“COMPARATIVE STUDY ON THE EFFECT OF SLOPES ON A BUILDING IN DIFFERENT SEISMIC ZONES”

A

PROJECT REPORT

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

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Prof. (Dr.) Ashish Kumar

(PROFESSOR & HEAD OF DEPATMENT)

by

RAKSHIT SHARMA (181635)

ANUSHKA ANAND (181644)

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 Project report entitled **"COMPARATIVE STUDY ON THE EFFECT OF SLOPES ON A BUILDING IN DIFFERENT SEISMIC ZONES"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Prof. (Dr.) Ashish Kumar.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Rakshit Sharma

Roll No. 181635

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

Signature of Student

Anushka Anand

Roll No. 181644

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"COMPARATIVE STUDY ON THE EFFECT OF SLOPES ON A BUILDING IN DIFFERENT SEISMIC ZONES"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Rakshit Sharma (181635) and Anushka Anand (181644)** during a period from August 2021 to May, 2022 under the supervision of **Prof.(Dr.) Ashish Kumar** (Professor & Head of Department of Civil Engineering), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: 14-05-2022

Signature of Supervisor

Prof. (Dr.) Ashish Kumar

Professor & Head of Department

Department of Civil Engineering

JUIT,Waknaghat

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We also take this opportunity to express a deep sense of gratitude to our university Jaypee university of Information Technology which provided us with cordial support, valuable information and guidance, which helped me in completing this task through various stages.

Lastly, we thank almighty, my parents and friends for their constant encouragement without which this project would not be possible.

ABTRACT

The principal objective of this project is the comparative study on design and analysis of multistorey building (B+G+4) in slopy and plain region by using software like STAAD. Pro. The comparisons between the varying slope angles of the ground and different seismic zones. A multi-storey commercial building (B+G+4) is designed then analysed for different conditions like 0^0,10^0,20^0,30^0 slopes and seismic Zone I and V. The building is analysed using STAAD. Pro. software. The design methods used in STAAD. Pro. analysis are Limit State Design conforming to Indian Standard Code of Practice. The comparative study includes results like lateral forces, max bending moment, maximum axial force and max displacement of the structure.

Key words: Sloping ground, Seismic forces, hilly regions, Structural analysis.

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 GENERAL

To carry any work, Hilly regions are the most difficult but also most exciting and challenging features to carry any development or construction work. Due to difficult terrain, steep gradients, varying climatic conditions, complex geographical structure and rich flora, the construction buildings are constrained. Due to these conditions the built, construction techniques and patterns can be seen similar in different hilly regions. Area having altitude of more than 600m or area having an average slope of 30^0 is classified as hilly region of the country. (BIS, 2005). About 21% of Indian land is Hilly or mountainous, which mostly includes the northern mountains of Himalayan region. Most of the Himalayas are located in seismic zone V and seismic Zone V. Which are seismically most vulnerable atlas (NDMAD, 2007). During any high magnitude of earthquake, these regions may lead to enormous destruction. Shimla, Mussoorie, Manali, Dalhousie, Nainital, Srinagar, Shillong and Itanagar are some of the most visited tourist places and due to their popularity. They face huge pressure of development. Hill stations are mostly located in the ecologically sensitive zones. (Menon, Kapoor, & Kohli, 2009). As mentioned in IS code 14243 Part 2 (1995), The development of hill site, stability analysis of hill slopes, field survey should be carried out for cuttings. The building should be located on stable slopes. Due to bad weather conditions the slopes and cutting which are stable in normal weather conditions undergoes movements and failure due to weathering along joints and other discontinuities in rocks, excavation, change in drainage conditions, erosion and etc. But moreover, cutting and excavations are required to locate a building on a stable hill slope. Such type of cutting often requires protection work to deal with some other problems, which add to the site development cost. Therefore, it is very important to ensure the stability of such cuttings. Hill slopes which are less than 30^0 are considered to be safer as gradient corresponds to the safe angle of the repose of slope forming materials. In general building sites are not constructed on slopes higher than 30^0. Non- residential temporary building may be constructed on slopes having slope up to 45^0.

Figure 1 Development in the peripheral regions of hill town.

1.2 SEISMIC BEHAVIOUR OF BUILDING ON SLOPE

In India hilly region is mainly in the North and north eastern part. These areas are also categorized under various seismic zones like Zone IV and Zone V. The demand and popularity of multistorey RC buildings in these areas on hilly slopes is also high. It mainly due to increasing urbanization and rapid economic growth in these regions. Also, tourism in these areas is a big reason for increasing multistorey buildings. It must be noted while construction that the construction in plains and in hilly areas is common. The topography of hilly region is very irregular and unsymmetric. Since there is lack of plain land in hilly regions. The buildings are constructed on slopy grounds. As past earthquake data of these regions, the building which have different height of columns in same floor have suffered more. Also, buildings on hilly slopes attract large amount of shear force, torsion moments and shows unequal distribution due to varying column lengths.

Figure 2 Different seismic zones in INDIA

1.3 CONFIGURATION OF THE BUILDING ON HILL

In Hilly regions due to hill slopes the buildings are constructed in setback configuration. The floors of building are in successive order. There is also sometimes step type construction of building since some additional floors gets added automatically due to Slopy ground.

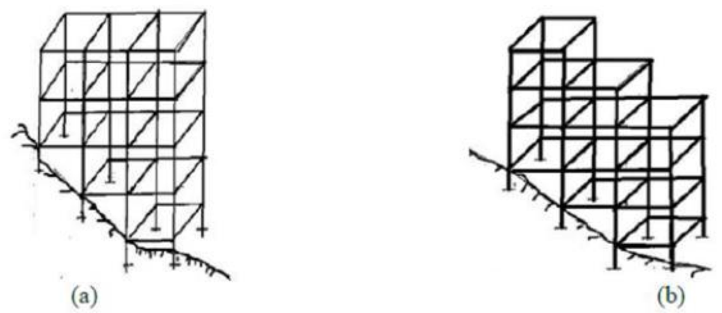

Figure 3 Building Configurations

1.4 CONCLUSION

In this chapter we discussed the various aspects of building situated in hilly area. Their rules, regulations and criteria provided by the BIS. The seismic behavior of the building was also briefly discussed. The earthquake prone areas in India were mentioned. The configuration of building in sloping ground is included in this chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 GENERAL

In previous chapter Introduction we have discussed the aspects of building in hilly region. Various criteria, seismic behavior of building. Also discussed the configuration of building. In this chapter we are going to do some literature review regarding our topic "Comparative study on the effect of slope on a building in different seismic zone". Various research papers regarding our studies are studied and important information is being collected.

2.2 REVIEWED RESEARCH PAPER

- R. S. Malik et. al. (2015) have presented a study where they compared the Staad. Pro. calculations with manual calculations. A multistorey building was designed. The design included load calculation, analysis. They used Limit State method for the calculations. The IS 456 (2000) was also taken under consideration. The whole process involved first modelling, then analyzing the members due to the effect of seismic load, wind load. The height of building was 33- meters, (G+10) storied building with 3 meter as height of each floor. The overall dimensions of building were 21.30m X 14.0 m.

- Ashwani Kumar et. al. (2014) in his studies have presented the regulations for safety against the hazards in the hill towns of India. In his paper, he raises various issues regarding the various developments in hilly towns. Also, a comparative study of existing building regulations for safety was done in his paper. His study mainly focused on the Himalayan region, only northern part of India.

- Jivanya Tiwari et. al. (2014) they presented a study on building structures and construction in hilly regions. In their research paper they took a particular building that was hotel Dalhousie. As the architecture and beauty of buildings in hilly regions looks very soothing to eyes. But it is equally difficult and challenging for an architect or an engineer to make such structures. As Himachal is one of the most beautiful and tourist attracting state. Therefore, many people come from different states. Major part consists of the design approach of the building in hilly region and the construction techniques used in this research paper. Study of a Hotel was taken in this study to take step ahead for the urbanization of hilly regions.

- Mr. A.P. Patil et. al. (2013) They have designed and analyzed multi strorey building (G+10) by using Stadd. Pro. V8i and found various results like Max axial forces, Max shear forces, Max bending moments and displacements in the building.

- Deependra Singh Raghuvanshi et. al. (2016) They have presented a study on the Analysis of a multistorey building frame for lateral forces at sloping strata under the effect of seismic forces using Staad. Pro. In their study they have taken a sample building structure (G+8) building and taken three sloping angles. Dynamic analysis method is used as per IS 1893 part-1 2002. They have included four seismic zones and three soil types (medium, soft, hard). The modelling and analysis were done through Staad. Pro. As results they have done a comparison between all model they prepared with different conditions and graphically represented the data.

2.3 RESEARCH GAP

Various research paper compared the buildings with different seismic zones, with different climatic conditions, different land profiles but there is very less research regarding effect of slopes on the building with varying seismic zones. In this project we have compared a Building for different slopes like 0^0, 10^0, 20^0, 30^0 and vary seismic zones likes I, V.

2.4 RESEARCH OBJECTIVES

The objective of this project is a Comparative study of the effect of slopes on a building in different seismic zones. In this project, we are going to analyze multistorey building (B+G+4) in varying slopes by using software like STAAD. Pro and Revit. In this project, we are going to structurally compare the building(B+G+4) with various slopes like 0^0, 10^0, 20^0, 30^0 and with different seismic conditions like Zone I and Zone V. And at the end we will find some results. The results include

Axial forces, Bending moment, shear forces, deflections, reactions. Also, the data will be graphically be presented to understand the effects more precisely. Standard problems also have been solved to show how Staad. Pro. can be used in different cases. These typical problems have been solved using basic concept of loading, analysis, condition as per IS code.

2.5 LIMITATIONS OF STUDY

Since we are going to model (G+B+4) storey building which is not a high rising building. So, the results we will get are not going to be very different for Seismic Zone I and V. High rising buildings shows more gap in values. Also, the structure is modelled only considering the Dead loads, Live loads and Seismic loads. But in actual scenario, the Wind load is also present, Snow loads etc. might be present too.

2.6 CONCLUSION

In this chapter we have studied various research papers and collected important data and information needed for our studies. Also, Research gap, research objective was also discussed. Limitations of studies is also included in this chapter.

CHAPTER 3: DESIGN CONSIDERATIONS AND MODELLING OF STRUCTURE ON REVIT

3.1 GENERAL

In previous chapter we have done the Literature review. Various research papers have been studied and important needed information is collected. In this chapter, we are going to study the Approach to our building, Design considerations. We will 3D model our building on Revit software. Also, Assumptions, Preliminary design and Load calculations will be included in this chapter.

