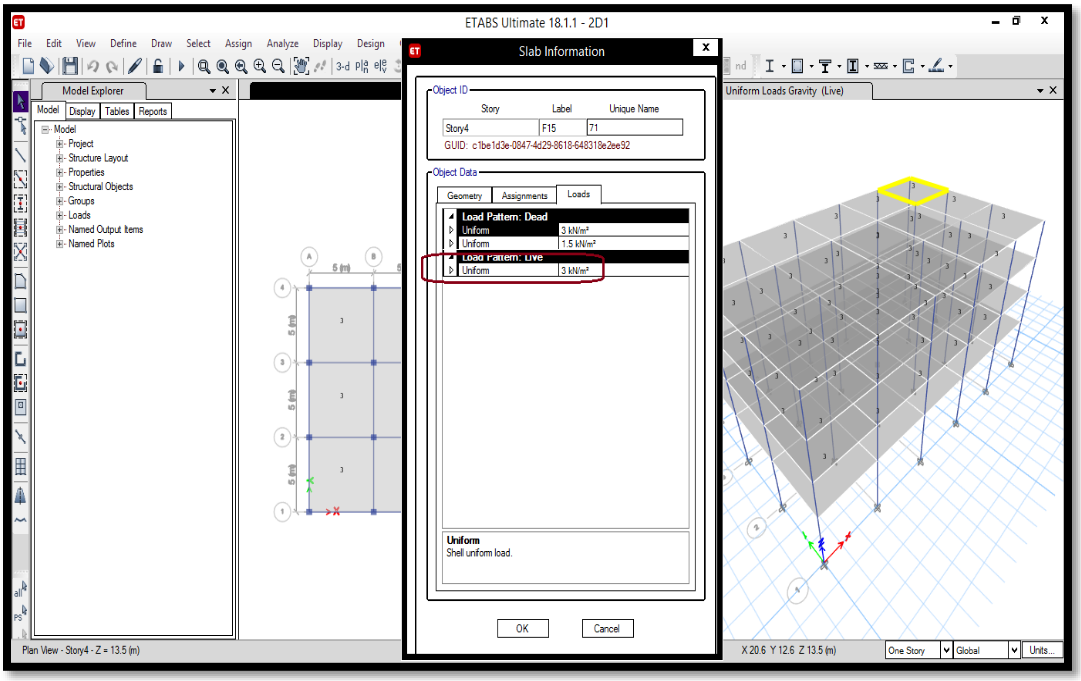


Figure 3.12: Assigned live load for all story of G+3 Building

9. The seismic load is added as per IS 1893:2016 having zone V which has value of zone factor 0.36 and soil type III. The value of I which is termed as Importance factor is taken as 1. The value of R is taken as 5 in X & Y earthquake load direction as shown in figure 3.13 and figure 3.14.

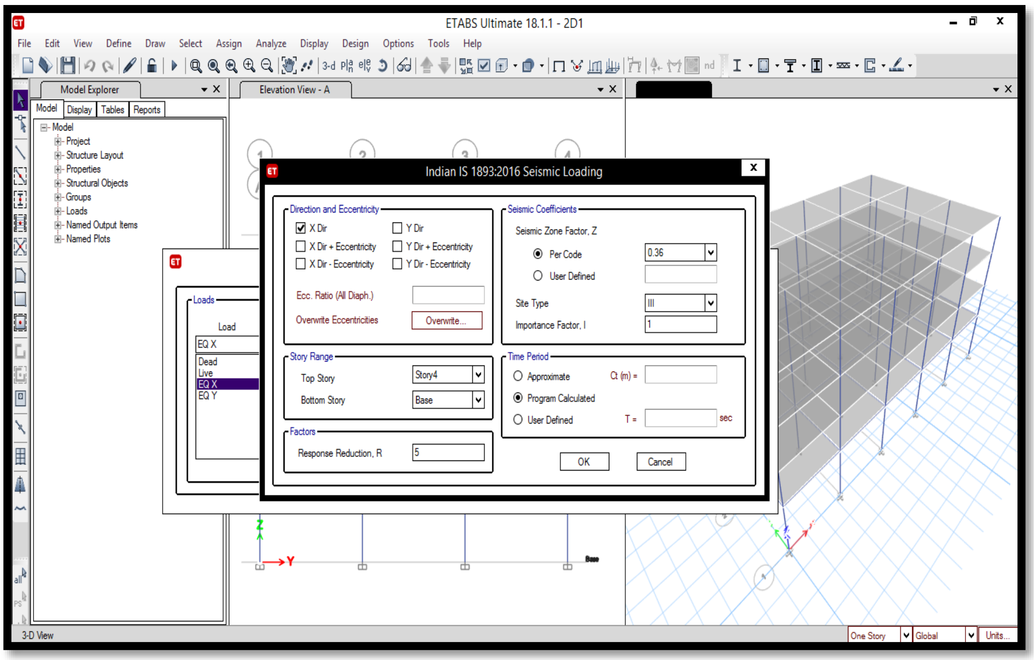


Figure 3.13: Defined seismic load in X direction for G+3 Building

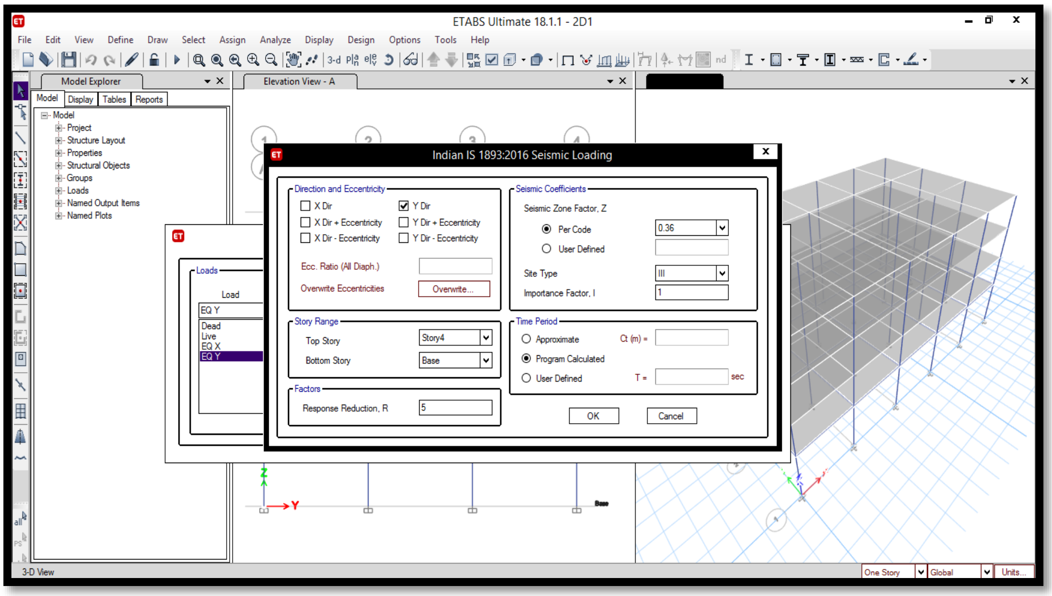


Figure 3.14: Defined seismic load in Y direction for G+3 Building

3.5.2 Analysis and Design of G+3 Building

1. A mass source data for specified load patterns. Add mass multiplier as 1 and 0.25 for dead and live load. Go to Define > Function > Response spectrum. A define response spectrum dialogue box is opened. Here choose function type as IS 1893:2016. Enter the applied load data as acceleration loading type in UX and UY direction having response spectrum function which is having scale factor of 1633.5 as shown in figure 3.15. This scale factor is calculated by using formula i.e. S = (Ig/2R) = (1*9801/2*5) = 980.1

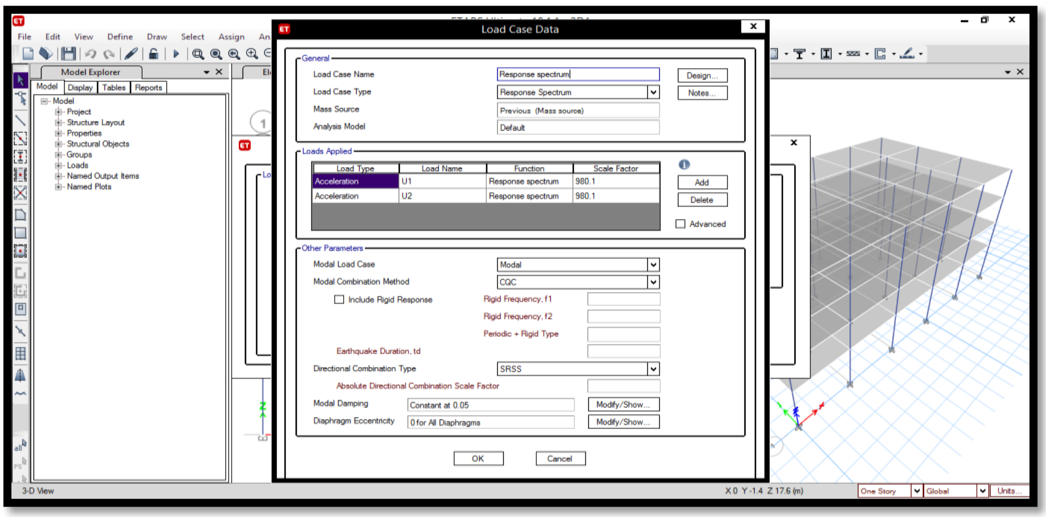


Figure 3.15: Response spectrum load case data for G+3 Building

2. After analyzing the model we have to design it. For designing unlock the model. Click on concrete frame design icon in toolbar, designing of structure starts. After designing gets completed click on drop down menu of concrete frame design icon and here go to verify all members passed. In this model all members passed the design check as shown in figure 3.16.

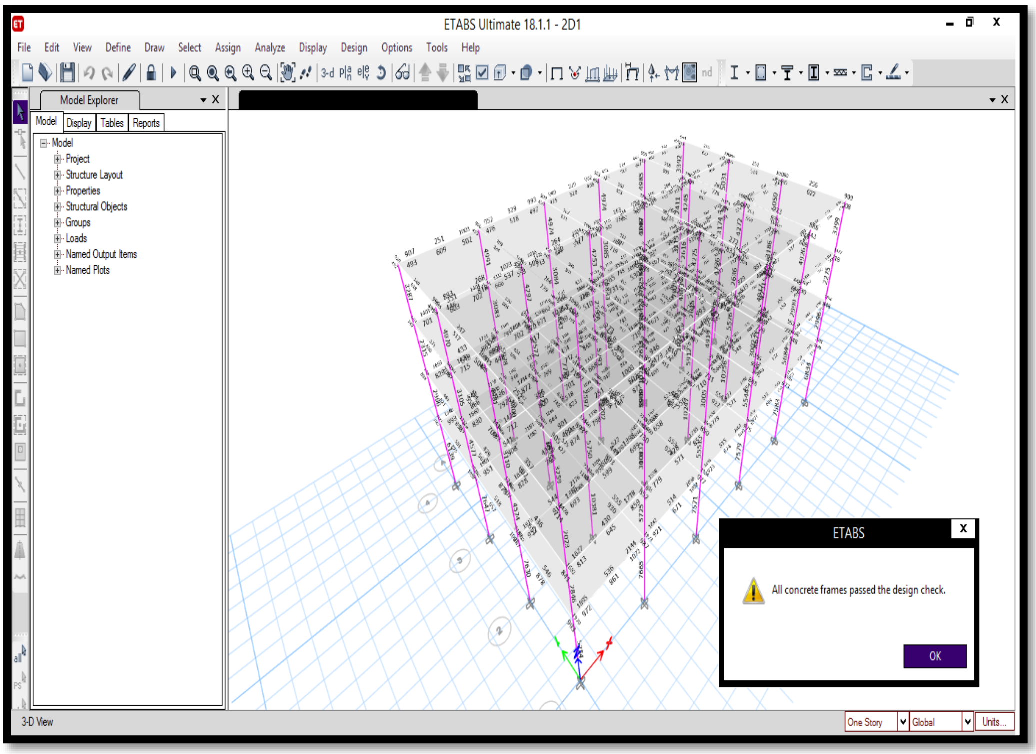


Figure 3.16: Analysis and Design of G+3 Building

3.5.3 Pushover Analysis of G+3 Building

Before applying pushover load cases we have to make dead load as non-linear static load. For defining pushover cases firstly go to Define then load case and then add new load case. A Load case data dialogue box is opened. Define the various parameters for push X and Push Y. Modify the load application to displacement control and add monitored displacement as 540mm which is 4%H i.e. 0.04*13.5 = 0.54m. Select all beams and columns > assign > frames > hinges. Assign the frame hinges and select auto hinge type as 0.1 and 0.9 from table ASCE 41-13, hinge table as table 10-7 concrete beams-flexure and concrete column for case combo pa-x and pa-y. After analyzing pushover load cases the hinge formations in both X and Y direction are shown in figure 3.17 and figure 3.18.

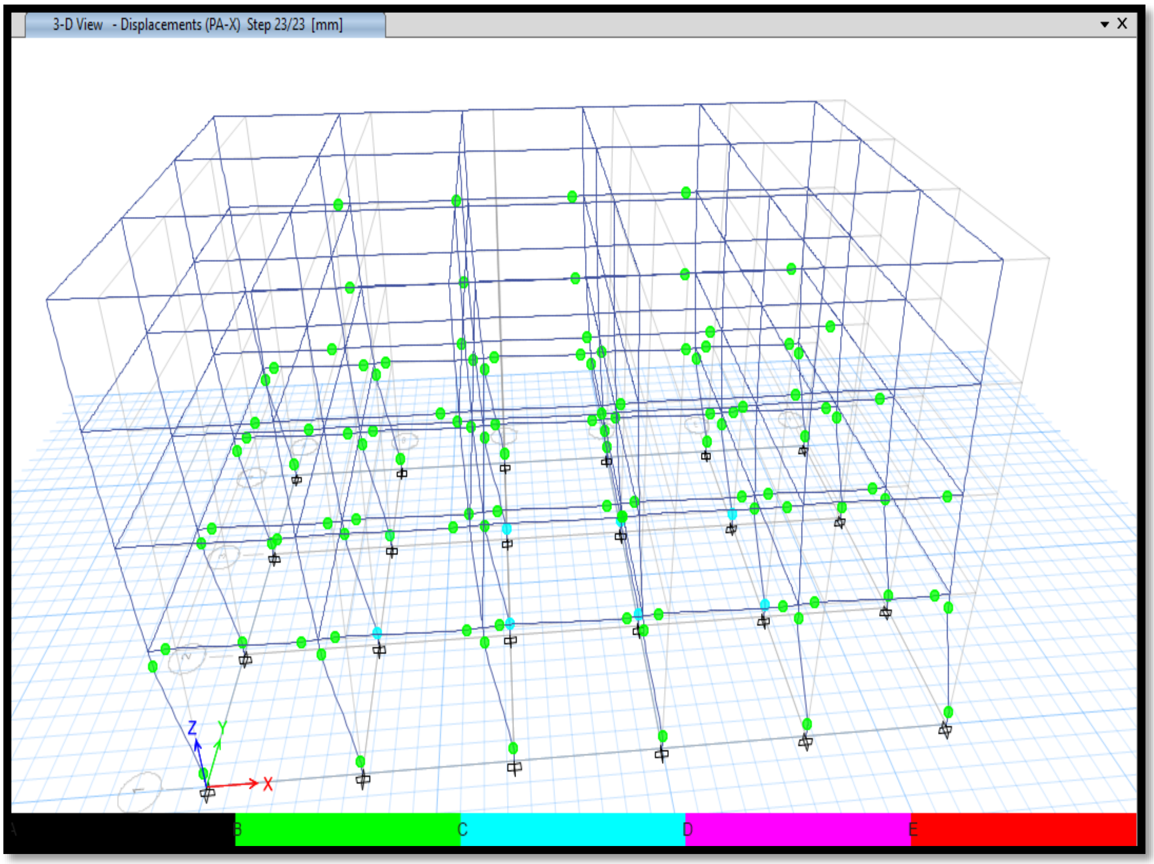


Figure 3.17: Hinge formation in X direction for G+3 Building

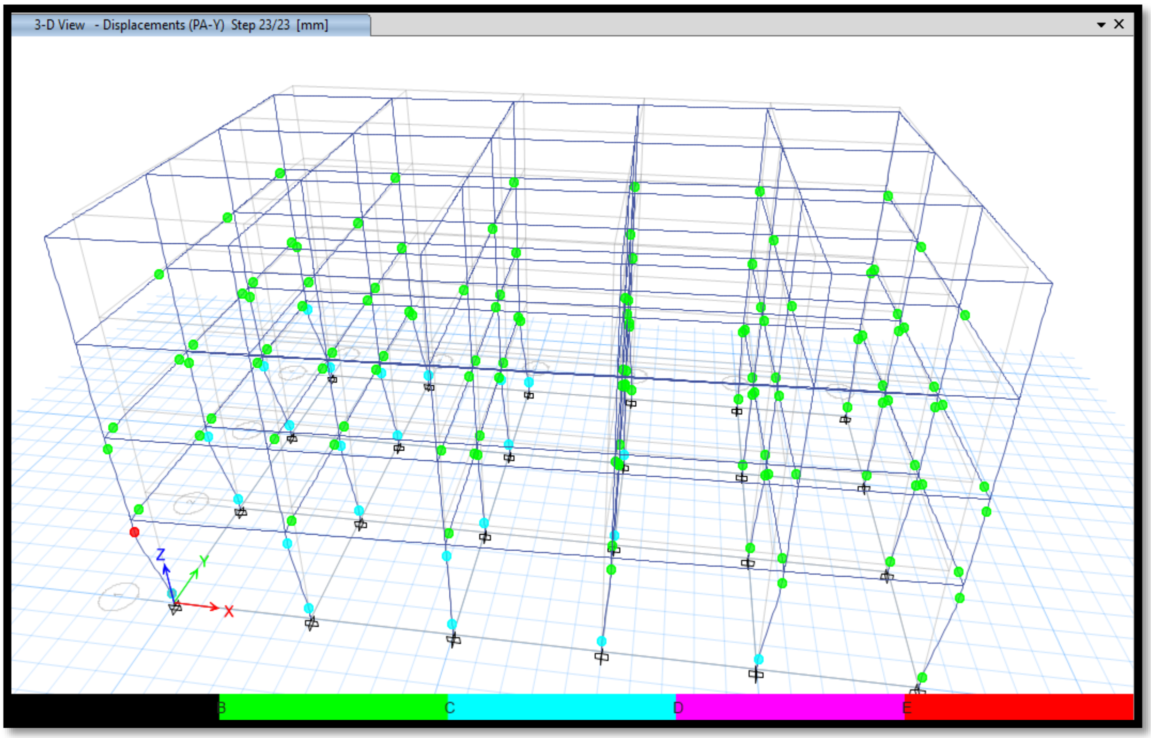


Figure 3.18: Hinge formation in Y direction for G+3 Building

3.5.4 Seismic Retrofitting Of G+3 Building

Firstly stiffness of building is modified for retrofitting. A Frame assignment – property modifiers dialogue box is opened. Change the value of Moment of inertia about 2 axis and 3 axis as 0.7 for columns as shown in figure 3.19 (as per IS stiffness modifier for beam is 0.35 and slab is 0.25).

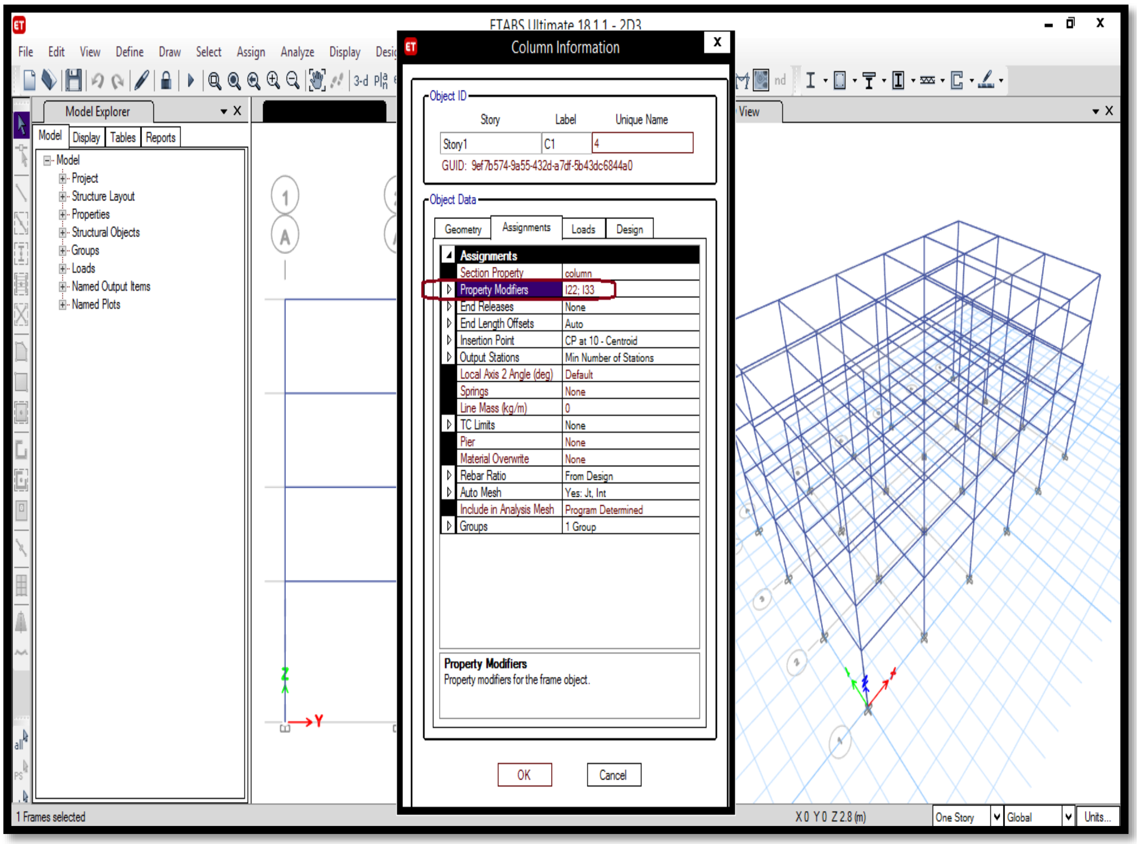


Figure 3.19: Assigned stiffness modifiers for G+3 Building

3.5.4.1 Retrofitting of G+3 Building with Bracing

Go to Define > frame sections > Add new property > Auto select. A Dialogue box is opened. Add material as Fe 250 for bracing section. Select the imported properties and add them into auto select list. Click on quick draw braces cursor. The drawn braces in 3D view is shown in figure 3.20. From the brace information dialogue box it is concluded that section property ISB 122*61*4.5 is used as appropriate section property for bracing by ETABS for G+3 building.

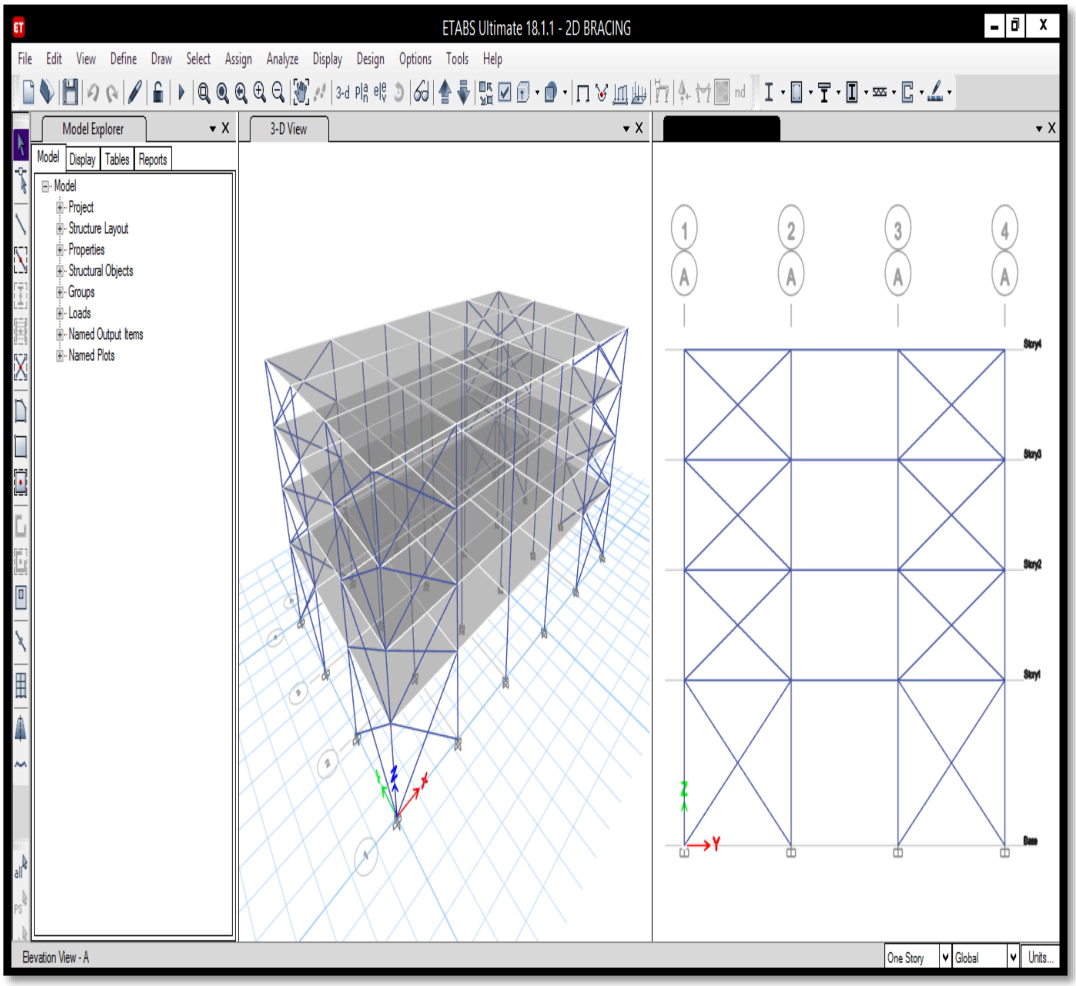


Figure 3.20: G+3 Building with Bracing

3.5.4.2 Seismic Retrofitting of G+3 Building with Jacketing

1. Firstly the manual Design of RC column jacketing is carried out by using IS 15988:2013 for G+3 building

Given data for design of column jacketing: Column height is given as 4500mm, Size of column is given as 450*450mm, 25 N/mm^2 is given as grade of concrete used, and the grade of steel used is 415 N/mm^2. The value of the Load, P_u is 317.1336kN.

Reinforcement provided (pt) = 2.03%

$$Ast = \frac{p_{t*B*D}}{100} = \frac{2.03*450*450}{100} \qquad = 4110.75\text{mm}^2$$

Using 20mm dia bars

Area of one bar = $\frac{3.14*20^2}{4} = 314mm^2$

Number of bars required = $\frac{4110.75}{314} = 13.09 = 14\ bars$

Providing 14 no. of 20mm dia bars

Therefore, total area of steel = $\frac{14*3.14*20^2}{4}$

=4396mm^2.

= 4396mm^2 > 4110.75mm^2

Design Procedure for cross section of concrete jacketing

Pu= 0.4* fck * Ac+0.67* fy *Asc

As per IS 15988:2013, the grade of concrete must be at least 5MPa greater than the grade provided earlier. So earlier the grade of concrete is 25 MPa so here the value for concrete grade is taken as 35 N/mm2. The value assumed for Asc is Asc=0.8%Ac

317.1332*10000 = 0.4* 35* Ac + 0.67*415*0.8*Ac

Ac= 19551.9852 mm^2.

As per IS 15988:2013 it is suggested to take 100mm thickness of concrete jacketing.

B= 450 + 200 = 650mm

D=450 + 200 = 650mm.

650*650=422500 (area of concrete jacketing)

> 19551.9852mm^2

As= 0.8 % *650 * 650=3380 mm^2

As per IS 15988: 2013, As = (4/3)*A's

As= (4/3)*3380=4506.66 mm^2

Assuming 20mm diameter bars

Area of one bar = $\frac{3.14*20^2}{4} = 314mm^2$

Number of bars required = $\frac{4506.66}{314} = 14.35 = 15\ bars$

Thus, for jacketing section 15 number of bars having diameter of 20mm is provided.

650mmx650mm cross section is taken for concrete jacketing of RCC Building

Design procedure of lateral ties for jacketing section:

The IS code 15988:2013 suggests 8mm as the minimum diameter of ties and maximum diameter of lateral ties should be about one third of the longitudinal bar diameter.

Calculated bar diameter for lateral ties = one third of largest longitudinal bar which approximately comes out to be 8mm.

The Spacing of ties= s= $\frac{fy*d2}{sqrt(fck)tj}$

$$= \frac{f_y*d^2}{\sqrt{f_{ck}}*t} = \frac{415*20^2}{\sqrt{35}*200} = 140.29 = 150mm$$

Provide 8mm diameter bars @ 150mm c/c.

2. Go to Define > Section property > Frame section > Section Designer. A Section Designer Section property data dialogue box has been opened. Add the grade of concrete M 35 for jacketing section then click on section designer to design the required concrete jacketing. The designed column concrete jacketing in section designer is shown in figure 3.21.

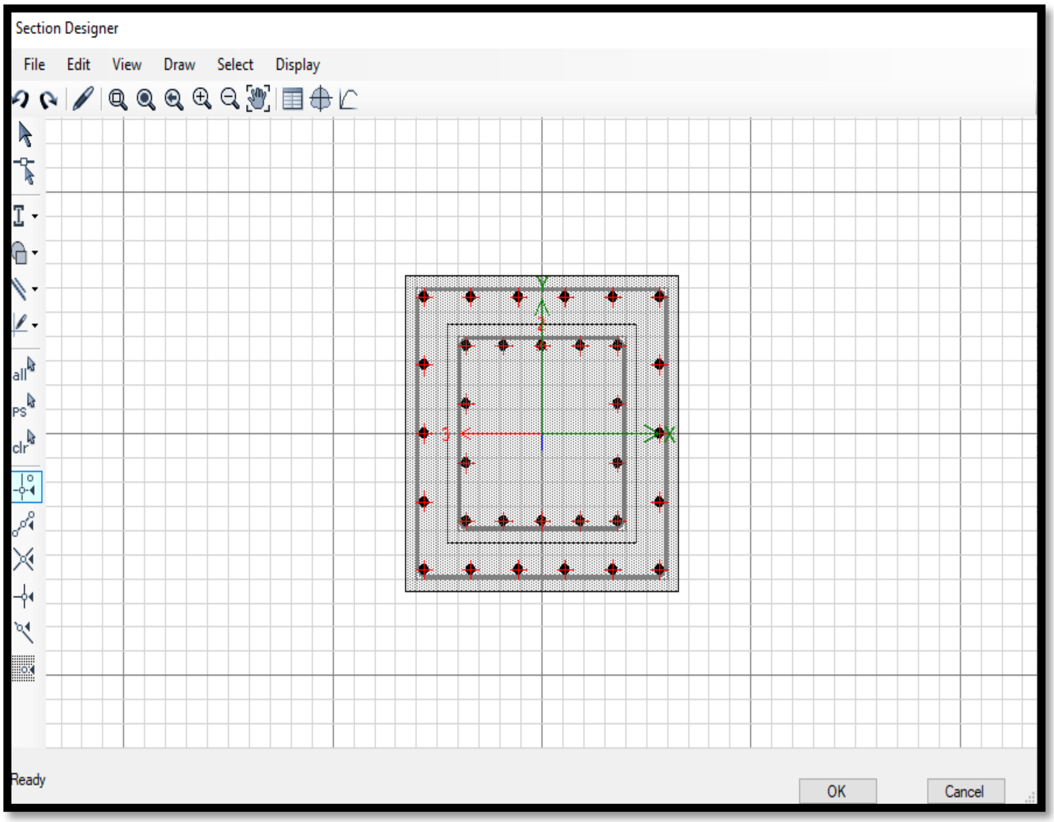


Figure 3.21: Designed concrete column jacketing for G+3 Building

3. The assigned column concrete jacketing is shown in plan view of building as shown in figure 3.22.

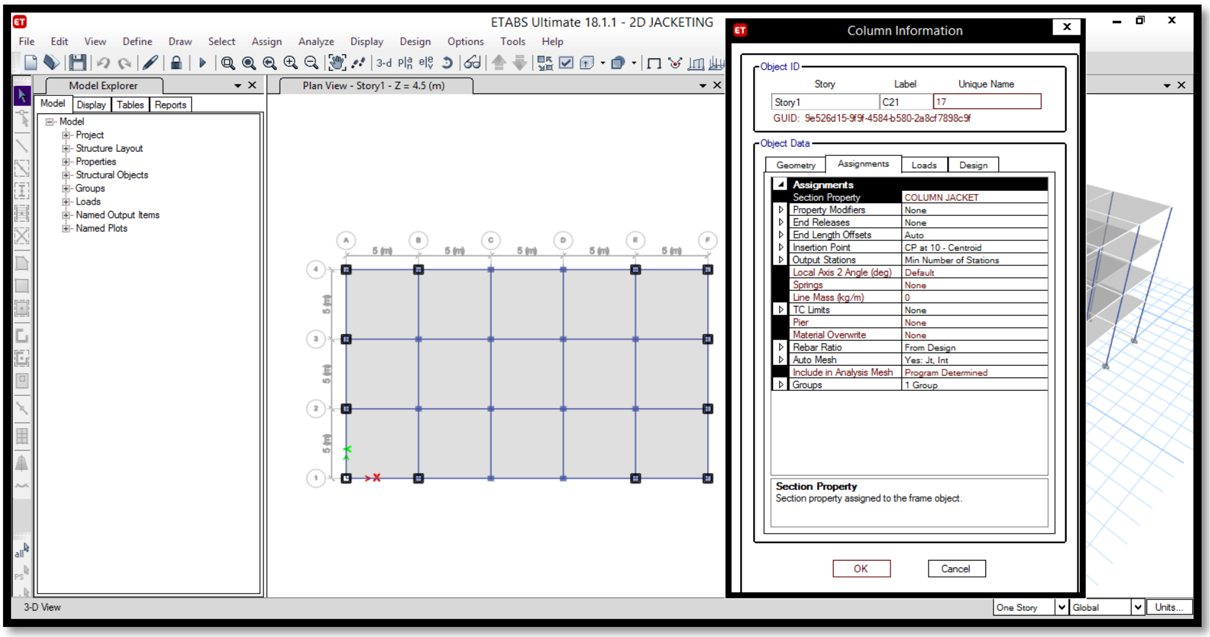


Figure 3.22: G+3 Building with Jacketing

3.6 Modelling, Analysis & Retrofitting of High Rise Building

3.6.1 Details of the High Rise Building

In this project a G+19 Building is modelled and analyzed in software ETABS 2018. The plan of the building is 36 * 36 m. The height of each floor given as 3m and total height of building is 60m.