3.2 APPROACH TO THE BUILDING STRUCTURE

Architecture and beauty of buildings in hilly region looks very pleasing to eyes but also, they are major challenge for architecture. Small buildings like houses, small shops, temples etc. have easier construction than the large-scale buildings like hotels, etc. Therefore, the building should be constructed strong to resist the frequent seismic tremors, topography of the region and should also carry the load of building. The building should also be aesthetically pleasing for tourists. The topography, plays important role in design and planning of building. The Concrete have many advantages with no doubt like strength, durability, weather resistance. Also, concrete is accepted a better construction material al around the world. But due to lack of proper knowledge and proper guidelines about the use of construction material, it may lead to huge loss of lives too with the wake of earthquake or any other natural disaster.

- **Design Considerations: -**

The construction of building in hilly region should be compact, without any re-entrant angles. Since they lead to concentrate shear force during earthquake and increase the impact of damage on the building. There should be more than 6m distance between corners of the walls and doors, doors and corners of windows and between corner of window and end of wall. Addition to pilasters is also recommended at even and regular intervals. These Pilasters adds extra strength to the mass. There should be 15 m distance between any kind of plantation from the building. Since Stilt is often seen as favorable solution for parking, but building on stilt should be avoided. Stilt also disturbs the uniformity of load vertically. The buildings should not be constructed in a way that if one building collapse, it creates chain reaction and affect all other buildings. 3.2m should be the maximum height for each storey. In case of foundation on rocky strata. It should be 0.15m inside rocky base and should not be just directly on rocky base. The depth foundation should be less than 0.5m and width 0.75m in case of sand soil.

3.3 3D MODELLING THE STRUCTURE ON REVIT

Making the 3D model of a commercial building which satisfies the above design criteria. The commercial building is of 6 storeys. Having One Basement, Ground floor and 4 Upper floors. First rough drawing on AutoCAD is made. Once the rough drawing is ready, moved to Revit and made 3D model. All components like walls, doors, windows and every element are added to the model.

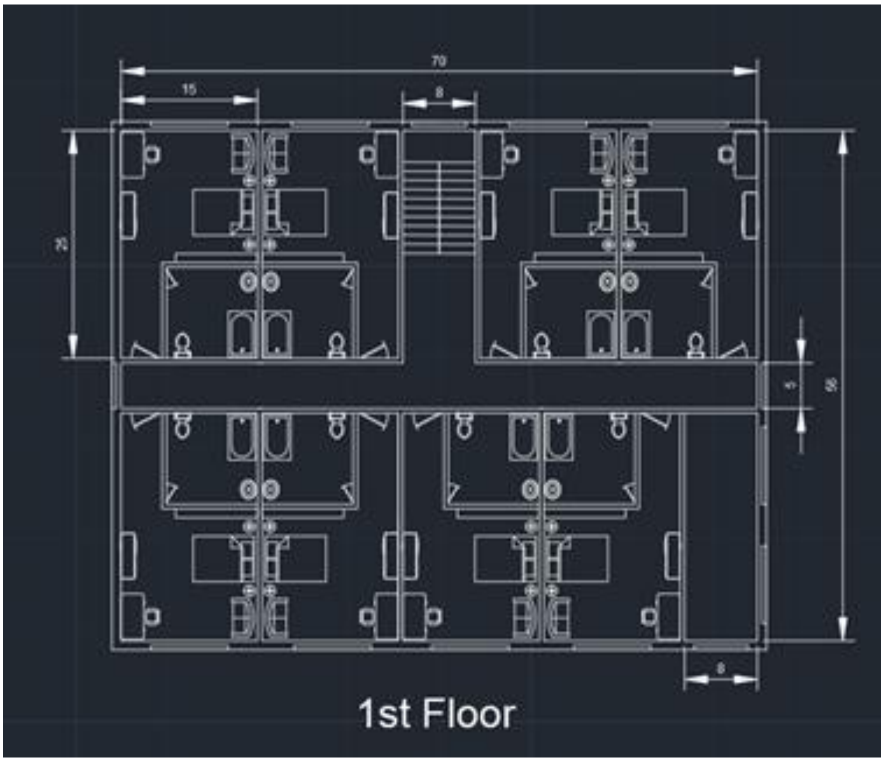

Figure 4 AutoCAD rough floor plan

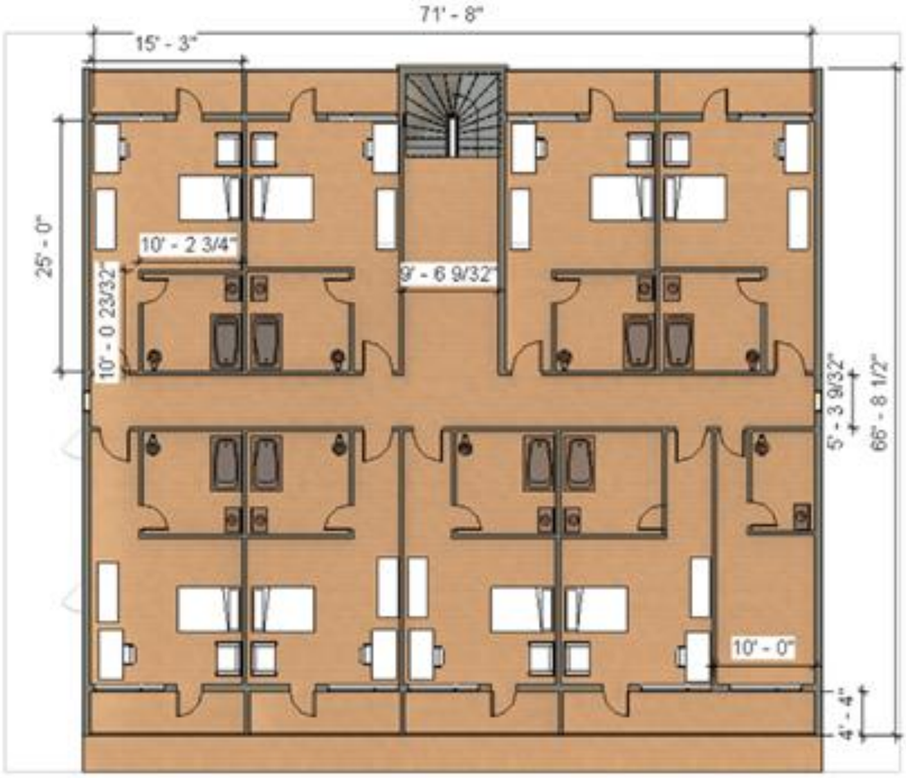

Figure 5 Floor plan on Revit

Room dimensions are 25x15 sq. ft with attached bathroom have dimensions 10x10 sq. ft. Eight rooms in each floor. 8 ft opening for staircase, 5 ft gallery and 4 ft balcony in north and south of building. The thickness of outer walls is 9 inches and thickness of inner walls is 4.72 inches. The floor height is 10 ft. Total internal floor area is 70x66 sq ft.

Figure 6 Three-dimensional view of building.

3.4 ASSUMPTIONS

- **Materials**

Concrete grade of M30 is used in the building. Also steel of grade Fe415 is used. Bearing capacity of soil is taken as 300 KN/m^2.

Table 1 Materials used

Concrete grade	M 30
Steel grade	Fe415 grade
Bearing capacity of soil	300KN/m^2

- **Density of Materials used**

Concrete density is assumed to be 25 KN/m^3. Floor material density is taken 20 KN/m3 and Brick masonry is taken 19 KN/m^3.

Table 2 Density of materials used

Concrete	25 KN/m^3
Floor material	20 KN/m^3
Brick masonry	19 KN/m^3

- **Live Load: -**

Live load on slabs is taken 2KN/m^2

- **Assumptions in Design**

As per clause #6.4 of IS-456-2000 using partial factor of safety for loads $Y_t = 1.5$

As per clause 36.4.2 in IS-456-200 using partial safety factor for steel $Y_{st} = 1.15$

Using load combinations as per IS-456- 2000

1.5 (Dead load + Live load)

1.2 (Dead Load + live load + Earthquake load)

3.5 PRELIMINARY DESIGN OF BUILDING MEMEBERS

- **Calculation of depth of the beam**

As per CL. 23.2.1 of IS 456: 2000

(Length of beam /depth of beam) should be approx. 12 to 15

d = (Span of the longest beam/15)

d = (6.09/15) = 406 mm.

Overall depth, D = d + ½(dia. Of bar) + clear cover.

D = 410 + 8 + 50 = 468 = approx. 500mm

- **Calculation of breadth of the beam**

Breadth of beam is taken D/2 to (2/3)D
Breadth = 468/2 = 234 = approx. 230mm

- **Preliminary design of column**

From equation,

Pu = 0.4Fck Ac + 0.67 Fy Asc

Pu = Ultimate axial Load.

Ag = Gross area of column.

Fck = Characteristic compressive strength of concrete.

Ac = Area of concrete in column = 97% of Ag.

Asc = Area of steel in column = 3% of Ag.

Pu for one floor = 148200 KN

Pu for each column = 7410 KN, With factored load of 10%; Pu = 8151KN

Putting this in equation, Ag = 358096 mm2.

(Column length)2 = 358096 mm2

Length of column = 598.411mm approx. 600 mm.

Therefore, dimension of column = (600 X 600) mm^2

- **Load Considerations**

Generally, there are two types of Load considerations: -

Gravity Loads and Lateral Loads.

- **Gravity Load**

All Loads which exert pressure downwards or vertically down like Structure load, human occupancy, snow loads etc. All these types of loads come under the Gravity load. These types of loads need a complete load path to transfer it to ground.

- **Dead Load**

Dead load basically the load of structure itself. It includes the weight walls, floor, the whole concrete structure, stairs, doors etc. The dead load can easily be calculated from the dimensions of the members ma multiplying it with the unit weight of the same material used in that member. The unit weight of plain concrete and reinforced concrete made of gravels, sand and aggregates can be taken 24 KN/m^3 and 25 KN/m^3.

- **Dead Load Calculation**

- Full brick wall load: -

As per IS 875 Part-1, Unit weight of brick =19 KN/m3

Area of wall = 10 ft. X 9 in. = 7.5 sq. ft. = 0.69 m2

Load= 19 KN/m2 X 0.69 m2 = 13.11 KN/m

In case of opening in the wall only 70% of load in considered. Therefore, Load for full brick wall with opening = 9.177 KN/m

- Half brick wall load: -

Area of wall = 10 ft. X 4.72 in. = 3.93 sq. ft. = 0.36 m2

Load = 0.36 X 19 = 6.84KN/m

In case of opening, 0.7 X 6.84 = 4.788 KN/m

- Parapet wall load: - 19 X 1 X 0.11 = 2.09 KN/m

- Staircase Load: -

Total volume of staircase = 70.776 ft3 = 2 m3

Weight of staircase = 2 m3 X 25 KN/m3 = 50KN

Floor finish load for staircase = 11.88 m2 X 1 KN/m2 = 11.88 KN

Total Dead Load of staircase = (50 + 11.88) KN = 61.88 KN

Since this load is divided between three beams. Therefore, Load on each beam = 20.62 KN

- **Live Load**

Live load are varying loads, those loads which are not constant. Since the dead load are always constant on a structure but Live loads can increase or decrease according to the movement of various things or humans in the building. IS875 part 2 deals with the imposed load on building produced by intended occupancy or use.

- **Live Load Calculation**

Staircase load: -

Intensity = 3KN/m2

Area = 88 ft.2 = 8.17 m2

Load of staircase = 24.52 KN

Since the load is divided between three beams. Therefore, Load on each beam = 8.173 KN

- **Lateral loads**

Lateral loads include the horizontal forces that act on a building or structure. Thay include earthquake load, wind load etc. These loads show displacement on a building in X- direction or Y- direction.

- **Seismic Loads**

  Seismic load is one of the Lateral loads. Since it acts horizontally either in x-direction or in z-direction. The computation of design lateral force should be done for a building as a whole. Then the distribution of this lateral force should be done for each floor level. In India the seismic zone is divided into four zone those are Zone II, Zone III, Zone IV, Zone V. Zone II is very less earthquake prone are whereas Zone V is highly earthquake prone area and also the riskiest place with high intensity zone.

3.6 CONCLUSION

In this chapter we have 3D modelled our structure in Revit software. Also, the preliminary design of building member is done in this chapter. The calculation of Loads is also present in this chapter. In next chapter, we are going to model and analyze our structure on Staad. Pro.

CHAPTER 4: STAAD. PRO. MODELLING AND ANALYSIS

4.1 GENERAL

In previous chapter we have 3D modelled our building on Staad. Pro. Also the Assumptions for the building is also present in that chapter. The preliminary design plus load calculation, all present in that chapter. Now, in this chapter we are going to follow the procedure to make a (B+G+4) building in Staad. Pro. Eight structures will be modelled for the comparison of results. All data regarding the structures will be present in this chapter.

4.2 PROCEDURE USED FOR MODELLING AND ANALYSIS

- **Step 1: - Define the Geometry.**

In Staad. Pro. We first start with defining the geometry of the structure. So, the coordinates of the building members are added. To fasten the process translational repeat command can also be used. Also copy past of coordinates to upper floor can also be very useful to fasten the geometry defining process. After that all the coordinates can be connected by beams tool according to the respective member needed or defined.

- **Step 2: - Define properties.**

In general tab there is define properties, Where the properties to member can be defined like the dimensions. But before that slab should be added to the structure which can be done through the plate cursor. Once it is done then all the beams can be selected and then assigned the respective width and height. Similarly for the columns height and width is defined. For the slabs the width is taken, which is most of the time is constant that is 0.15m. After that the supports are added to the structure. Fixed support is selected and placed to the base of the building.

- **Step 3: - Define Loads**

In Staad. Pro we first start with the Seismic load definition, then dead loads consideration and then live load. In seismic load, the seismic conditions are entered for respective soil type, zone, topography, etc. Then the member loads, staircase load, floor loads are applied in the seismic load definition. In load case detail the direction of lateral load is selected for the earthquake. After defining the Seismic load, now the Dead load is defined to the structure. It includes dead weight of the members, floor weight, wall loads and staircase loads. After that the Live load is defined it consists of floor live load, staircase live load. In the end the load combinations are added for the perspective loads applied on structure.

- **Step 4: - Analysis and print: -**

After all that click on analyze and print. Then Run analysis. View the output file for any error. If any beam or column failed. Once all errors are corrected. Again, run analysis.

- **Step 5: - Post processing mode: -**

In post processing mode, all results are present regarding the structure. Like Reactions, Deflections, Axial forces, Shear forces, bending moments for all co-ordinates and members. Visual presentation and values both are present in post-processing mode. From here the results can be checked.

- **Step 6: - Design the structure: -**

In design part of the Staad. Pro. We can define the IS-codes, in select parameters we can define more properties like strength of concrete and steel, max dia. Of bars, min Dia of bars, clear cover, max percentage of reinforcements. In commands, we can select the options like design beams, columns and weight of steel used and many other results. Which in result when we see our output file will show the weight of steel used, amount or concrete used and will also show the design of each beam and column separately in the output file.

4.3 DESCRIPTION OF STRUCTUIRES: -

Code used to describe the structure contains three parts S, which stands for structure, I or V, which stands for Seismic zone I or Seismic zone V and 0 to 30 values which signifies the slope of ground.

Table 3 Description of Structure

Structure	**Description**
SI0	Structure with Seismic zone I and Slope 0^0
SI10	Structure with Seismic zone I and Slope 10^0
SI20	Structure with Seismic zone I and Slope 20^0
SI30	Structure with Seismic zone I and Slope 30^0
SV0	Structure with Seismic zone V and Slope 0^0
SV10	Structure with Seismic zone V and Slope 10^0
SV20	Structure with Seismic zone V and Slope 20^0
SV30	Structure with Seismic zone V and Slope 30^0

4.4 STRUCTURES FOR SEISMIC ZONE I

- **Structure SI0: -**

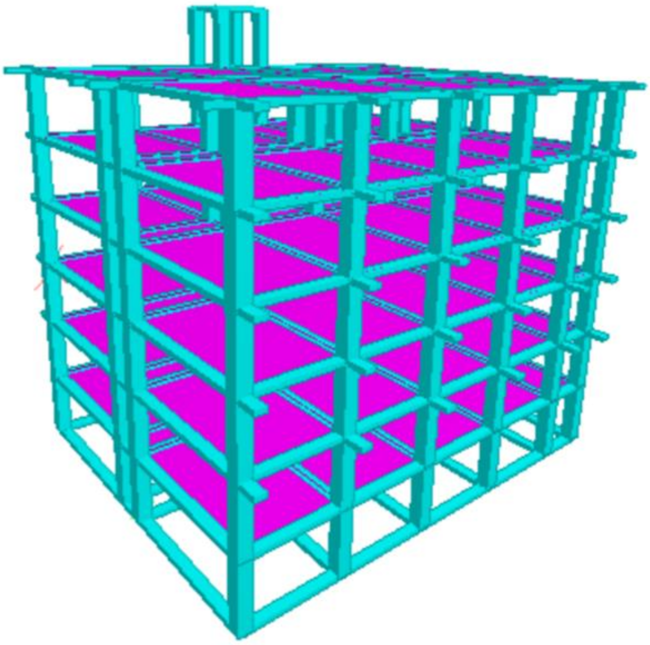

Figure 7 Building on plain ground

- **About the Structure SI0: -**

Table 4 About Structure SI0

Plan Dimension	20.726m X17.983m
Height of each storey	3m
Number of storeys	(B+ G+4) storey
Length in X-direction	20.726m
Length in Z-direction	17.983m
Length in Y-direction	21.336m

Dimension of Column	(600 X 600) mm
Dimension of Beam	(230 X 500) mm
Slab Thickness	(150) mm
Grade of the concrete	M30
Grade of the steel	Fe415
Type of Soil	Type II, Medium Soil
Slope	0^0
Seismic Zone	I
Building Frame Systems	Ordinary RC moment-resisting