Table 3.1: Salient features and Geometric data given for modelling of RCC structure

Parameter	Description
Stories	G+19
Structure Type	Framed RCC Building
Wall Masonry	Brick Masonry
Concrete & steel Grade	M30, Fe 415

Table 3.2: Size of Structural members given for RCC Structure

Column sizes	Beam sizes	Slab Thickness
From ground floor to tenth floor: 750mm*900mm. From eleventh floor to twenty one floor: 450 mm * 750 mm.	400 X 600 mm	120

1. The plan and 3D view of building is shown in figure 3.23.

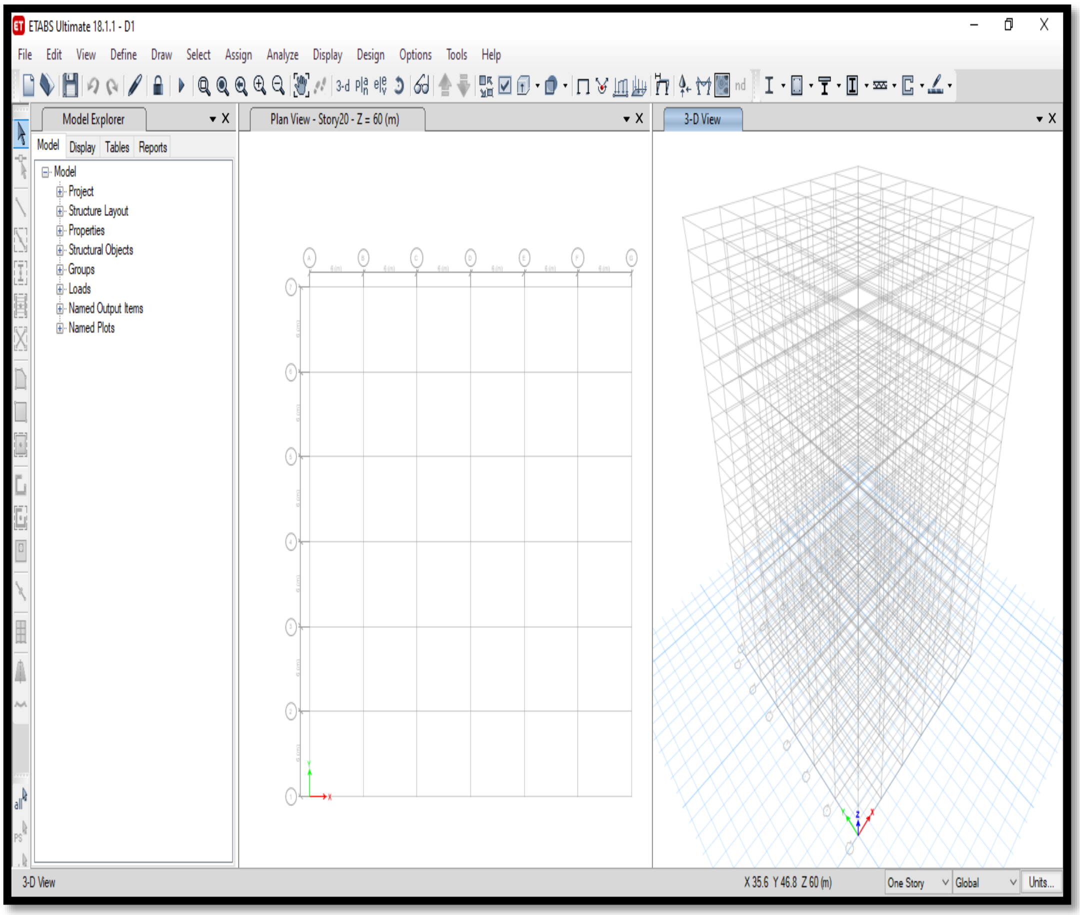


Figure 3.23: Plan and 3D view of building for high rise building

2. Go on Define > material property, add new material property dialogue box is opened. Select grade of concrete as M30, grade of rebar as HYSD 415 and Mild 250 as shown in figure 3.24.

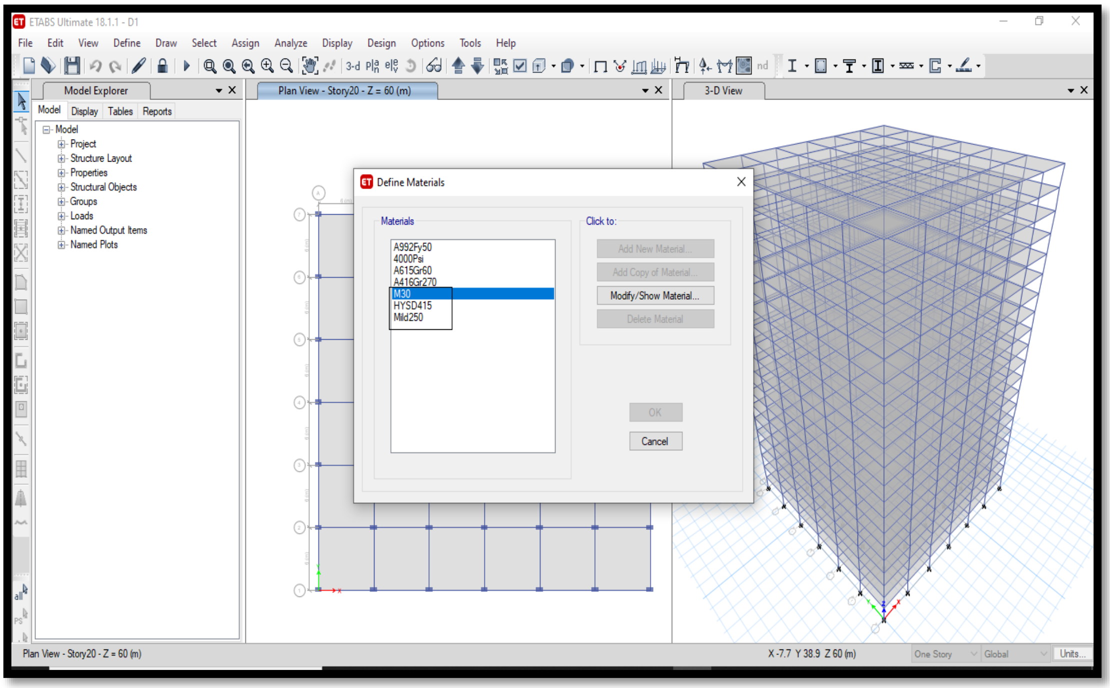


Figure 3.24: Defined material and section property for high rise building

3. Go to Define > Section property > Frame sections and Slab sections. A frame property and slab property dialogue box is opened and by clicking on add new property define the beam size of 400*600mm for all stories, column size of 750*900 mm for story 1 to story 10, column size of 450*750 mm for story 11 to story 20 and slab thickness of 120mm for building as shown in figure 3.25.

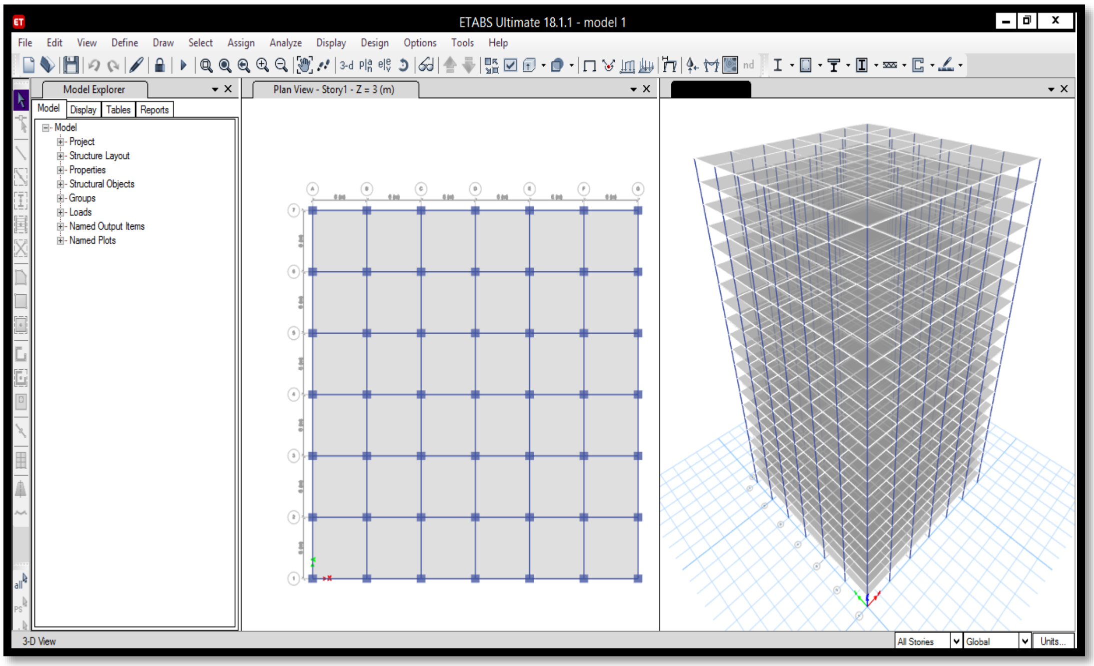


Figure 3.25: Assigned section property for high rise building

4. Go to Define > Load patterns. A define load patterns dialogue box is opened. By clicking on add new load define dead, live, wind and earthquake load as shown in figure 3.26.

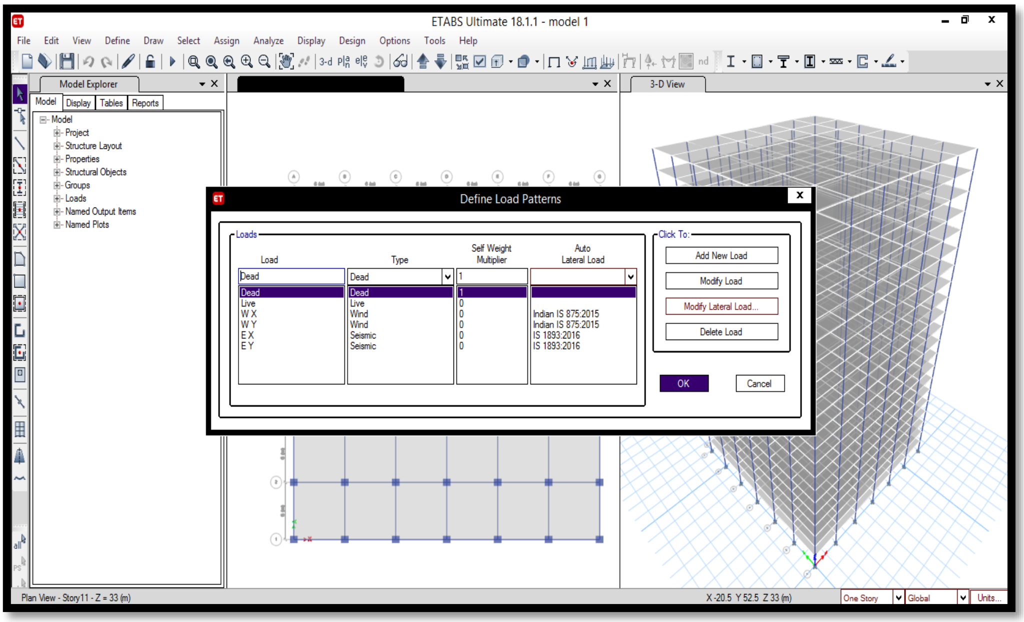


Figure 3.26: Load patterns for high rise building

5. For self-weight addition of 1Kn is done on joints. After applying the self-weight of building the joint loads are shown in figure 3.27.

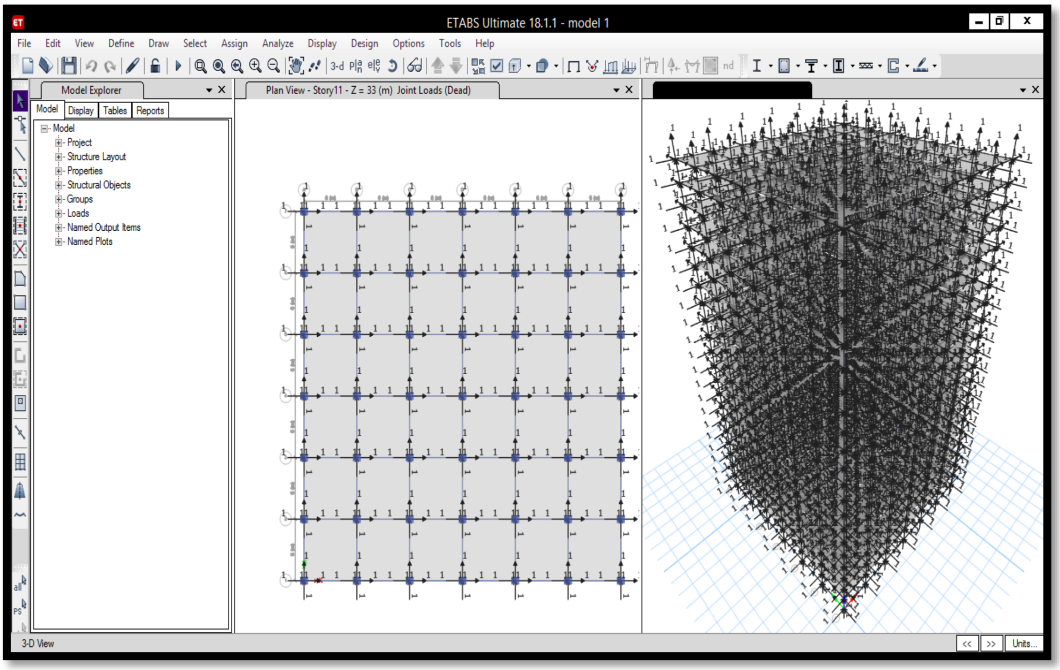


Figure 3.27: Assigned self weight for high rise building

6. The dead load is calculated by multiplying the thickness of slab with density of concrete i.e. 120*25 = 3kn/m2, the Floor finish is 1.5 kN/m2. The load on walls is calculated by

multiplying density of brick masonry with floor height and thickness of wall i.e. 12 kN/m. After assigning dead load on slabs and walls the loads are as shown in figure 3.28, figure 3.29.

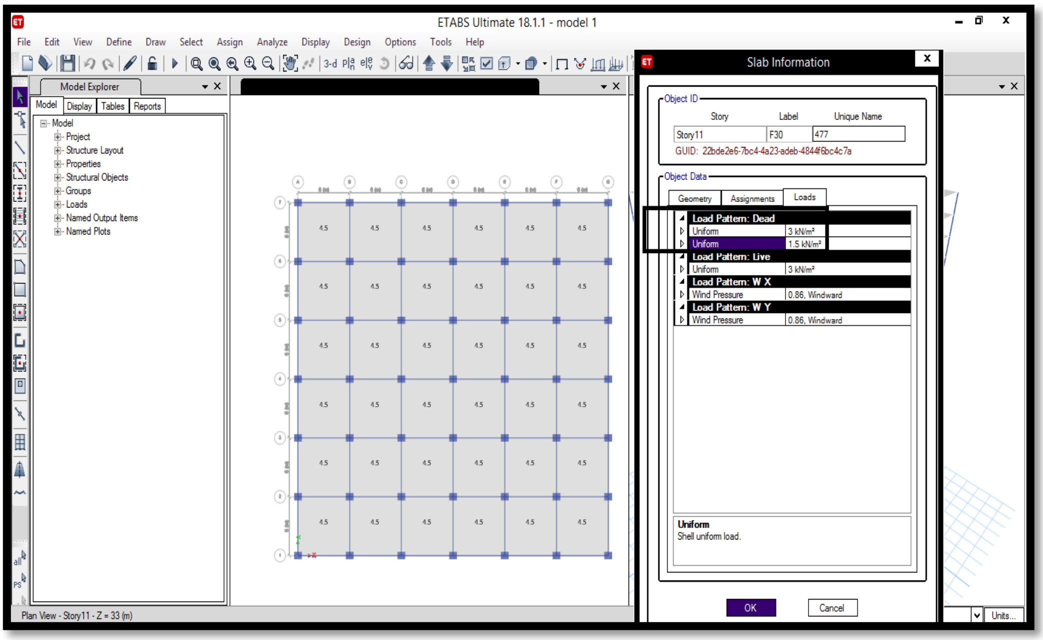


Figure 3.28: Total Dead load assigned on slab for high rise building

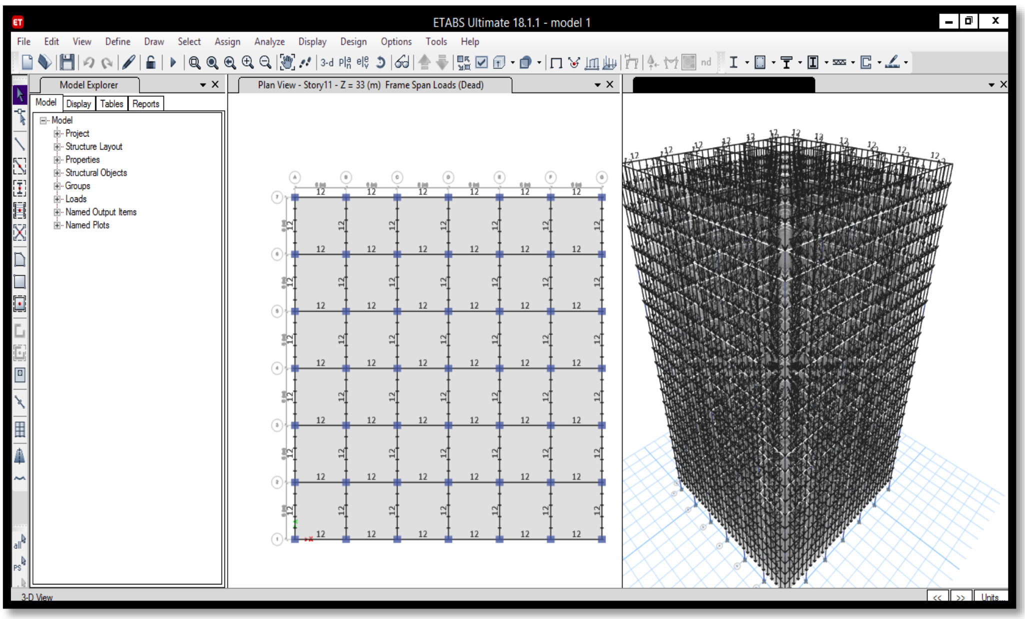


Figure 3.29: Assigned wall load on beams for high rise building

7. Imposed load of 3 Kn/M2 on story 1 to story 14th is 3 Kn/M2 and Live load on 14th floor is 1.5 kN/m2. After assigning live load on slabs for story 1 to story 14 and story 15 to story 20 the assigned loads are as shown in figure 3.30 and figure 3.31.