- **Results for Structure SI0: -**

- Maximum reaction forces on the structure: -

Table 5 Max Rxn For slope 0^0 and zone I

In X-direction	10.115 KN
In Y-direction	2304.594 KN
In Z-direction	35.982 KN

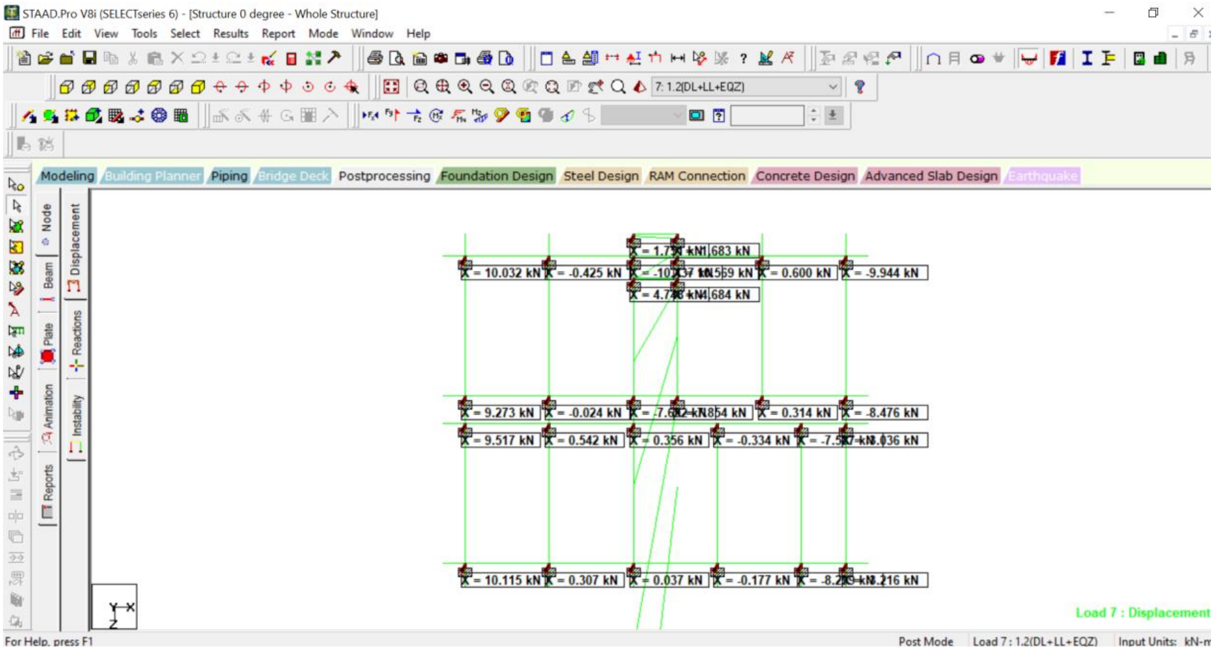

Figure 8 Reaction in x-direction slope 0^0 zone I

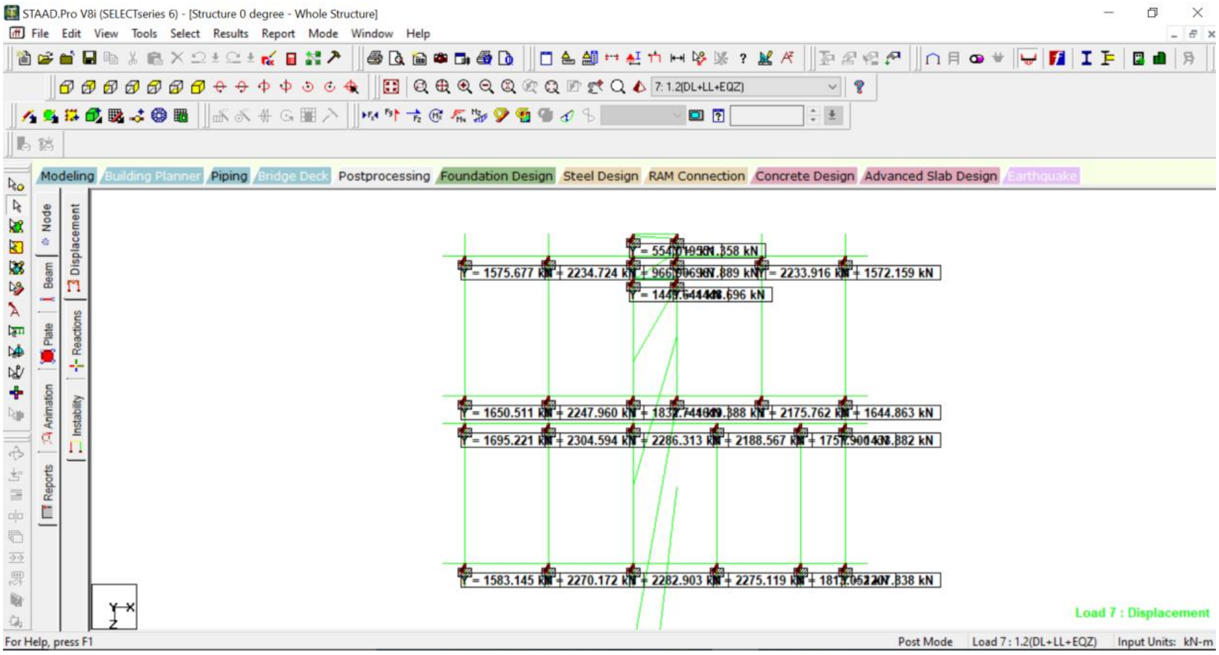

Figure 9 Reactions in y-direction slope 0^0 zone I

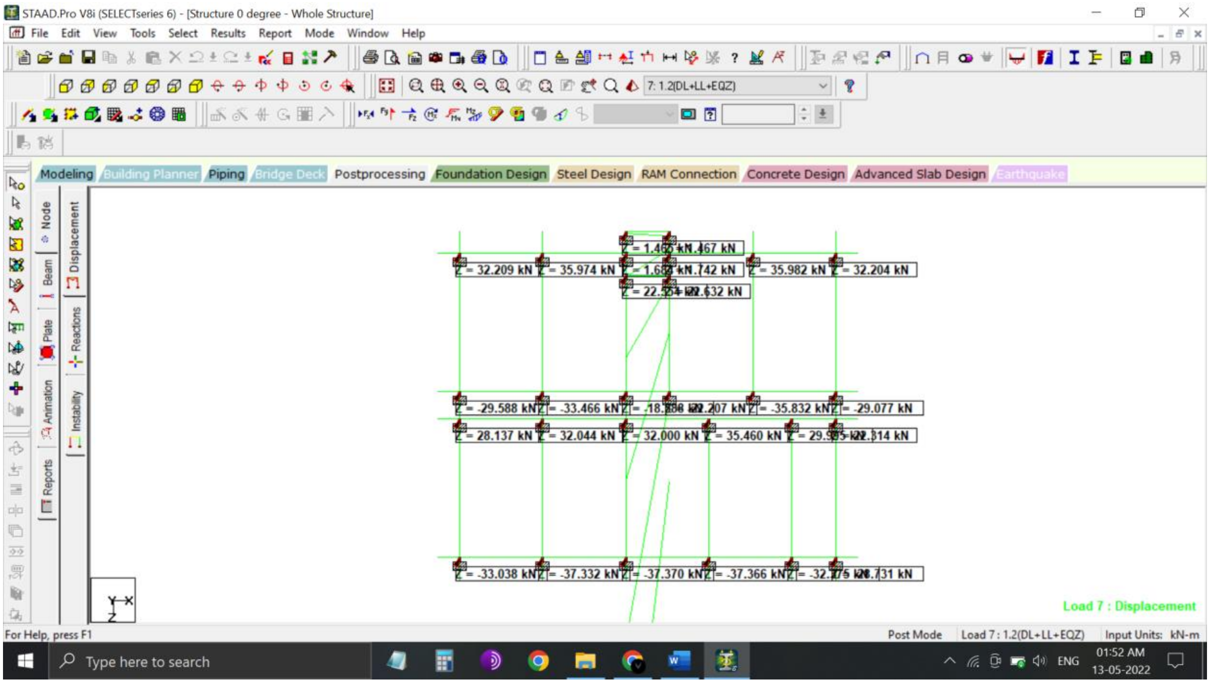

Figure 10 Reaction in z-direction slope 0^0 zone I

- Maximum Bending moment on the structure: -

Table 6 Max B.M. for slope 0^0 and zone I

Mx	144.427 KN-m
My	0.087 KN-m
Mz	39.436 KN-m

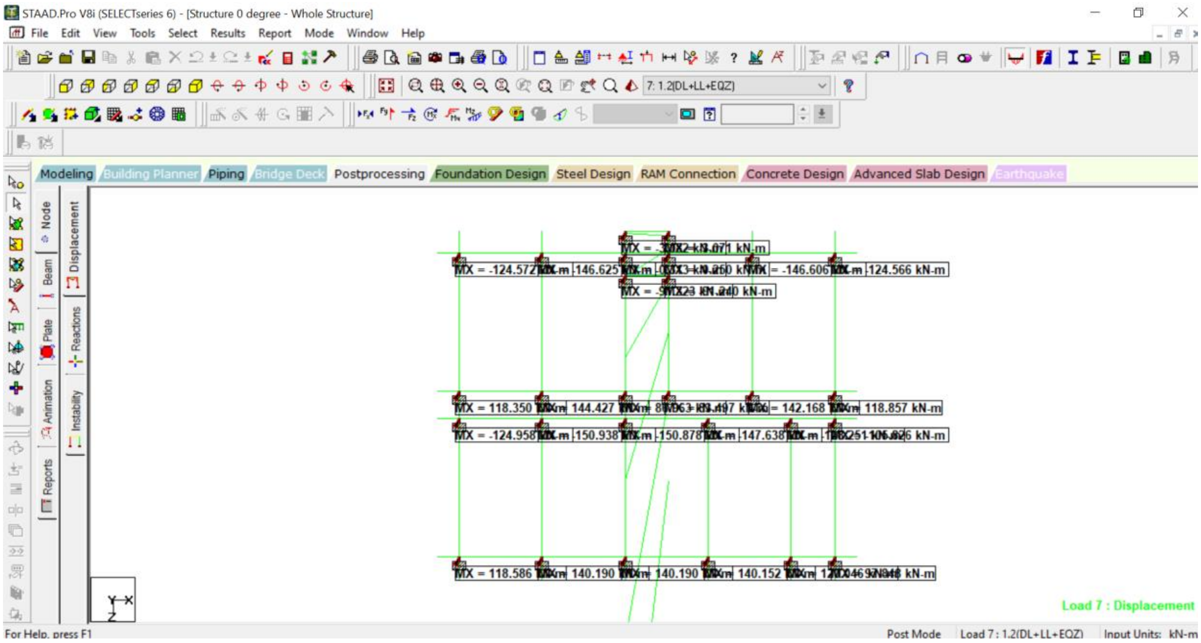

Figure 11 Bending moment in x-direction slope 0^0 zone I

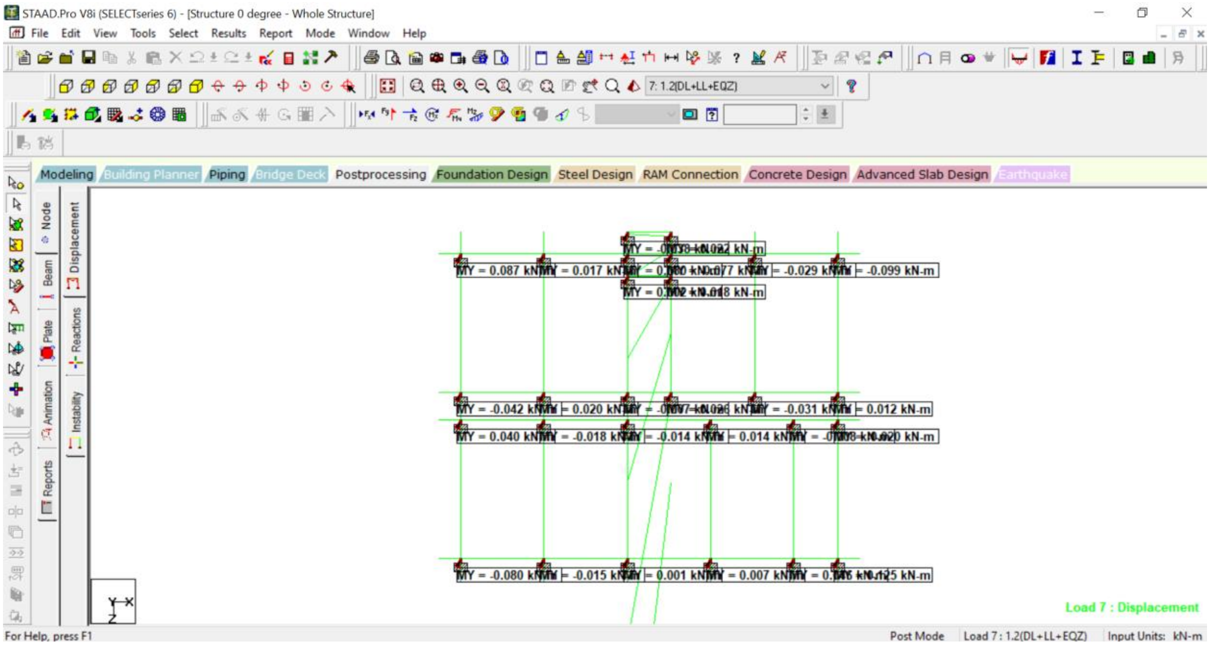

Figure 12 Bending moment in y-direction slope 0^0 zone I

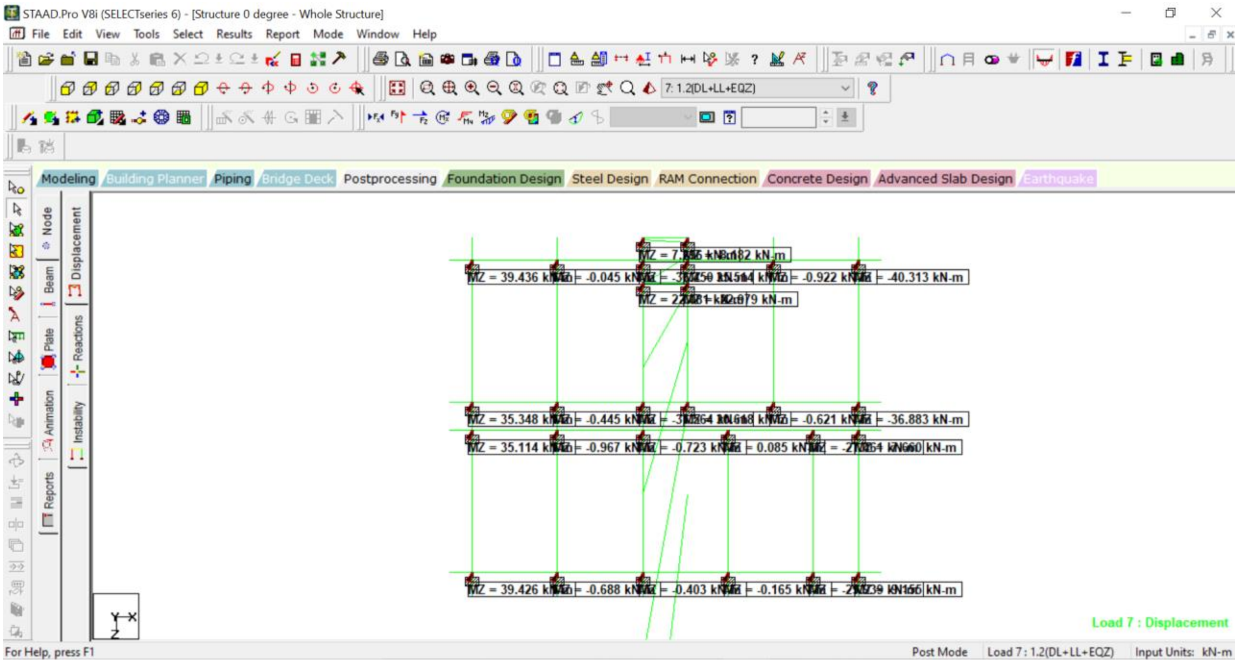

Figure 13 Bending moment in z-direction slope 0^0 zone I

- Maximum Lateral Displacements in the Structure: -

Table 7 Max Displacement for slope 0^0 and zone I

Basement	27.453mm
Ground Floor	30.393mm
1st Floor	31.664mm
2nd Floor	32.212mm
3rd Floor	32.748mm
4th Floor	33.141mm
Roof	33.312mm

- **Structure SI10: -**

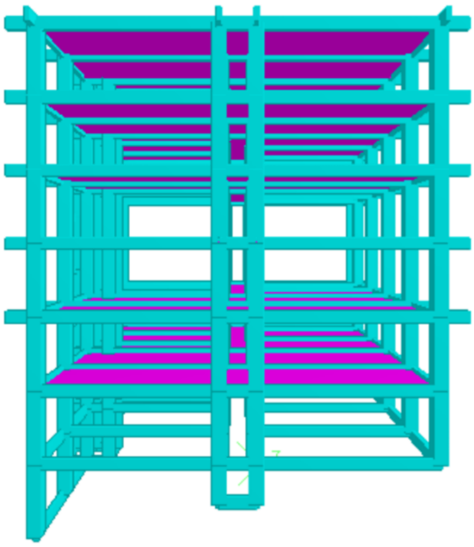

Figure 14 Building on 10^0 slope

- **About the Structure SI10: -**

Table 8 About Structure SI10

Plan Dimension	20.726m X17.983m
Height of each storey	3m
Number of storeys	(B+ G+4) storey
Length in X-direction	20.726m
Length in Z-direction	17.983m
Length in Y-direction	24.286m
Dimension of Column	(600 X 600) mm
Dimension of Beam	(230 X 500) mm

Slab Thickness	(150) mm
Grade of the concrete	M30
Grade of the steel	Fe415
Type of Soil	Type II, Medium Soil
Slope	10^0
Seismic Zone	I
Building Frame Systems	Ordinary RC moment-resisting

- **Results for Structure SI10: -**

- Maximum reaction forces on the structure: -

Table 9 Max Rxn. for slope 10^0 and zone I

In X-direction	21.516 KN
In Y-direction	2853.974 KN
In Z-direction	85.705 KN

- Maximum Bending moment on the structure: -

Table 10 Max B.M. for slope 10^0 and zone I

Mx	58.138 KN-m
My	0.522 KN-m
Mz	8.131 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 11 Max displacement for slope 10^0 and zone I

Basement	10.318 mm
Ground Floor	12.249 mm
1st Floor	13.065 mm
2nd Floor	13.101 mm
3rd Floor	13.657 mm