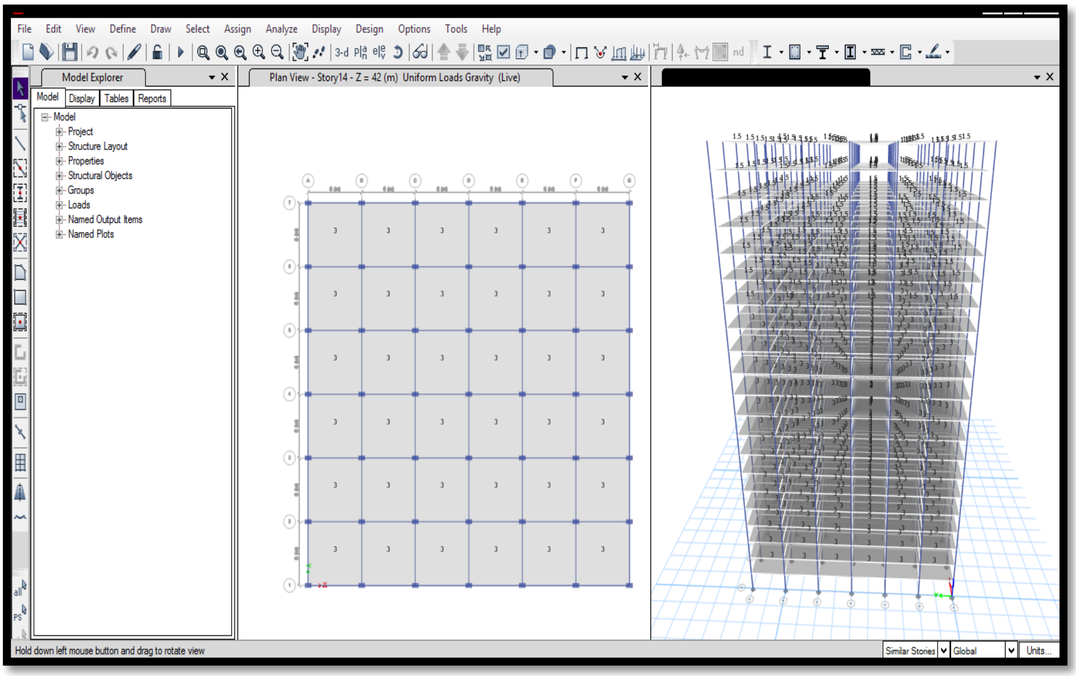


Figure 3.30: Assigned live load for story 1 to story 14 of high rise building

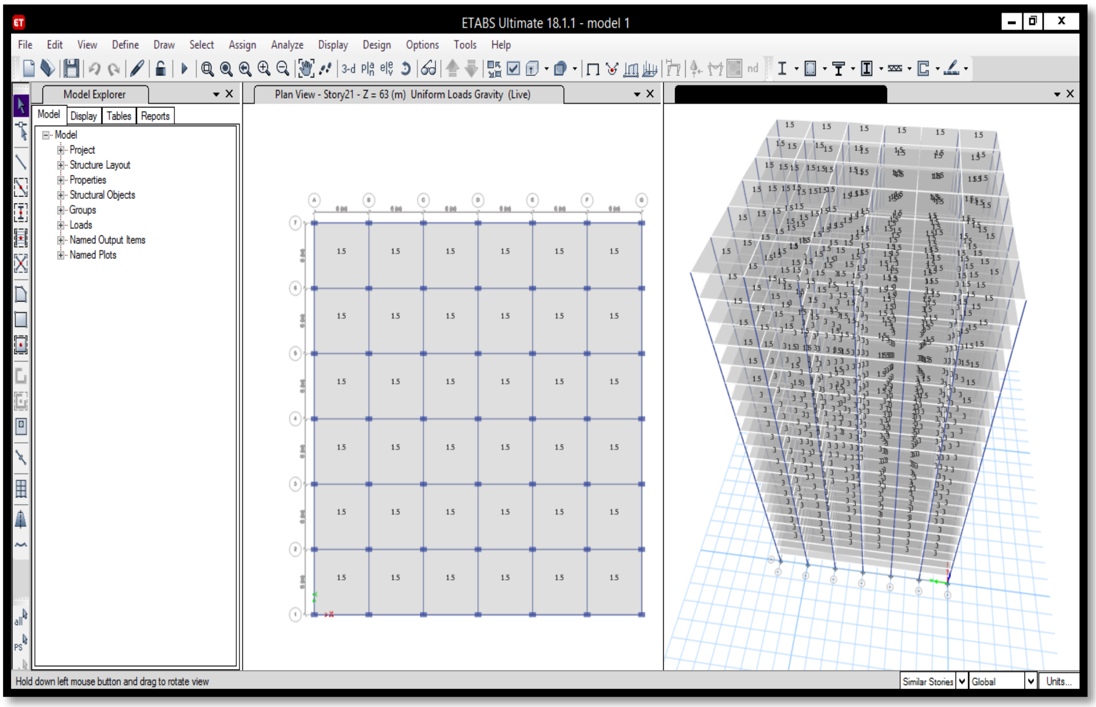


Figure 3.31: Assigned live load for story 15 to story 20 of high rise building

8. The wind speed is given as 44m/sec. For this building the category of terrain is taken as 4. The windward coefficient is taken as 0.8. The class of structure falls under class C having topography of 1. Also the value of risk coefficient is 1. After assigning the wind load in X direction and Y direction the load is shown as shown in figure 3.32 and figure 3.33.

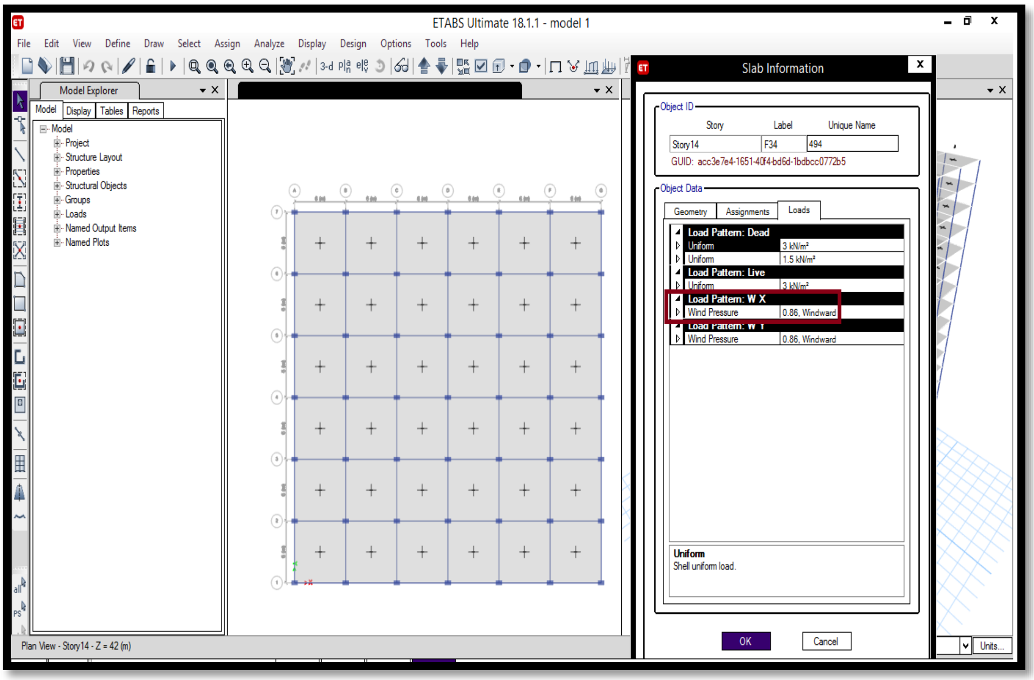


Figure 3.32: Assigned Wind load in X direction for high rise building

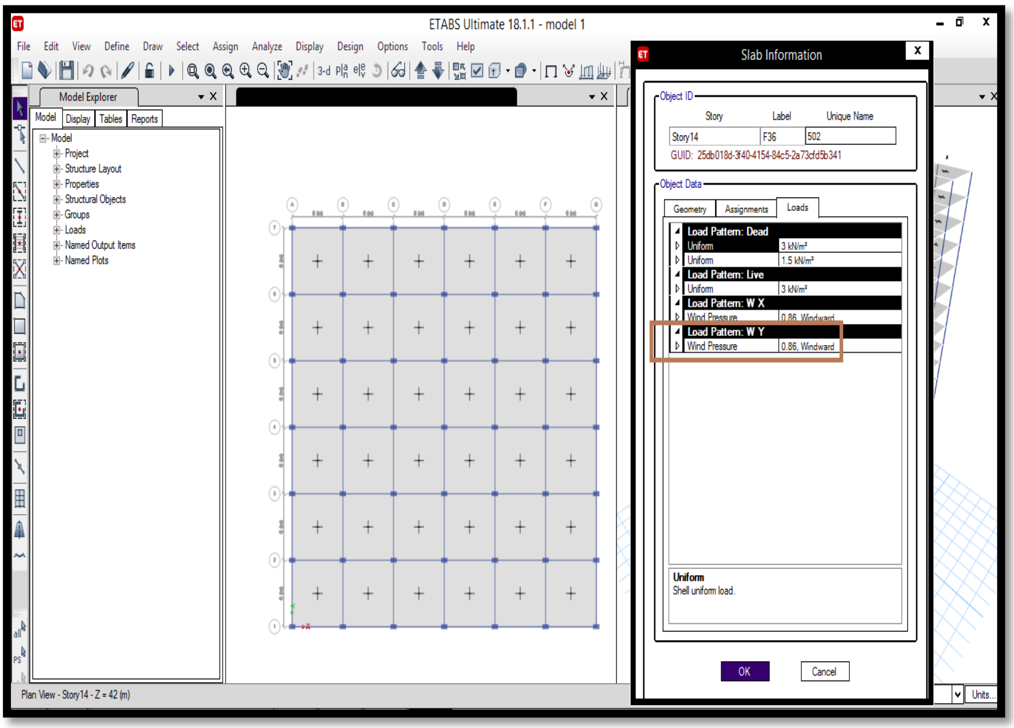


Figure 3.33: Assigned Wind load in Y direction for high rise building

9. For seismic load as shown in figure 3.34 and figure 3.35 in both X and Y direction the building falls in Zone V and as we know for Zone V the value of Z is taken as 0.36, value of R is taken as 5, Value of I is taken as 1. The soil type considered for this building is Soft soil.

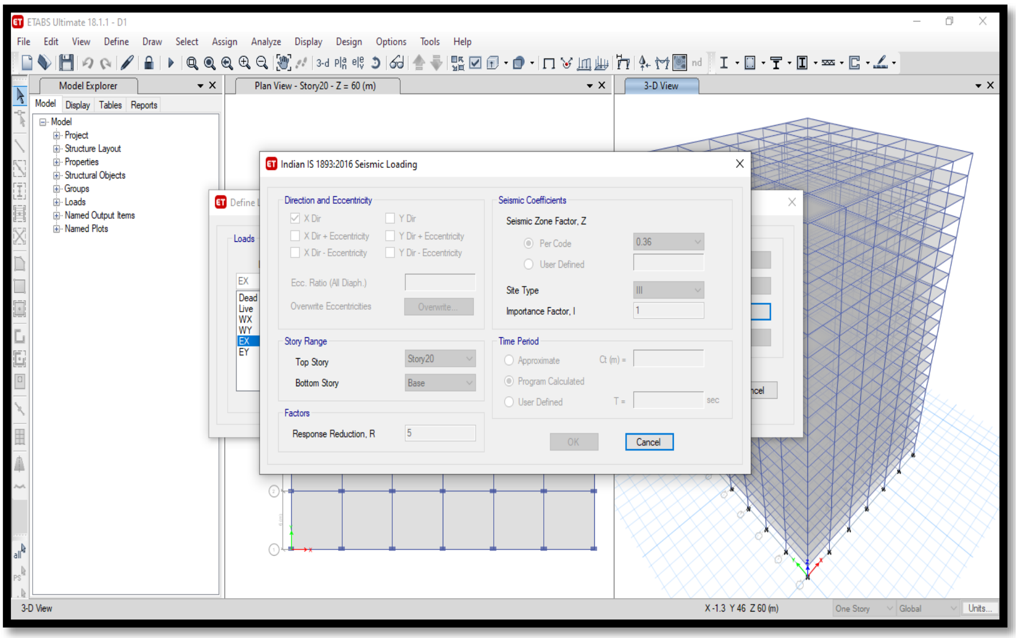


Figure 3.34: Defined seismic load in X direction for high rise building

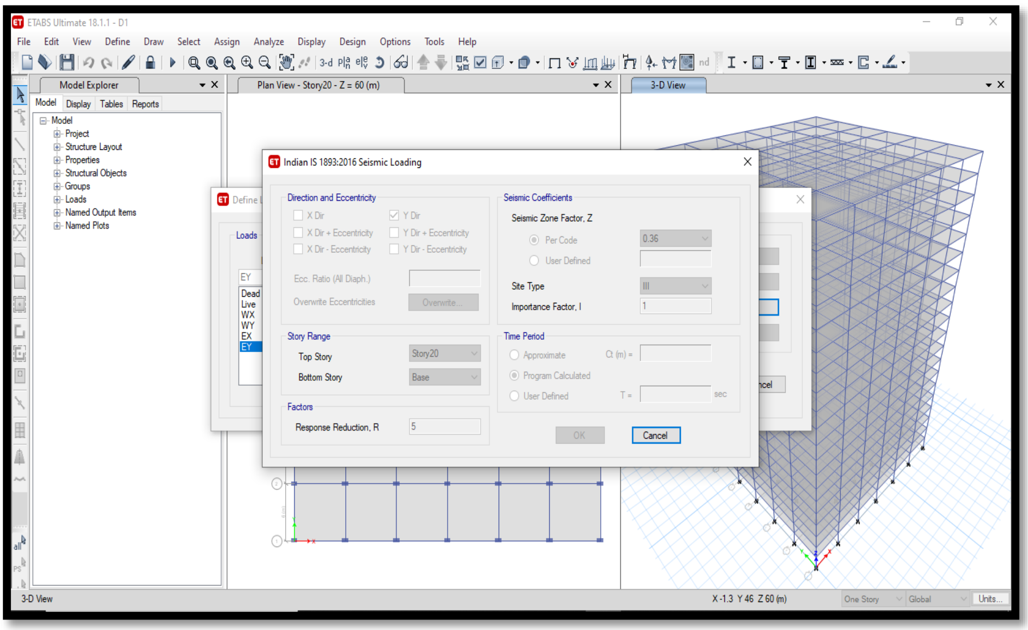


Figure 3.35: Defined seismic load in Y direction for high rise building

3.6.2 Analysis & Design of the High Rise Building

1. A mass source data for specified load patterns. Add mass multiplier as 1 and 0.25 for dead and live load. Go to Define > Function > Response spectrum. A define response spectrum dialogue box is opened. Here choose function type as IS 1893:2016. Firstly we have to

define load case of response spectrum. A Load case data dialogue box is opened. Enter the load applied data as acceleration loading type in UX and UY direction having response spectrum function which is having scale factor of 1633.5 as shown in figure 3.36. This scale factor is calculated by using formula i.e. S = (Ig/2R) = (1*9801/2*5) = 980.1

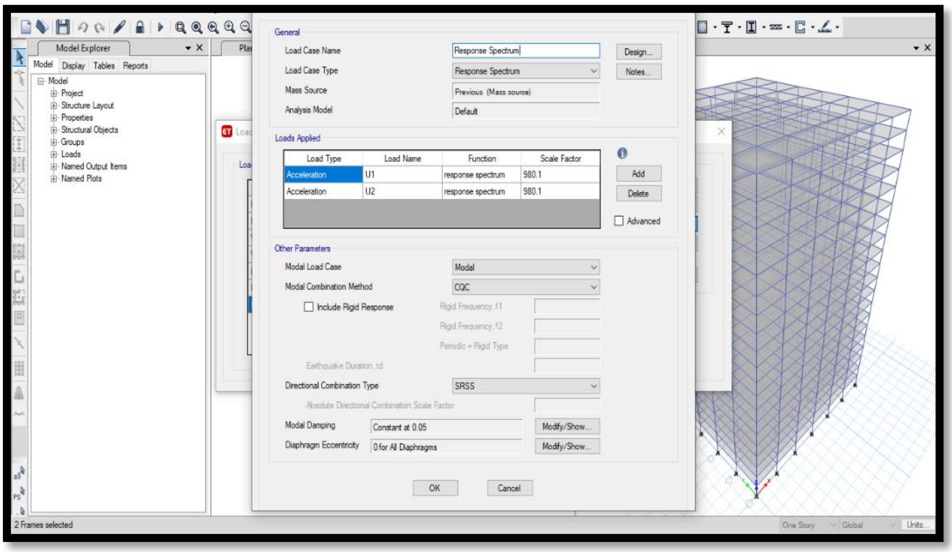


Figure 3.36: Response spectrum load case data for high rise building

2. After analyzing the model we have to design it. For designing unlock the model. Click on concrete frame design icon in toolbar, designing of structure starts. After designing gets completed click on drop down menu of concrete frame design icon and here go to verify all members passed. In this model all members passed the design check is shown in figure 3.37.