4th Floor	14.111 mm
Roof	14.331 mm

- **Structure SI20: -**

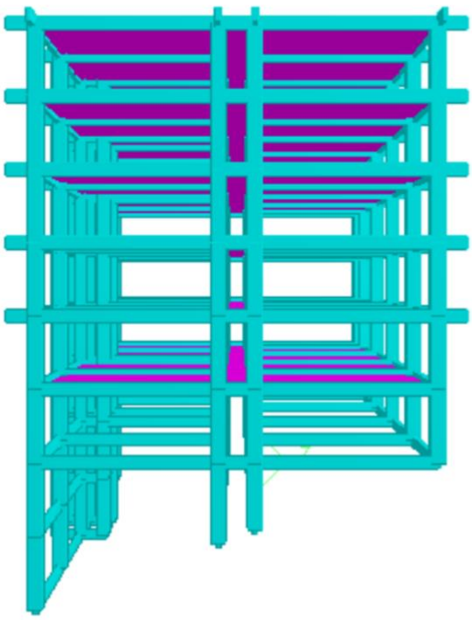

Figure 15 Building on 20^0 slope (Zone I)

- **About the Structure SI20: -**

Table 12 About Structure SI20

Plan Dimension	20.726m X17.983m
Height of each storey	3m
Number of storeys	(B+ G+4) storey
Length in X-direction	20.726m
Length in Z-direction	17.983m
Length in Y-direction	27.432m
Dimension of Column	(600 X 600) mm
Dimension of Beam	(230 X 500) mm
Slab Thickness	(150) mm
Grade of the concrete	M30
Grade of the steel	Fe415
Type of Soil	Type II, Medium Soil
Slope	20^0
Seismic Zone	I
Building Frame Systems	Ordinary RC moment-resisting

- **Results for Structure SI20:-**

- Maximum reaction forces on the structure: -

Table 13 Max Rxn. For slope 20^0 and zone I

In X-direction	11.551 KN
In Y-direction	2297.315 KN
In Z-direction	37.587 KN

- Maximum Bending moment on the structure: -

Table 14 Max B.M. for slope 20^0 and zone I

Mx	132.758 KN-m
My	0.318 KN-m
Mz	37.336 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 15 Max displacements for slope 20^0 and zone I

Basement	9.299 mm
Ground Floor	11.088 mm
1^{st} Floor	12.264 mm
2^{nd} Floor	13.006 mm
3^{rd} Floor	13.046 mm
4^{th} Floor	14.001 mm
Roof	14.032 mm

- **Structure SI30: -**

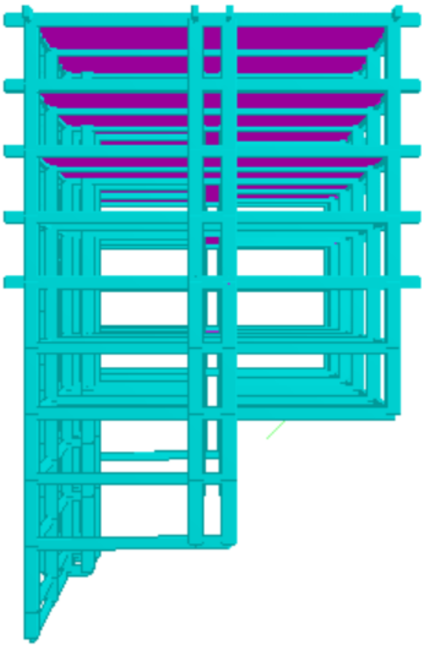

Figure 16 Building on 30^0 slope (Zone I)

- **About the Structure SI30: -**

Table 16 About Structure SI30

Plan Dimension	20.726m X 17.983m
Height of each storey	3m
Number of storeys	(B+ G+4) storey
Length in X-direction	20.726m
Length in Z-direction	17.983m
Length in Y-direction	31.710m

Dimension of Column	(600 X 600) mm
Dimension of Beam	(230 X 500) mm
Slab Thickness	(150) mm
Grade of the concrete	M30
Grade of the steel	Fe415
Type of Soil	Type II, Medium Soil
Slope	30^0
Seismic Zone	I
Building Frame Systems	Ordinary RC moment-resisting

- **Results for structure SI30: -**

- Maximum reaction forces on the structure: -

Table 17 Max Rxn for slope 30^0 and zone I

In X-direction	14.409 KN
In Y-direction	2897.363 KN
In Z-direction	19.892 KN

- Maximum Bending moment on the structure: -

Table 18 Max B.M. for slope 30^0 and zone I

Mx	175.562 KN-m
My	1.485 KN-m
Mz	46.761 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 19 Max displacement for slope 30^0 and zone I