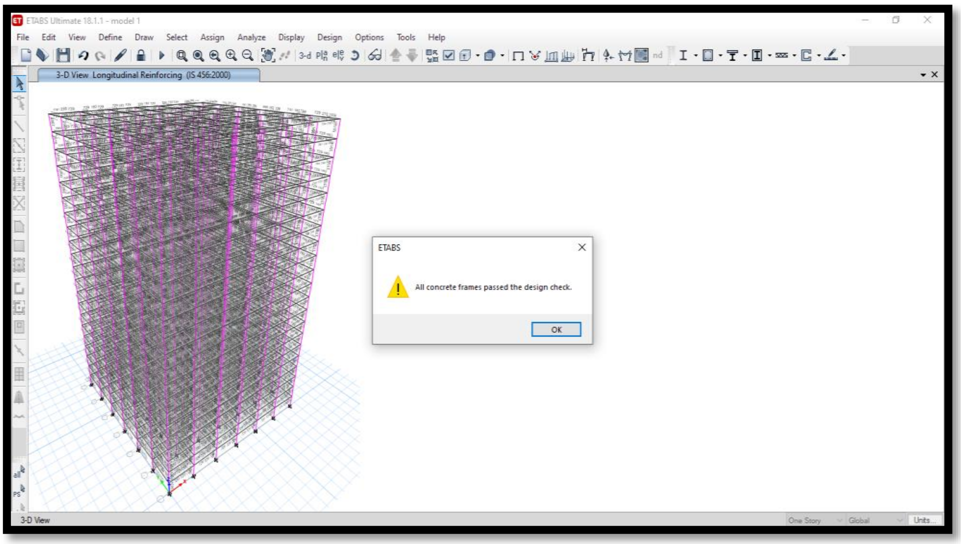


Figure 3.37: Analysis and Design of high rise building

3.6.3 Pushover Analysis of the High Rise Building

Before applying pushover load cases we have to make dead load as non - linear static load. Go to Define > load case > add new load case. A Load case data dialogue box is opened. Define the various parameters for push X and Push Y. Modify the load application to displacement control and add monitored displacement as 2400 mm which is 4%H i.e. 0.04*60 = 2.4 m. Select all beams and columns > assign > frames > hinges. Assign the frame hinges and select auto hinge type as 0.1 and 0.9 from table ASCE 41-13, hinge table as table 10-7 concrete beams-flexure and concrete column for case combo pa-x and pa-y. After analyzing pushover load cases the hinge formations in both X and Y direction are shown in figure 3.38 and figure 3.39.

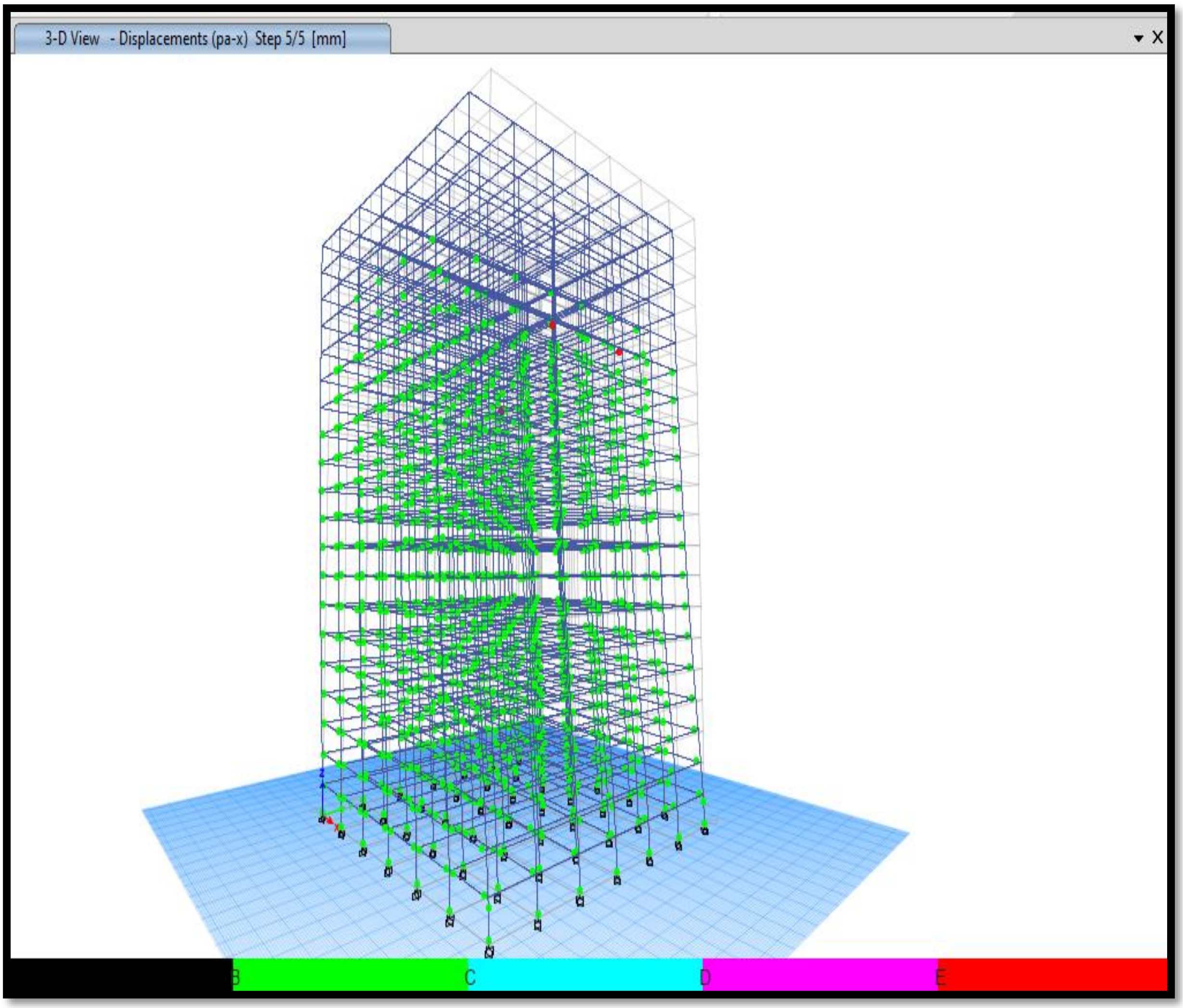


Figure 3.38: Hinge formations in X direction for high rise building

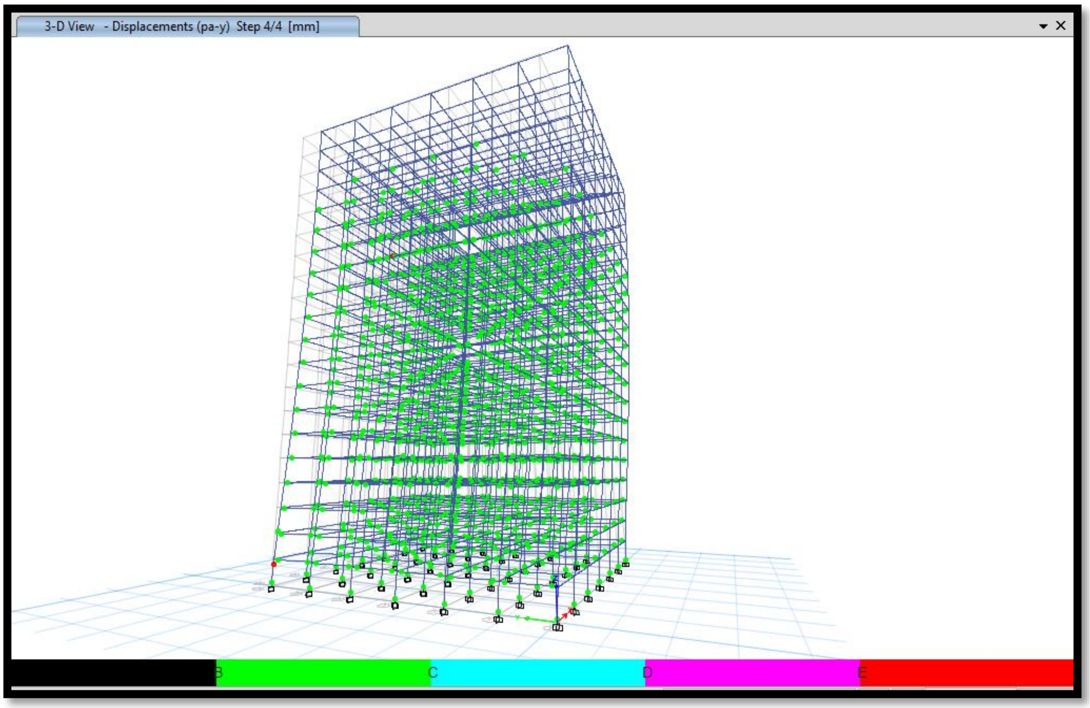


Figure 3.39: Hinge formation in Y direction for high rise building

3.6.4 Seismic Retrofitting Of High Rise Building

Firstly stiffness of building is modified for retrofitting. A Frame assignment – property modifiers dialogue box is opened. Change the value of Moment of inertia about 2 axis and 3 axis as 0.7 for columns as shown in figure 3.40 (as per IS stiffness modifier for beam is 0.35 and slab is 0.25).

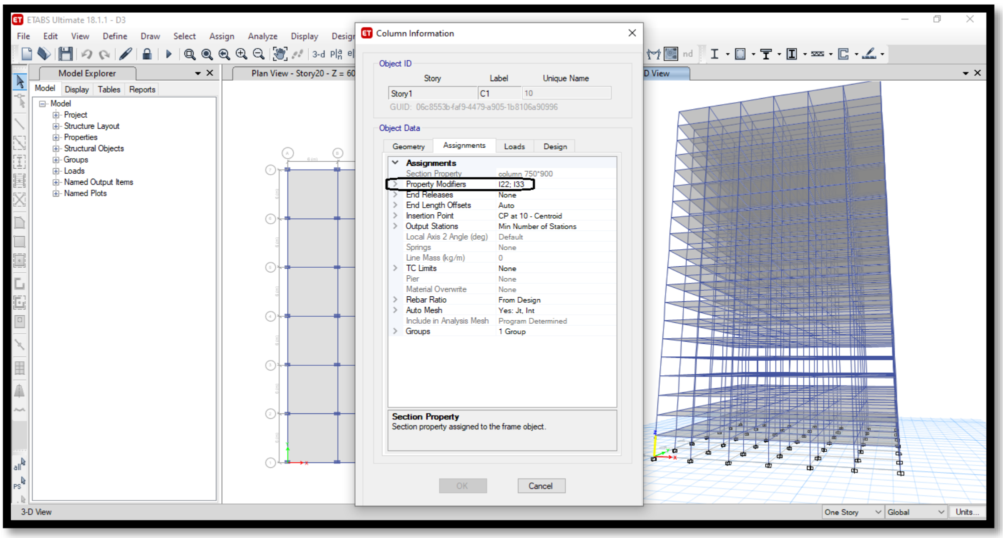


Figure 3.40: Assigned stiffness modifiers for high rise building

3.6.4.1 Seismic Retrofitting of High Rise Building with Bracing

1. Go to Define > frame sections > Add new property > Auto select. A Dialogue box is opened. Add material as Fe 250 for bracing section. Select the imported properties and add them into auto select list. Click on quick draw braces cursor. The drawn braces in 3D view is shown in figure 3.41.

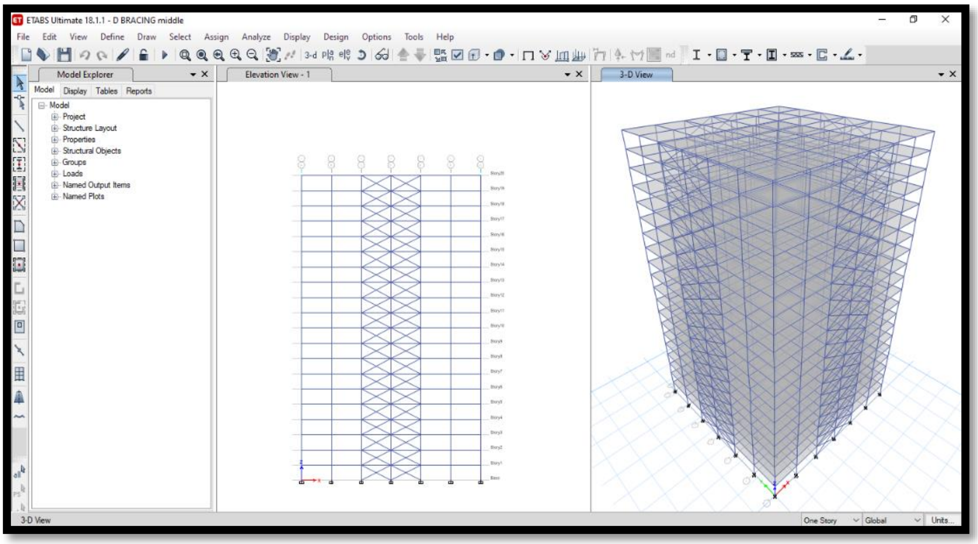


Figure 3.41: High rise building with Bracings

2. From the brace information dialogue box it is concluded that section property ISMB 175 is used as appropriate section property for bracing by ETABS for high rise building as shown in figure 3.42.

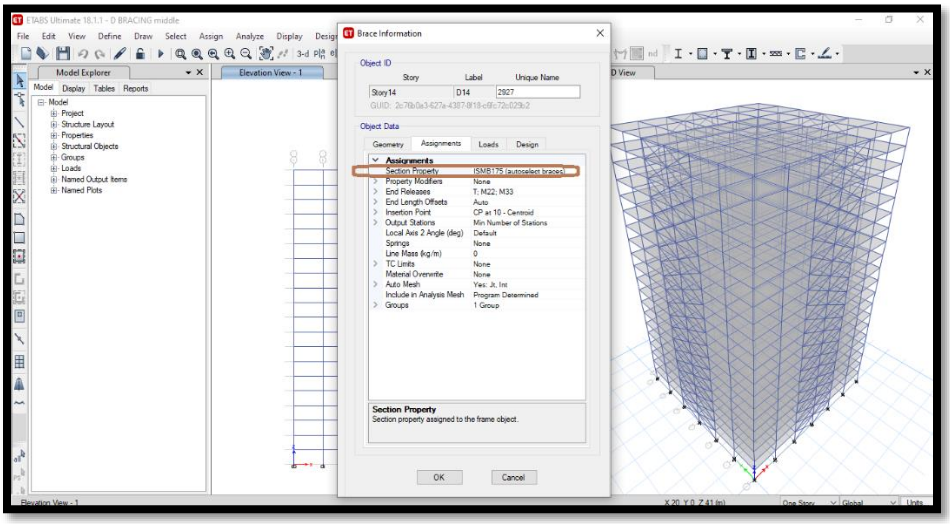


Figure 3.42: Brace information for high rise building

3.6.4.2 Seismic Retrofitting of high rise building with Dampers

Go to Define > Section property > Link / Support property. A link property data dialogue box has been opened. Add the link property FVD 500 and link type as Damper-exponential. Click on quick draw links cursor. The drawn links in 3D view is shown in figure 3.43.

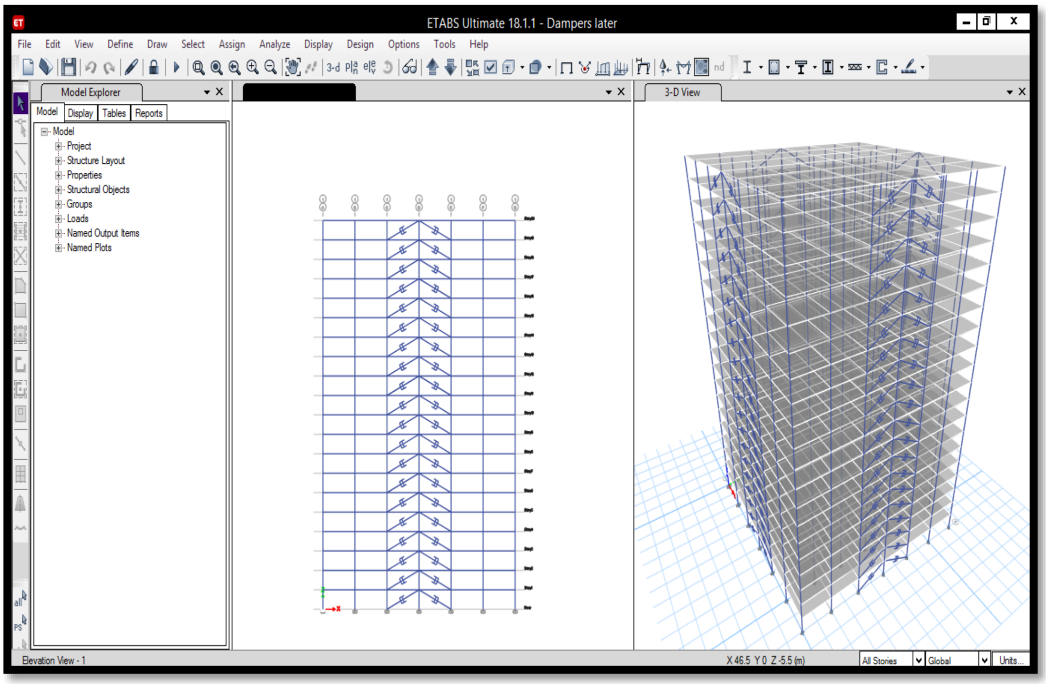


Figure 3.43: High rise building with dampers

CHAPTER 4

ANALYTICAL RESULTS

4.1 Story Response plot results for G+3 Building

4.1.1 Story Displacement for G+3 Building

1. The maximum story displacement for G+3 Building having seismic load in X direction comes out to be 27.367 mm for RC structure, 24.925 mm for RC Building with jacketing and 17.554 mm for RC Building with bracing as shown in figure 4.1 at top story in soft soil condition at zone V.

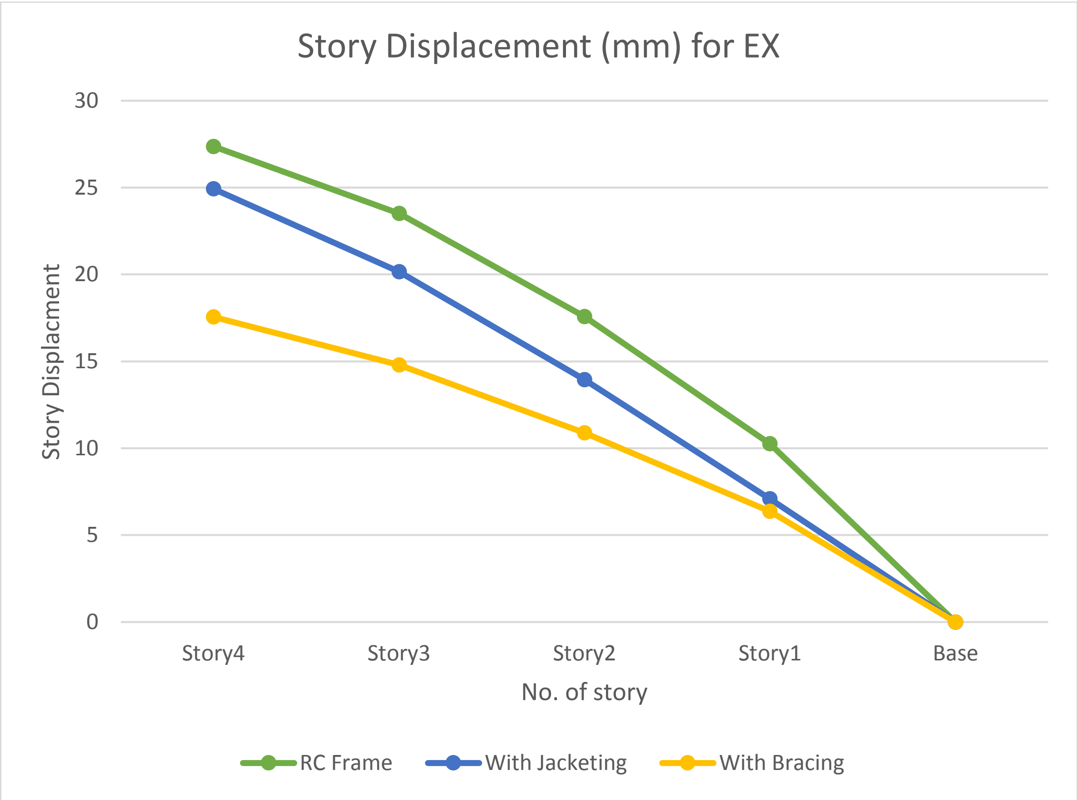


Figure 4.1: Story displacement in X direction for G+3 Building

2. The maximum story displacement for G+3 Building having seismic load in Y direction comes out to be 29.34 mm for RC structure, 25.997 mm for RC Building with jacketing and 18.531 mm for RC Building with bracing as shown in figure 4.2 at top story in soft soil condition at zone V.

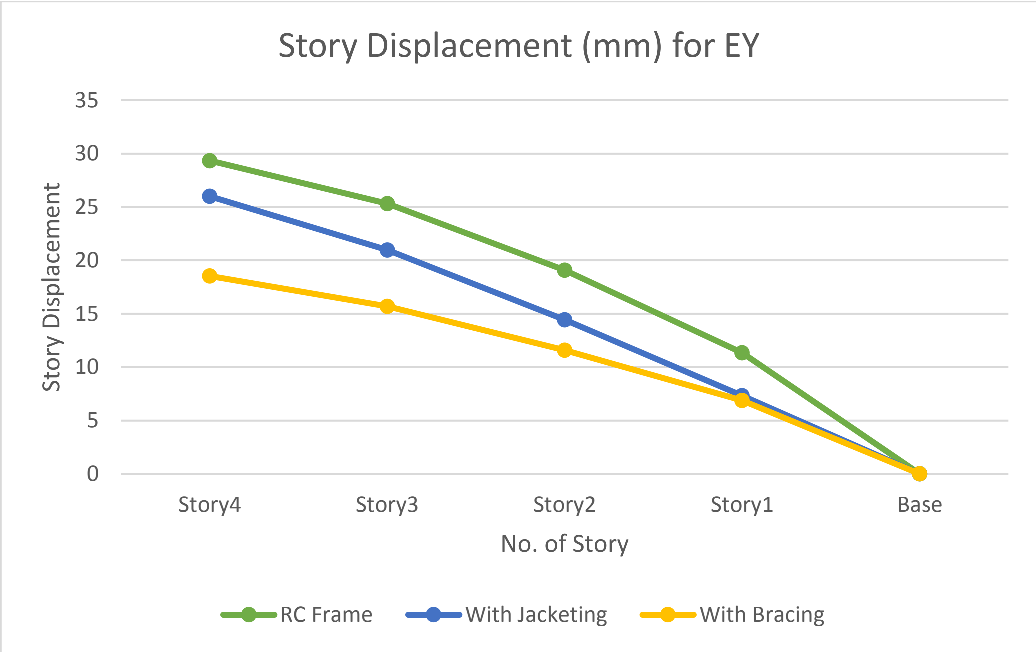


Figure 4.2: Story displacement in Y direction for G+3 Building

4.1.2 Story Drift for G+3 Building

1. The maximum story drift for G+3 Building having seismic load in X direction comes out to be 0.00244 for RC structure, 0.002301 for RC Building with jacketing and 0.001506 for RC Building with bracing as shown in figure 4.3 at story 2 in soft soil condition at zone V.

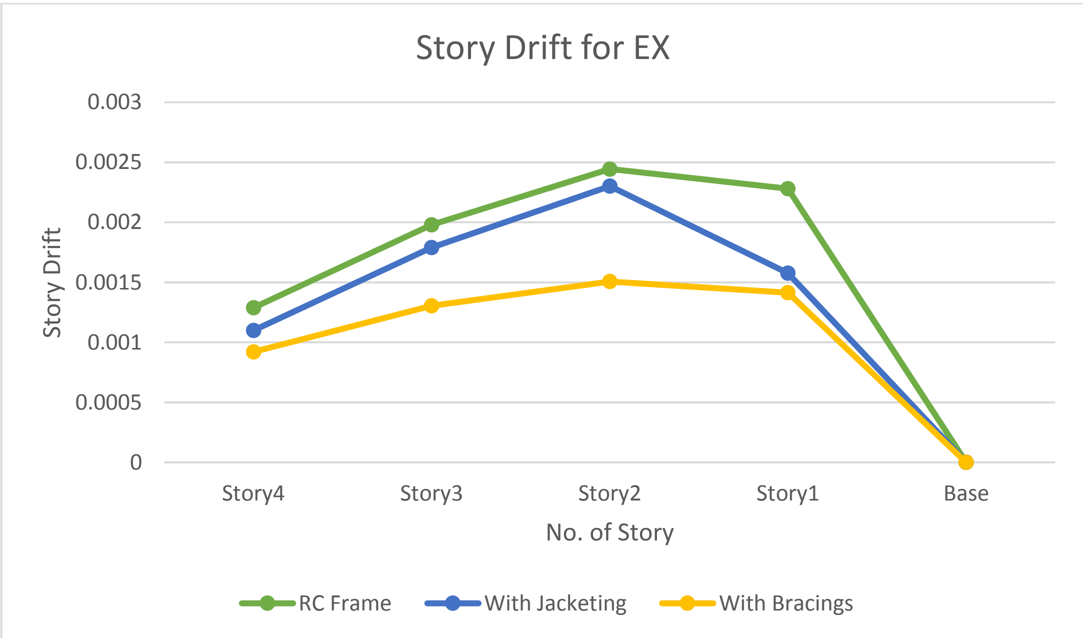


Figure 4.3: Story drift in X direction for G+3 Building

2. The maximum story drift for G+3 Building having seismic load in Y direction comes out to be 0.002583 for RC structure, 0.002397 for RC Building with jacketing and 0.001576 for RC Building with bracing as shown in figure 4.4 at story 2 in soft soil condition at zone V.

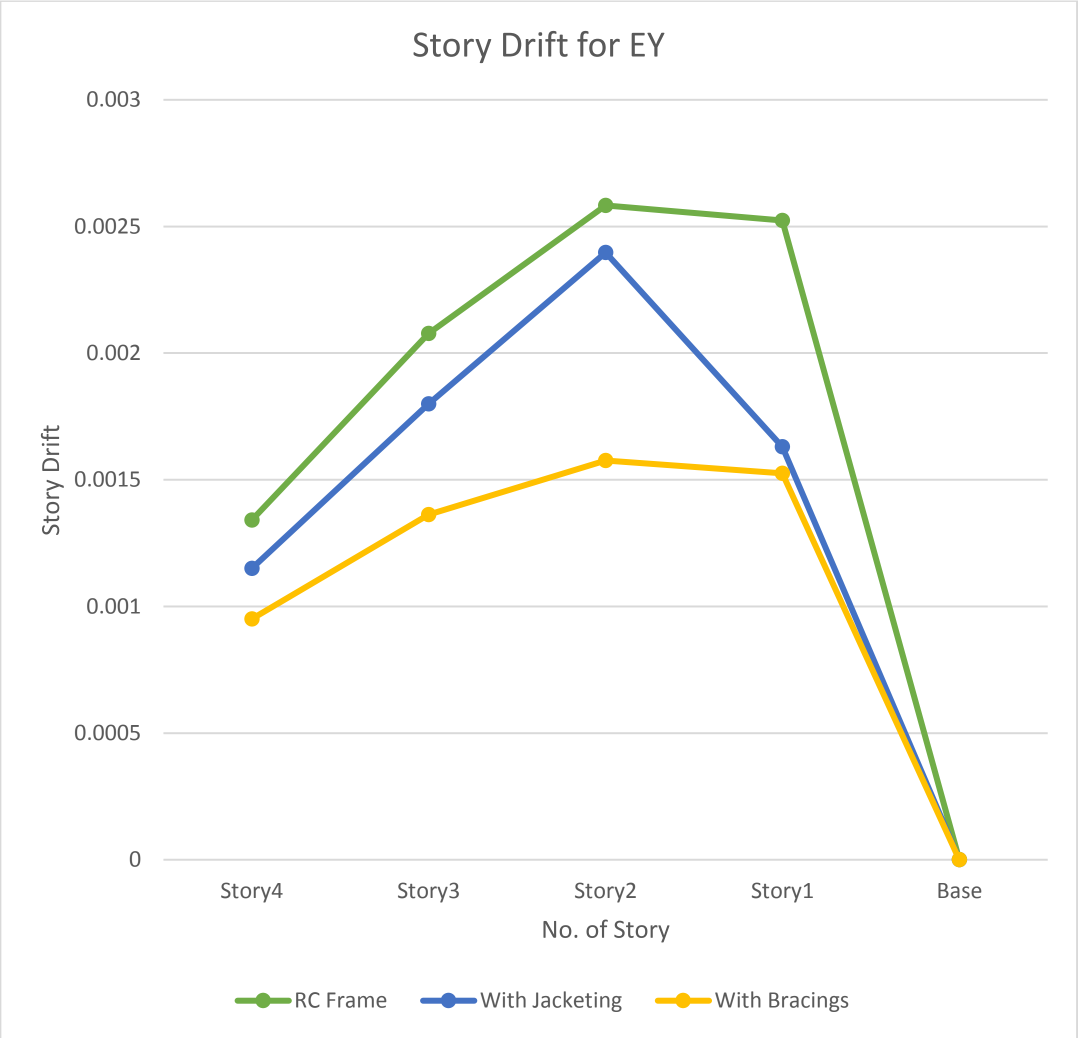


Figure 4.4: Story drift in Y direction for G+3 Building

4.1.3 Story Shear for G+3 Building

1. The maximum story shear for G+3 Building having seismic load in X direction comes out to be 1318.7628 kN for RC structure, 1618.6545 kN for RC Building with jacketing and 2150.6488 kN for RC Building with bracing in negative side as shown in figure 4.5 at bottom story (story 1) in soft soil condition at zone V.

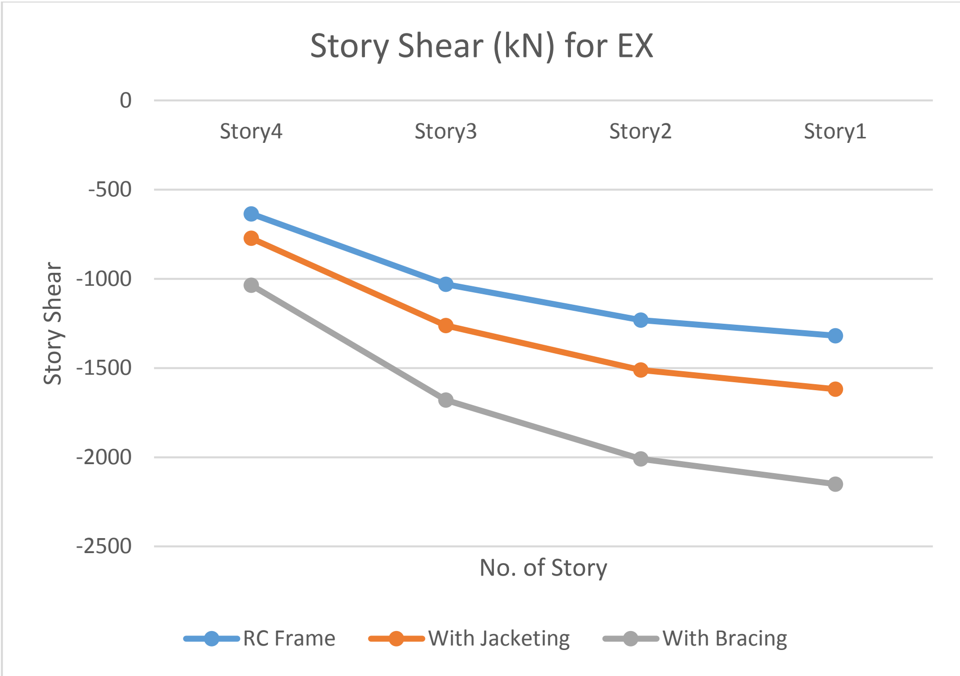


Figure 4.5: Story Shear in X direction for G+3 Building

2. The maximum story shear for G+3 Building having seismic load in X direction comes out to be 1218.6646 kN for RC structure, 1558.3668 kN for RC Building with jacketing and 2084.0257 kN for RC Building with bracing in negative side as shown in figure 4.6 at bottom story (story 1) in soft soil condition at zone V.