Basement	8.312 mm
Ground Floor	10.238 mm
1^{st} Floor	11.008 mm
2^{nd} Floor	11.180 mm
3^{rd} Floor	11.608 mm
4^{th} Floor	12.070 mm
Roof	12.293 mm

4.5 STRUCTURES FOR SEISMIC ZONE V

- **Applying seismic zone V: -**

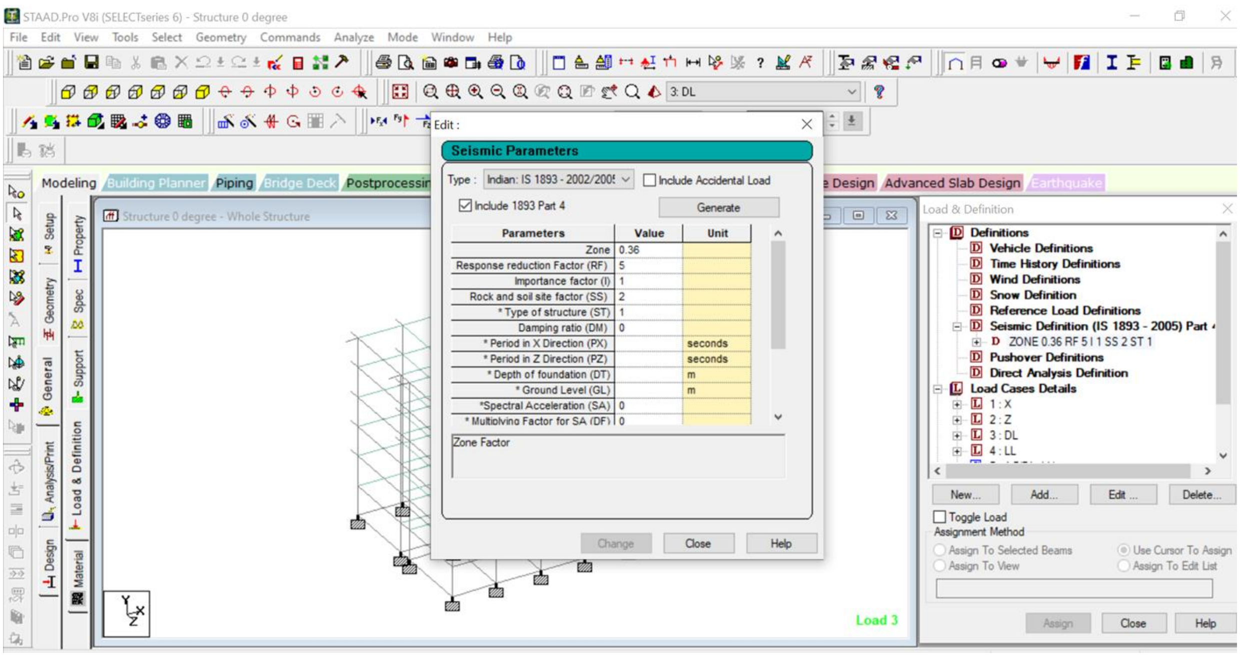

Figure 17 Seismic parameters

- **Results for Structure SV0: -**
- Maximum reaction forces on the structure: -

Table 20 Max Rxn for slope 0^0 and zone V

In X-direction	12.630 KN
In Y-direction	2877.199 KN
In Z-direction	45.259 KN

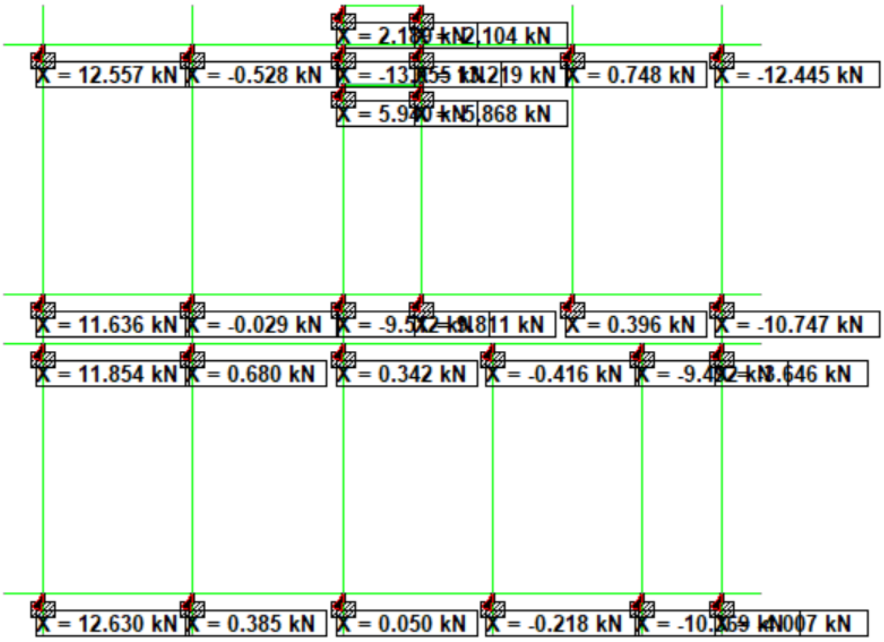

Figure 18 X-direction reactions for zone V slope 0^0

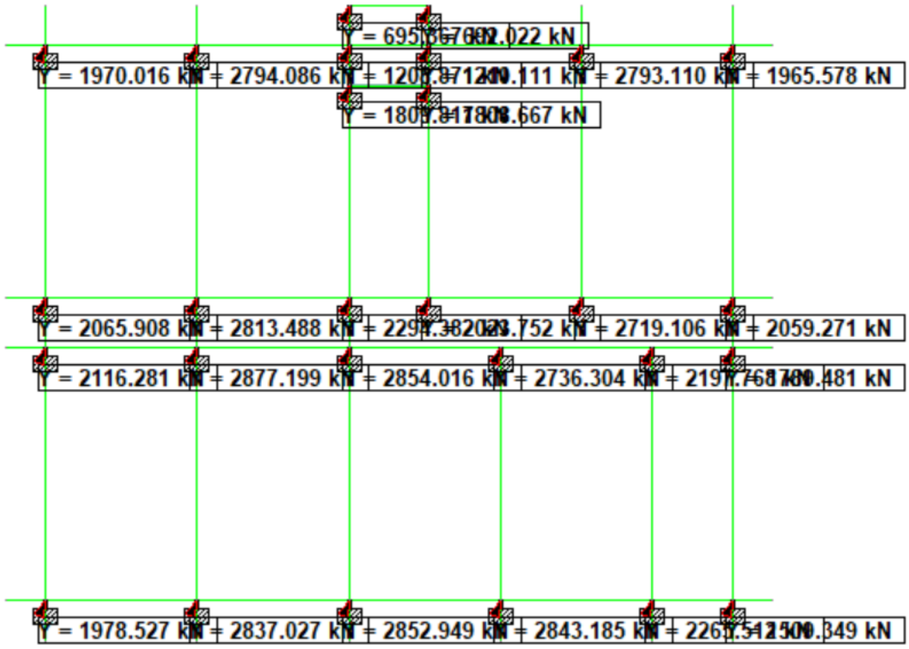

Figure 19 Y-direction reactions for slope 0^0 and zone V

Figure 20 Z-direction reactions for slope 0^0 and Zone V

- Maximum Bending moment on the structure: -

Table 21 Max B.M. for slope 0^0 and zone V

Mx	178.704 KN-m
My	0.107 KN-m
Mz	49.268 KN-m

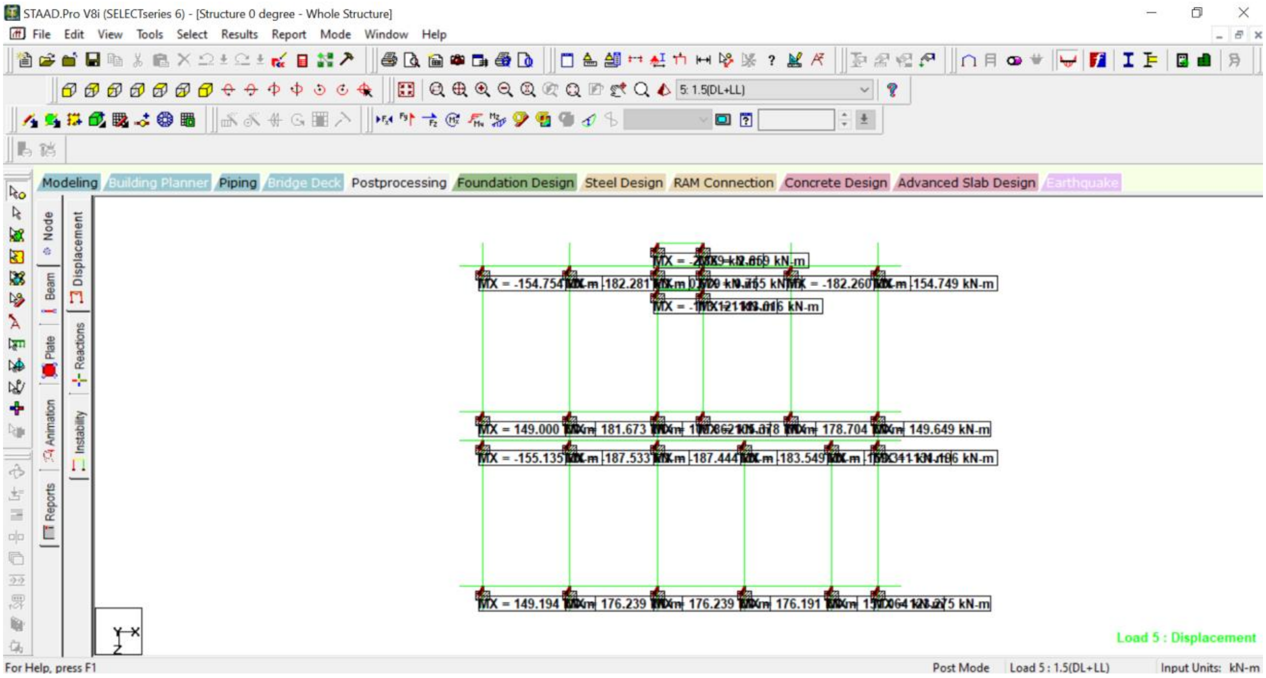

Figure 21 Bending moment in x-direction for slope 0^0 and zone v

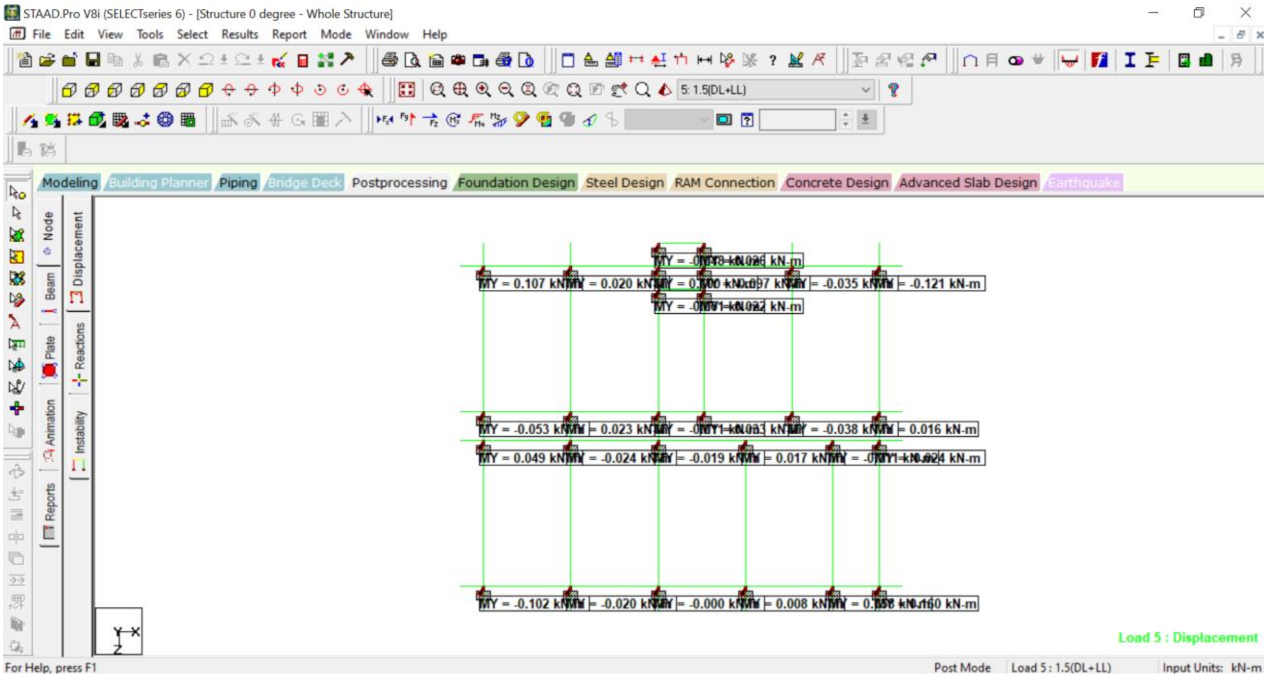

Figure 22 Bending moment in y-direction for slope 0^0 and zone V

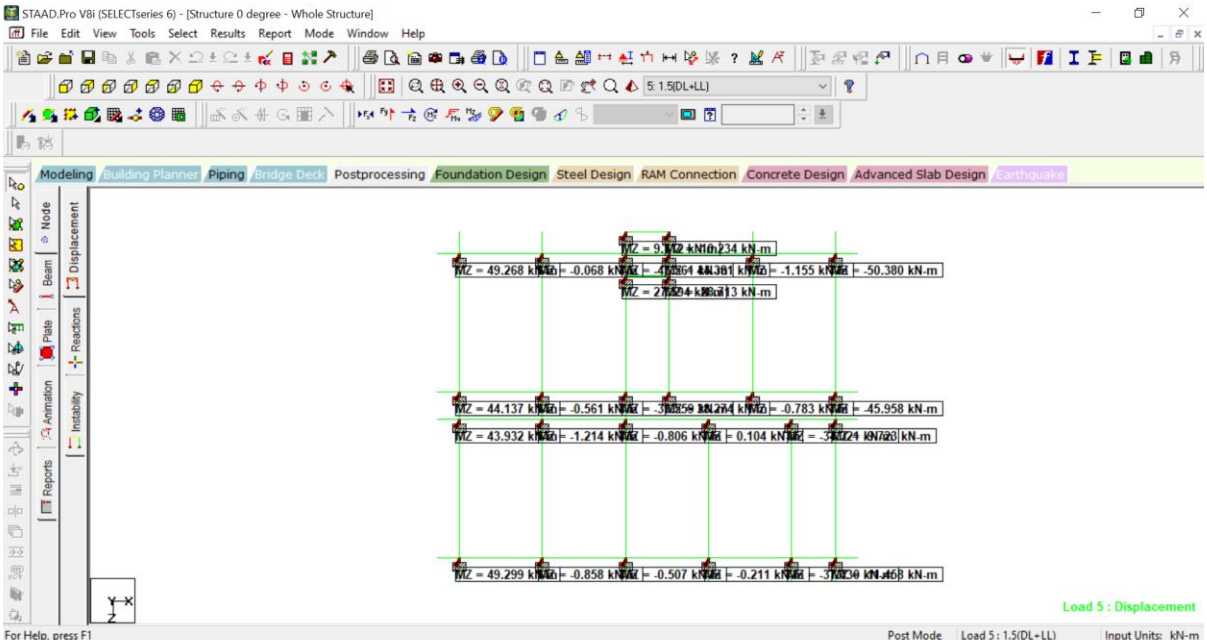

Figure 23 Bending moment in z-direction for slope 0^0 and zone v

- Maximum Lateral Displacements in the Structure: -

Table 22 Max displacement for slope $0^0$and zone V

Basement	34.309 mm
Ground Floor	37.992 mm
1^{st} Floor	39.992 mm
2^{nd} Floor	40.253 mm
3^{rd} Floor	40.935 mm
4^{th} Floor	41.423 mm
Roof	41.633 mm

- **Results for Structure SV10: -**

- Maximum reaction forces on the structure: -

Table 23 Max Rxn. for slope 10^0 and zone V

In X-direction	19.945 KN
In Y-direction	2955.382 KN
In Z-direction	69.905 KN

- Maximum Bending moment on the structure: -

Table 24 Max B.M. for slope 10^0 and zone V

Mx	-3.975 KN-m
My	5.816 KN-m
Mz	140.939 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 25 Max displacement for slope $10^0$and zone V

Basement	11.850 mm
Ground Floor	13.462 mm
1st Floor	19.930 mm
2nd Floor	27.097 mm
3rd Floor	33.629 mm
4th Floor	38.865 mm
Roof	42.440 mm

- **Results for Structure SV20: -**

- Maximum reaction forces on the structure: -

Table 26 Max Rxn for slope 20^0 and zone V

In X-direction	14.447 KN
In Y-direction	2871.255 KN
In Z-direction	46.826 KN

- Maximum Bending moment on the structure: -

Table 27 Max B.M. for slope 20^0 and zone V

Mx	166.721 KN-m
My	0.392 KN-m
Mz	5.279 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 28 Max displacement for slope 20^0 and zone V

Basement	10.451 mm
Ground Floor	12.246 mm
1st Floor	18.372 mm
2nd Floor	26.458 mm
3rd Floor	33.022 mm
4th Floor	37.547 mm
Roof	43.896 mm

- **Results for Structure SV30: -**

- Maximum reaction forces on the structure: -

Table 29 Max Rxn for slope 30^0 and zone V

In X-direction	26.833 KN
In Y-direction	2985 KN
In Z-direction	79.731 KN

- Maximum Bending moment on the structure: -

Table 30 Max B.M. for slope 30^0 and zone V

Mx	138.770 KN-m
My	6.982 KN-m
Mz	17.605 KN-m

- Maximum Lateral Displacements in the Structure: -

Table 31 Max displacement for slope 30^0 and zone V

Basement	9.399 mm
Ground Floor	10.910 mm
1st Floor	18.876 mm
2nd Floor	27.377 mm
3rd Floor	35.285 mm
4th Floor	41.736 mm
Roof	46.094 mm

4.6 CONCLUSION

In this chapter first we described our structures. Then the procedure followed to model and analyse these structures. Each model is separately modelled and description of its dimensions and material used is given. Also, the results from each structure are also mentioned like Displacements, Axial forces, Bending moments and Shear forces.

CHAPTER 5: FINAL RESULTS AND DISCUSSION

5.1 GENERAL

In previous chapter we have modelled the structures in Staad. Pro. And analysed them and found some important results. But in this chapter more precise results are collected. Final results which are important for our study are separated from previous chapter results. Also, the graphical presentation of the results is present in this chapter.

5.2 FOR ZONE I

Final results for Zone one are mentioned in the table below. The change in the Values of Max Axial force, Max Bending moment and Max Shear force with respect to slopes is present below.

Table 32 Final results for Zone I

For Zone I	0 degree	10 degree	20 degree	30 degree
Max Axial Force	2304.594 KN	2863.974 KN	2297.315 KN	2897.363 KN
Max Bending moment	144.427 KN-m	58.138 KN-m	132.758 KN-m	175.562 KN-m
Max Shear force	35.982 KN	85.705 KN	37.587 KN	19.892 KN

5.3 FOR ZONE V

Final results for Zone Five are mentioned in the table below. The change in the values of Max Axial force, Max Bending moment and Max Shear force with respect to slopes is present below.

Table 33 Final results for Zone V

For Zone V	0 degree	10 degree	20 degree	30 degree
Max Axial Force	2877 KN	2955.382 KN	2871.255 KN	2985.129 KN
Max Bending Moment	178.704 KN-m	140.939 KN-m	166.721 KN-m	138.770 KN-m
Max Shear Force	45.259 KN	69.905 KN	46.826 KN	79.731 KN

5.4 GRAPHICAL REPRESENTATION OF DATA

The data of results collected from the different structures which were modelled in previous chapter is graphically present here.

- **Displacement With respect to Floors: -**

- **For 0^0 Slope: -**

  Displacement of each storey with respect to the seismic zones for sloping ground 0^0 is present in the graph below.