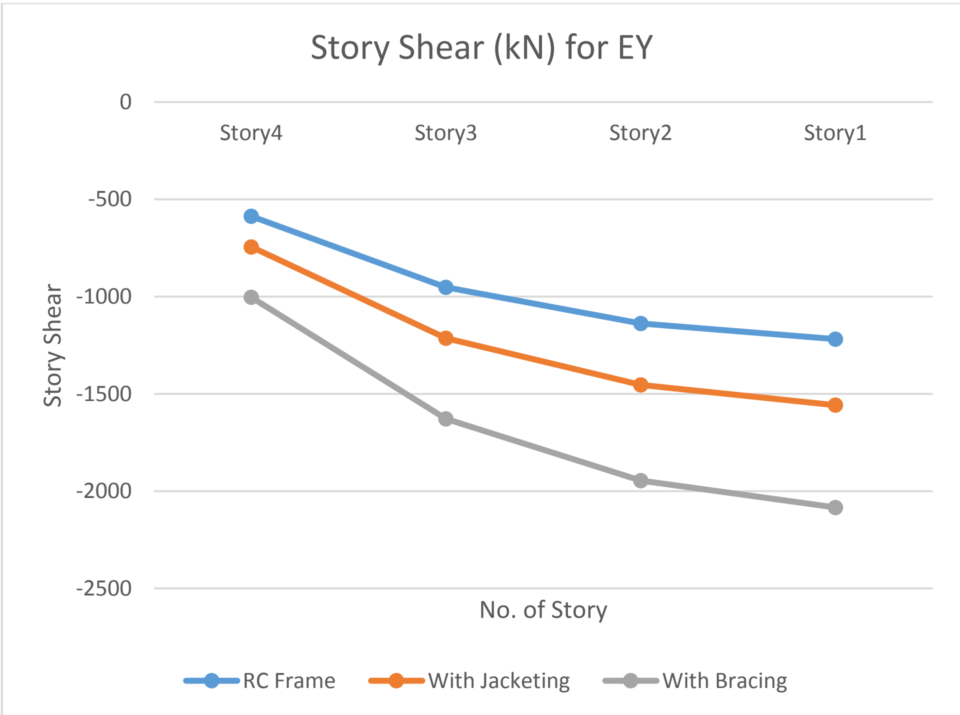


Figure 4.6: Story Shear in Y direction for G+3 Building

4.1.4 Story Stiffness for G+3 Building

1. The maximum story stiffness for G+3 Building having seismic load in X direction comes out to be 168301.095 kN/m for RC structure, 219757.225 kN/m for RC Building with jacketing and 458766.533 kN/m for RC Building with bracing as shown in figure 4.7 at story 2 in soft soil condition at zone V.

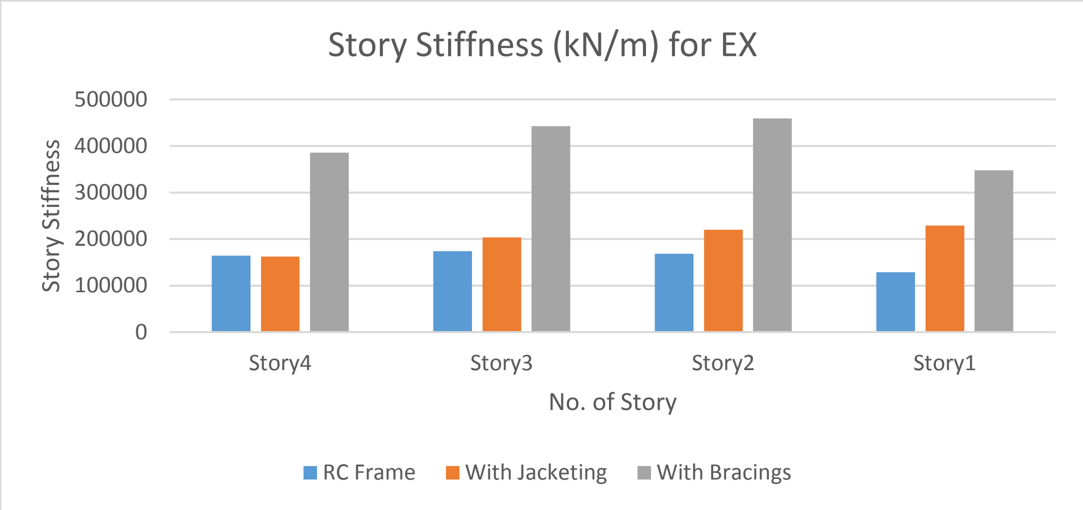


Figure 4.7: Story Stiffness in X direction for G+3 Building

2. The maximum story stiffness for G+3 Building having seismic load in Y direction comes out to be 147122.097 kN/m for RC structure, 203699.192 kN/m for RC Building with jacketing and 439907.995 kN/m for RC Building with bracing as shown in figure 4.8 at story 2 in soft soil condition at zone V.

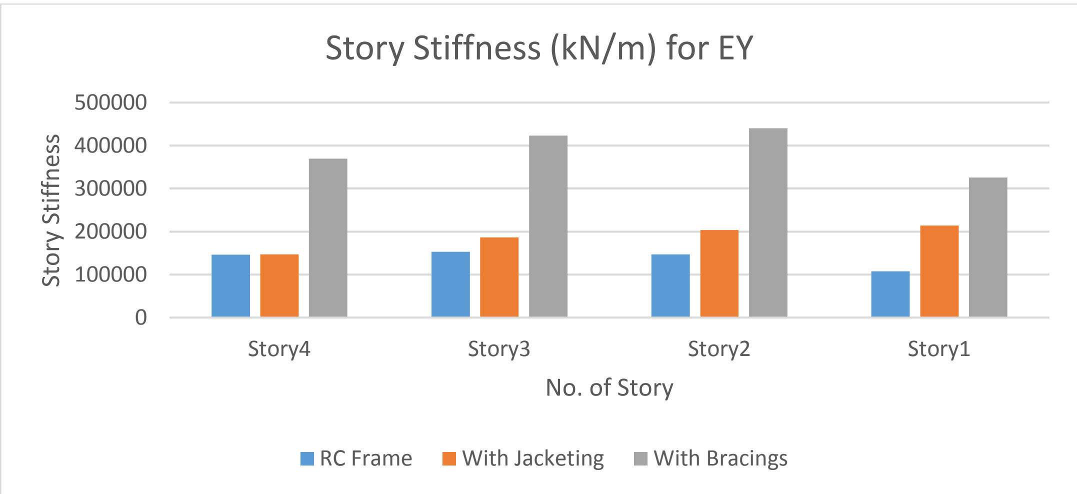


Figure 4.8: Story Stiffness in Y direction for G+3 Building

4.2 Story Response plot results for High Rise Building

4.2.1 Story Displacement for High rise Building

1. The maximum story displacement for high rise Building having seismic load in X direction comes out to be 82.047 mm for RC structure, 70.13 mm for RC Building with dampers and 74.584 mm for RC Building with bracing as shown in figure 4.9 at top story in soft soil condition at zone V.

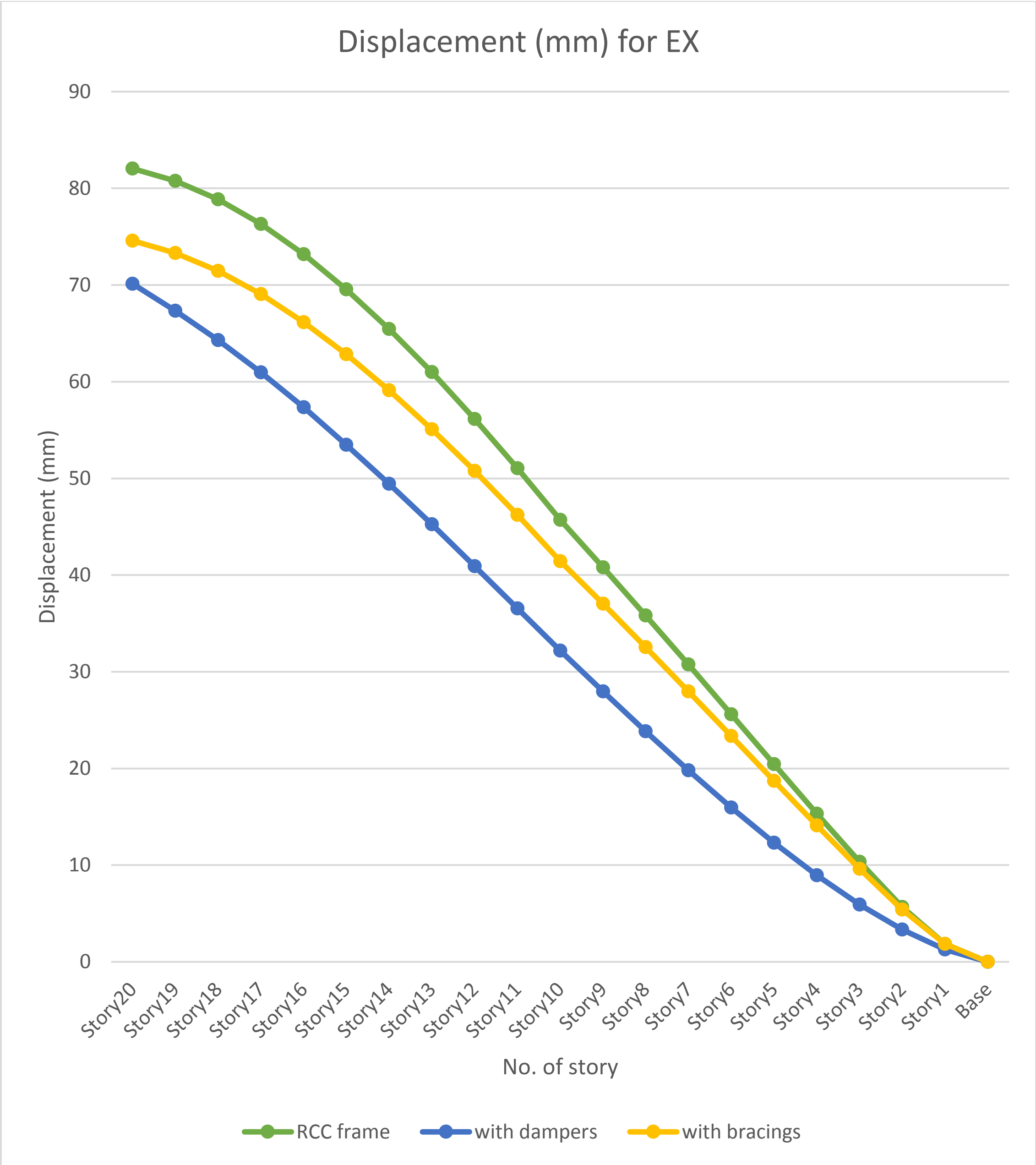


Figure 4.9: Story Displacement in X direction for High rise Building

2. The maximum story displacement for High rise Building having seismic load in Y direction comes out to be 89.674 mm for RC structure, 74.372 mm for RC Building with jacketing and 80.047 mm for RC Building with bracing as shown in figure 4.10 at top story in soft soil condition at zone V.

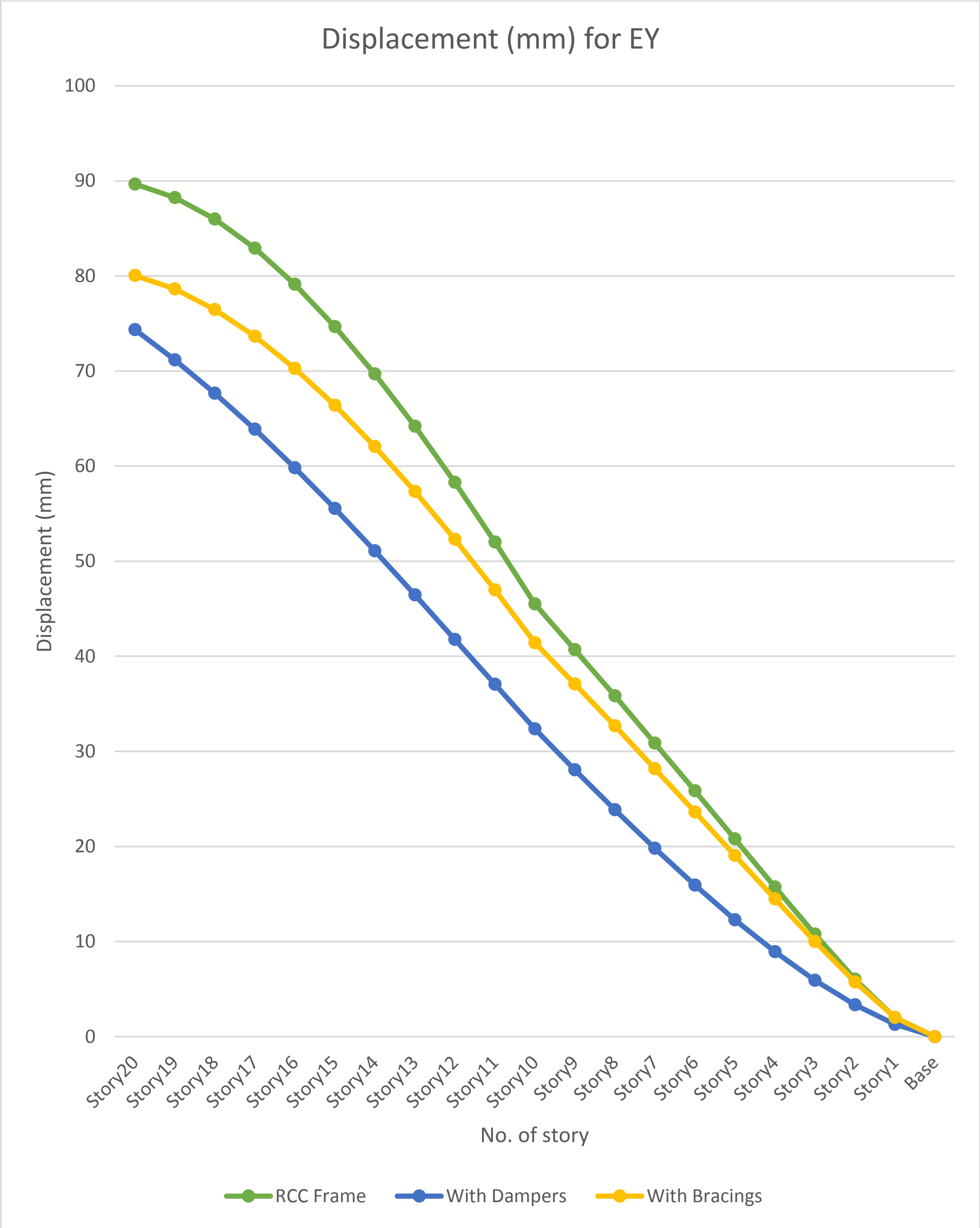


Figure 4.10: Story Displacement in Y direction for High rise Building

4.2.2 Story Drift for High rise Building

1. The maximum story drift for High rise Building having seismic load in X direction comes out to be 0.001788 for RC structure, 0.001501 for RC Building with dampers and 0.001597 for RC Building with bracing as shown in figure 4.11 at story 11 in soft soil condition at zone V.

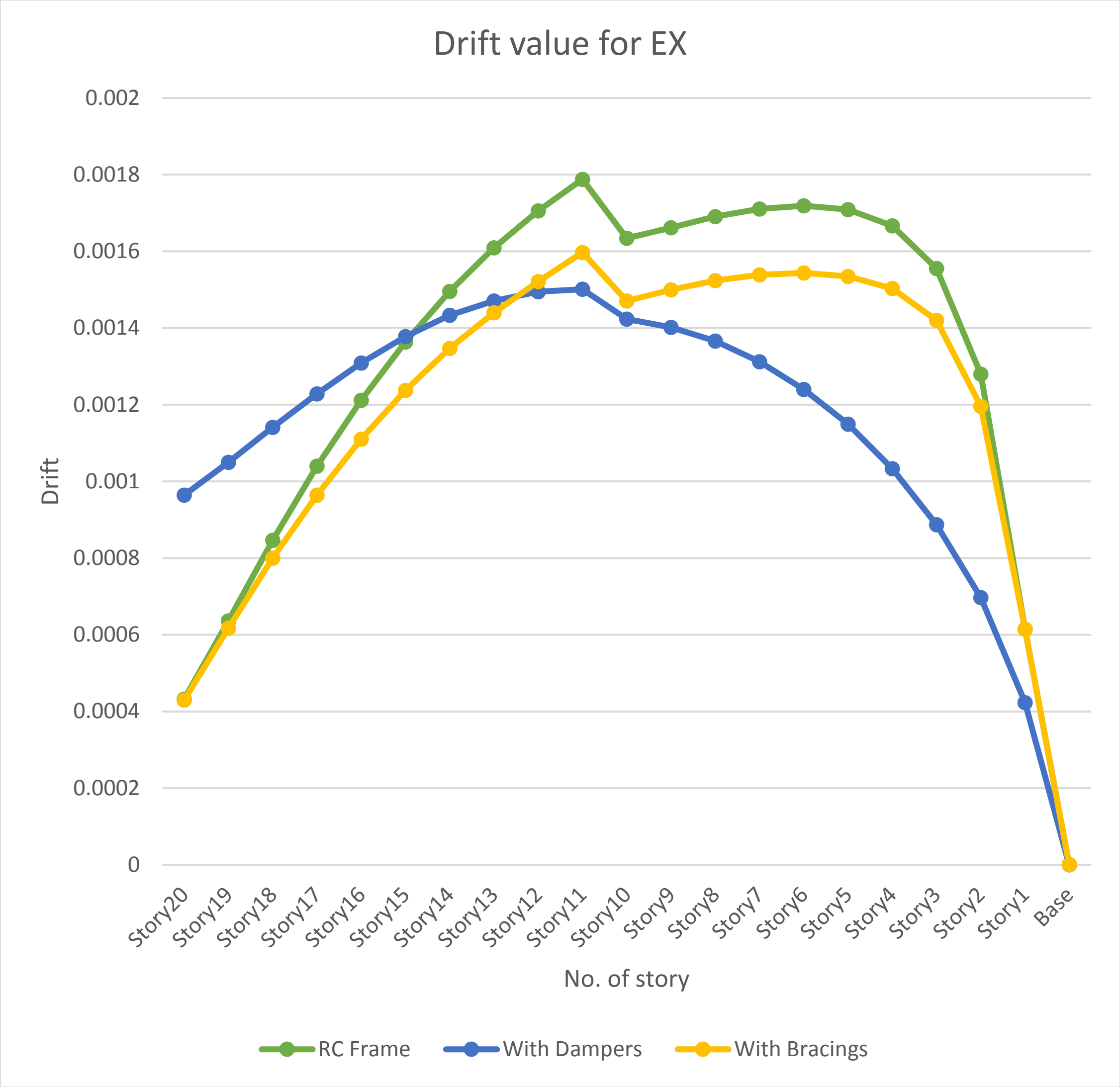


Figure 4.11: Story Drift in X direction for High rise Building

2. The maximum story drift for High rise Building having seismic load in Y direction comes out to be 0.002184 for RC structure, 0.001646 for RC Building with dampers and 0.001879 for RC Building with bracing as shown in figure 4.12 at story 11 in soft soil condition at zone V.

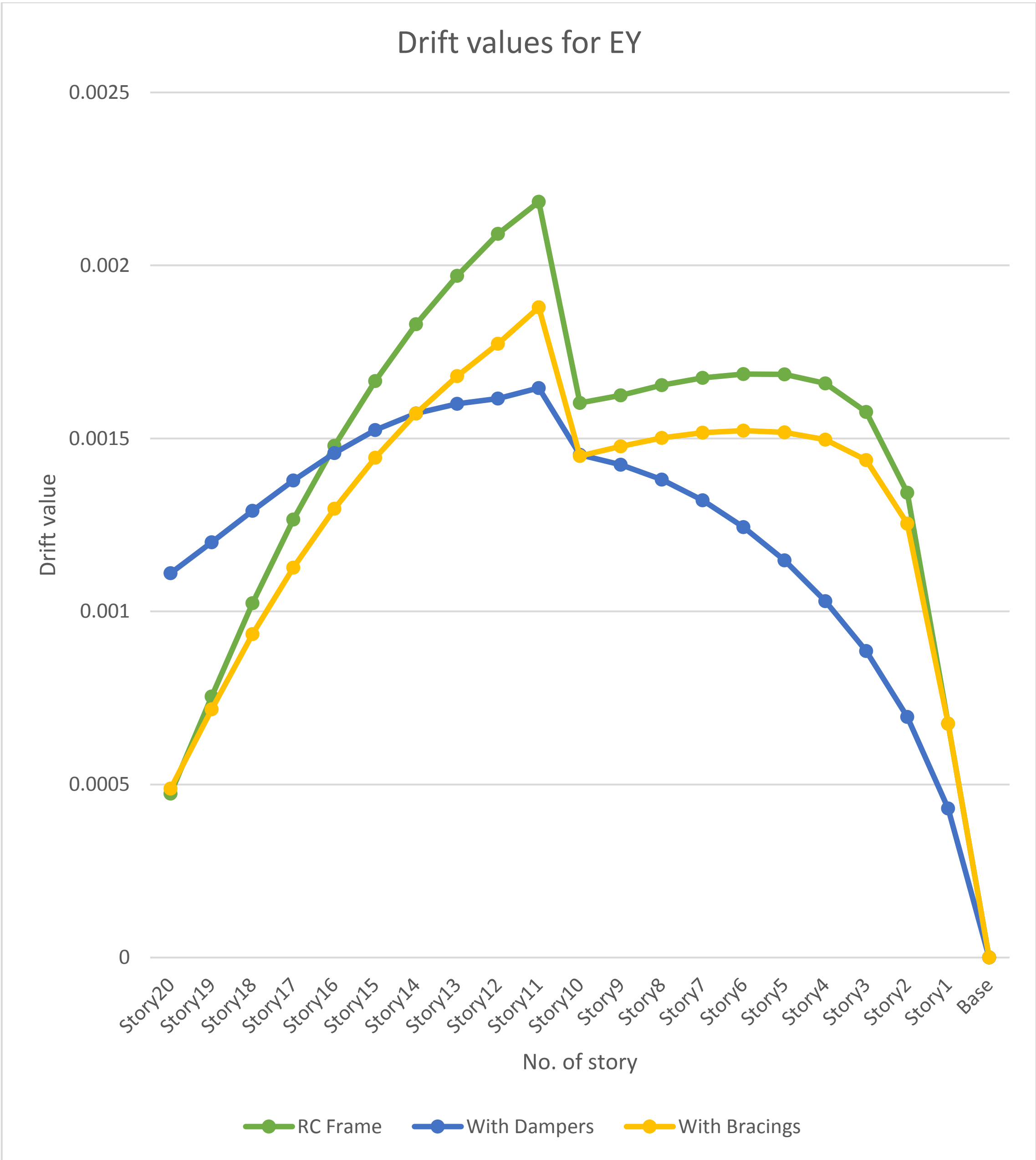


Figure 4.12: Story Drift in Y direction for High rise Building

4.2.3 Story Stiffness for High rise Building

1. The maximum story stiffness for High rise Building having seismic load in X direction comes out to be 4994077.511 kN/m for RC structure, 7001940.944 kN/m for RC Building with jacketing and 5620396.17 kN/m for RC Building with bracing as shown in figure 4.13 at story 1 in soft soil condition at zone V.

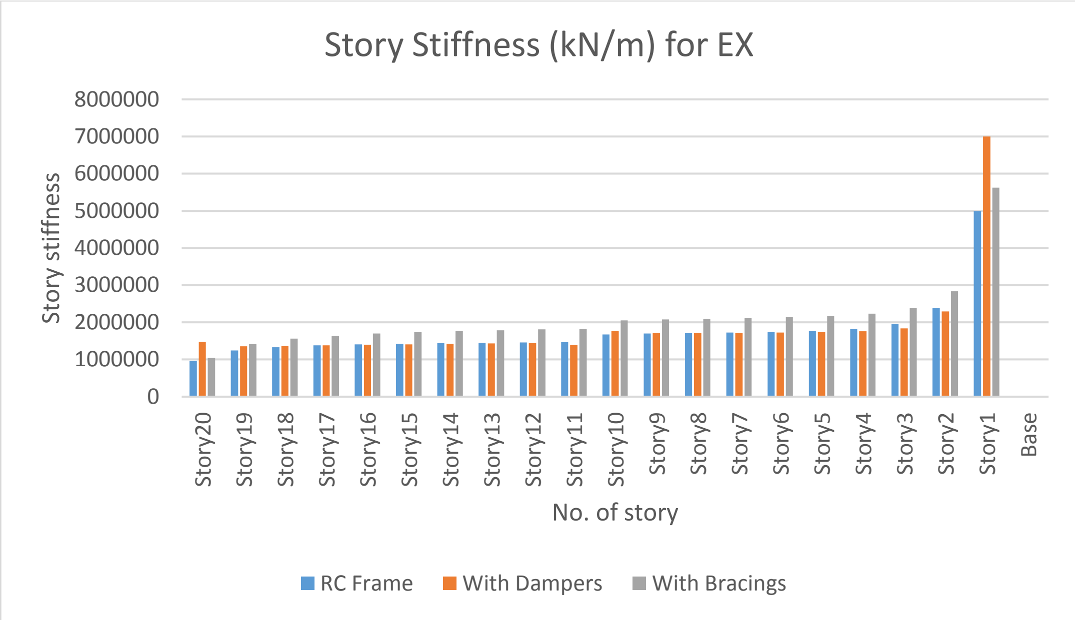


Figure 4.13: Story Stiffness in X direction for High rise Building

2. The maximum story stiffness for High rise Building having seismic load in Y direction comes out to be 4294388.841 kN/m for RC structure, 6004877.027 kN/m for RC Building with jacketing and 4884446.971 kN/m for RC Building with bracing as shown in figure 4.14 at story 1 in soft soil condition at zone V.

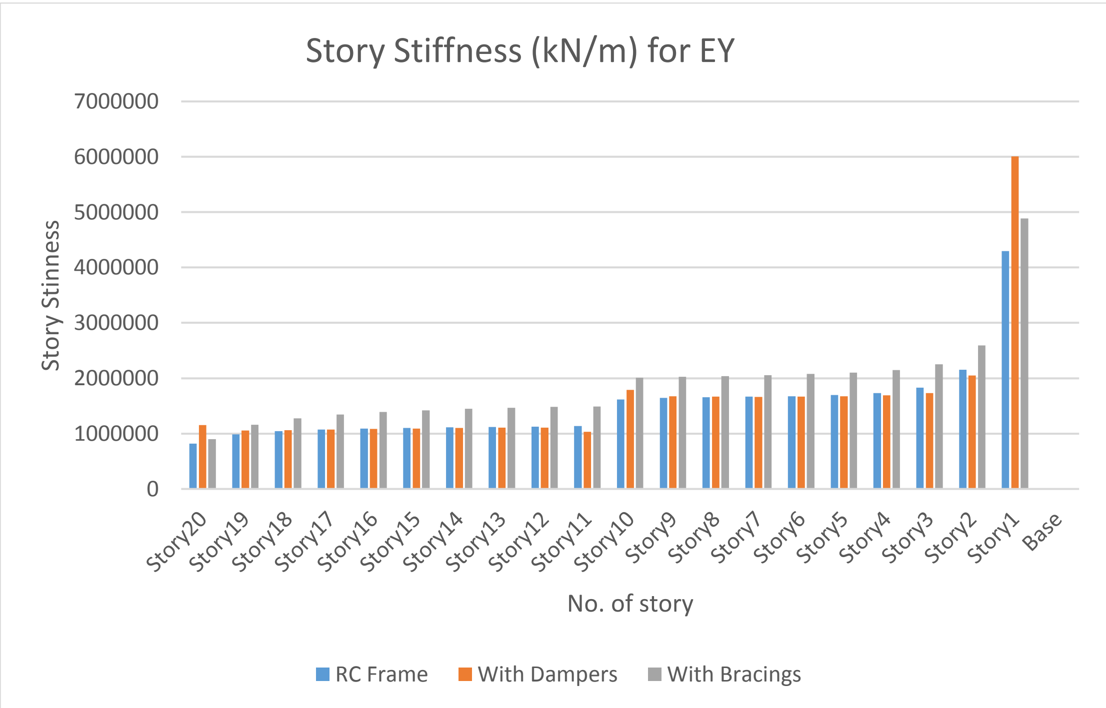


Figure 4.14: Story Stiffness in Y direction for High rise Building

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Conclusion

In this project I have modelled and analyzed G+19 & G+3 Building in ETABS under seismic loading conditions in both X and Y direction. After analysis, process of retrofitting is done by using retrofitting techniques like bracing, jacketing for G+3 Building and dampers, bracing for G+19 Building. After analysis the comparison of story response plots for both the buildings are studied which are mentioned below:

5.1.1 Conclusion for G+3 Building

1. The performance point from pushover analysis comes 81.37 for G+3 Building without retrofitting.
2. The maximum story displacement for G+3 building is reduced upto 10%, 12% with jacketing and 36%, 37% with bracing in both X and Y direction at top story in comparison to G+3 Building without retrofitting.
3. The maximum story drift for G+3 Building is reduced upto 6%, 8% with jacketing and 39%, 40% with bracing in both X and Y direction at story 2 in comparison to G+3 Building without retrofitting.
4. The maximum story stiffness for G+3 Building is increased upto 31%, 38% with jacketing and 172%, 200% with bracing in both X and Y direction at story 2 in comparison to G+3 Building without retrofitting.

5.1.2 Conclusion for high rise building

1. The performance point from pushover analysis comes out to be 305.13 for high rise building.
2. The maximum story displacement for High rise building is reduced upto 15%, 18% with dampers and 10%, 11% with bracing in both X and Y direction at top story in comparison to High rise Building without retrofitting.

3. The maximum story drift for High rise Building is reduced upto 17%, 25% with dampers and 11%, 14% with bracing in both X and Y direction at story 11 in comparison to High rise Building without retrofitting.
4. The maximum story stiffness for High rise Building is increased upto 40%, 40% with dampers and 13%, 14% with bracing in both X and Y direction at story 1 in comparison to High rise Building without retrofitting.

REFERENCES

[1] M, Geetha, & D M, Chaitra (2021). “Seismic Analysis and Retrofitting of an Existing Structure”. International Journal of Research in Engineering and Science (IJRES), Volume 9, Issue 8, pp. 29-39.

[2] Ganaie, K.G., & Saha, P., et.al. (2021). “Effects of Inverted V Bracing in Four-story Irregular RC Structures”. International Research Journal of Modernization in Engineering Technology and Science, Volume 3, Issue 4, pp. 2346-2351.

[3] Immanial, V., & Teja, R.S., (2018). “A Project on Retrofitting of Reinforced Concrete Frames using Steel Bracings”. Journal of Engineering Sciences, Vol 9, Issue 1, pp. 16-25.

[4] Hooda, Y., & Goyal, P.K., (2021). “Seismic Assessment of a Hospital Building: A Case Study”. IOP Conf. Series: Earth and Environmental Science, doi:10.1088/1755-1315/796/1/012006, pp. 1-14.

[5] Varsha, B.M., & Vijayananda, M.D., (2018). “Analysis, Design and Seismic Retrofitting of an Existing Building”. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 7, pp. 8023-8028.

[6] Al-Mudhafer, A., (2021). “Comparative Study of Seismic Response of Short Columns Retrofitted by Steel Jacket, brick wall and FRP Fiber”. Diyala Journal of Engineering Sciences, Vol 14, No 1, pp. 24-30.

[7] Khaing, S.Y., et.al. (2014). “Retrofitting of High Rise RC Building using CFRP to Resist Earthquake Effect”. International Journal of Scientific Engineering and Technology Research Volume.03, IssueNo.08, pp. 1357-1364

[8] Sthapit, Nima, & Sthapit, Nisha, (2021). “Retrofitting of an RC Frame building damaged in “April 2015 Gorkha earthquake” in Kathmandu valley”. Elsevier.

[9] Malhotra, A., & Carson, D., (2004). “Friction Dampers for Seismic Upgrade of St. Vincent Hospital, Ottawa”. 13th World Conference on Earthquake Engineering, Paper No. 1952.

[10] Begum, S.S., & Vani, G., (2016). “Seismic Analysis of a High Rise Unsymmetrical Building with Dampers Using ETABS”. International Journal of Scientific Research in Science and Technology, Volume 2, Issue 3, pp. 197-205.

[11] Naresh, B., Omprakash, J., (2018). “Seismic Design of Multistorey RCC-Building with Dampers Using ETABS”. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 1, pp. 180-190.

[12] Thomas, E.C., (2015). “Seismic Response of Soft Storey Buildings with Viscoelastic Dampers”. International Journal of Engineering Research & Technology, Volume 3, Issue 29, pp. 1-6.

[13] Nawrotzki, P., & Popp, T., et.al. (2012). “Seismic Retrofitting of Structures with Tuned-Mass Systems”. 15 WCEE.

[14] Roy, E., & Ghose, P., et.al. (2018). “Performance Evaluation of Shape Memory Alloy in Seismic Retrofitting of RC Building”. International Conference on Advances in Civil Engineering, pp. 636-641.

[15] Kadu, A.K., & Shantanu, P.T., et.al. (2019). “Base Isolation of Existing Structure by Retrofitting”. International Journal of Engineering Research & Technology, Vol. 8, Issue 04, pp. 433-438.

[16] Verma, S., & Sakhlecha, M., et.al. (2020). “Seismic Retrofitting by Base Isolation and Analysing Through ETABS”. International Journal of Trend in Research and Development, Volume 7(5), pp. 30-36.

[17] Vats, A., & Singh, A.K., et.al. (2019). “Seismic Analysis and Retrofitting of Reinforced Concrete Building in Indian Seismic Zone V”. International Research Journal of Engineering and Technology, Volume 6, Issue 6, pp. 3442-3453.

[18] Senthil, K., & Gupta, S.K., et.al. (2017). “Evaluation of RC Frames in Shifting on Seismic Zone 3 to 5 and Retrofitting Techniques using ETABS”. International Journal of Structural Engineering and Analysis, Vol. 3, Issue 2, pp. 1-19.

[19] Kumbhar, G., & Banhatti, A., (2016). "Seismic Retrofitting of Building with Soft Storey and Floating Column". International Research Journal of Engineering and Technology, Volume 3, Issue 7, pp. 1917-1921.

[20] Fauzan, & Ismail, F.A., et.al. (2019). "Seismic retrofitting analysis using concrete jacketing and shear wall on dental hospital building of Andalas University". IOP Conf. Series: Materials Science and Engineering.