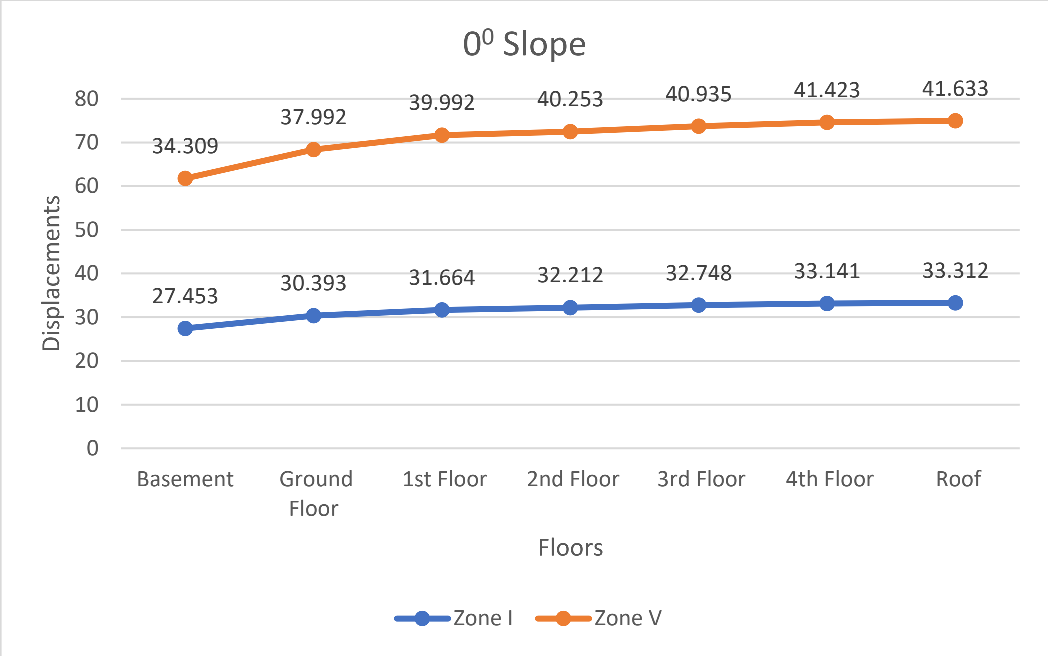

Figure 24 Displacement wrt. To Floors for slope 0^0

- **For 10^0 Slope: -**

Displacement of each storey with respect to Seismic zones on 10^0 sloping ground is present in the graph given below.

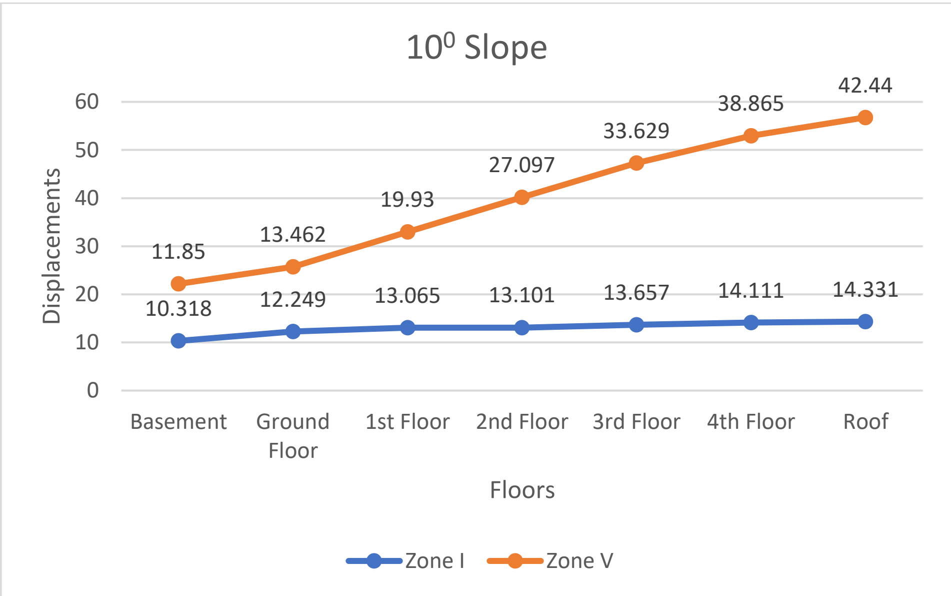

Figure 25 Displacement wrt. To Floors for slope 10^0

- **For 20^0 Slope: -**

Displacement of each storey with respect to Seismic zones on 20^0 sloping ground is present in the graph given below.

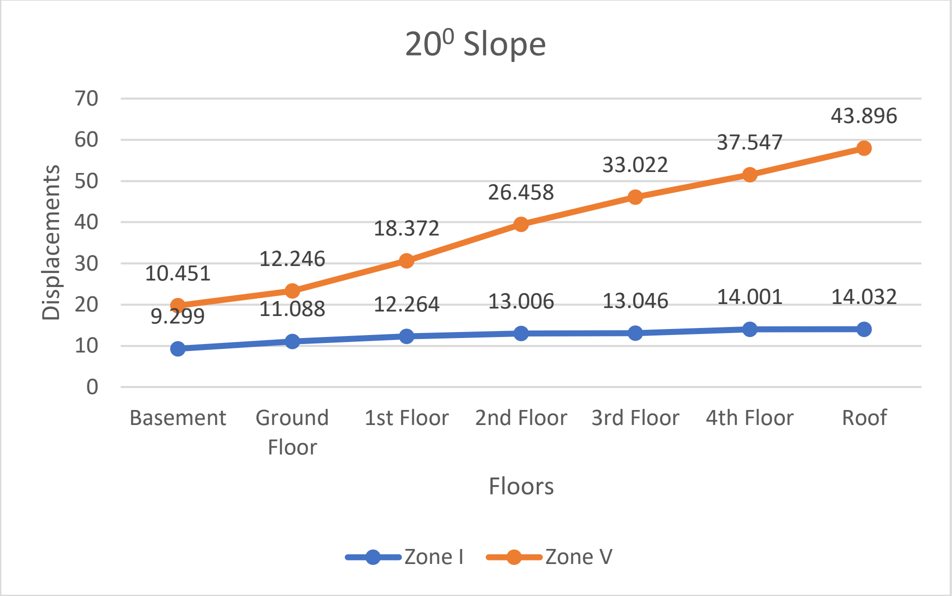

Figure 26 Displacement wrt. To Floors for slope 20^0

- **For 30^0 Slope: -**

Displacement of each storey with respect to Seismic zones on 30^0 sloping ground is present in the graph given below.

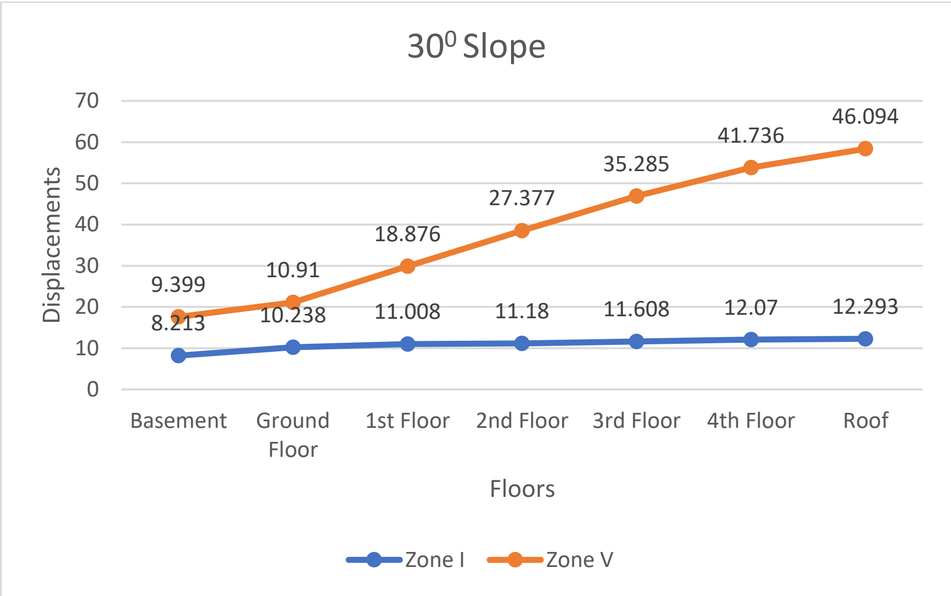

Figure 27 Displacement wrt. Floors for slope 30^0

- **Top Storey Displacement: -**

As shown in the graph below the displacements of the top floor for Seismic zone I and Seismic Zone V.

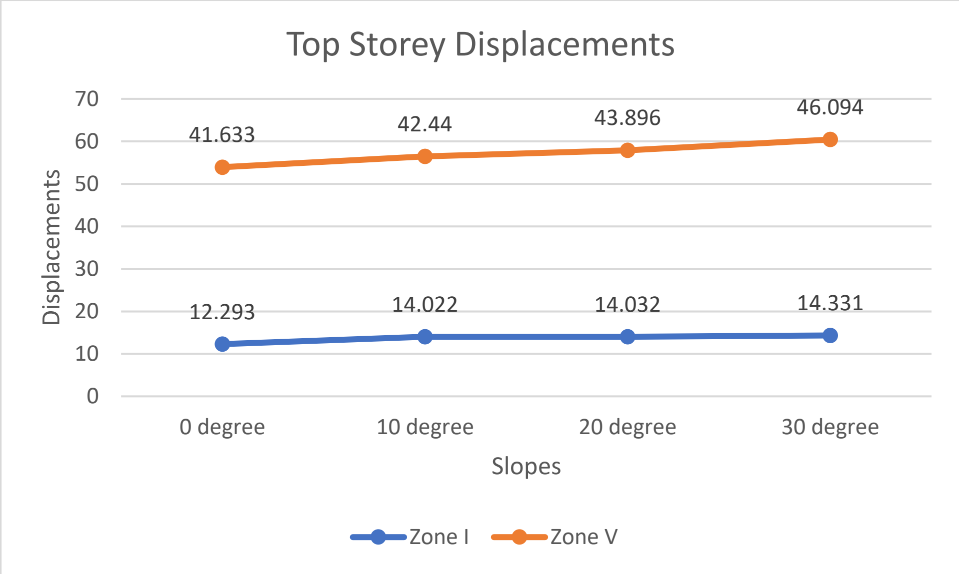

Figure 28 Top Storey Displacement

- **Max Axial force with respect to Slopes: -**

The graph given below shows the change in axial force with the change in slope from 0^0 to 30^0 for Seismic zone I and Seismic zone V

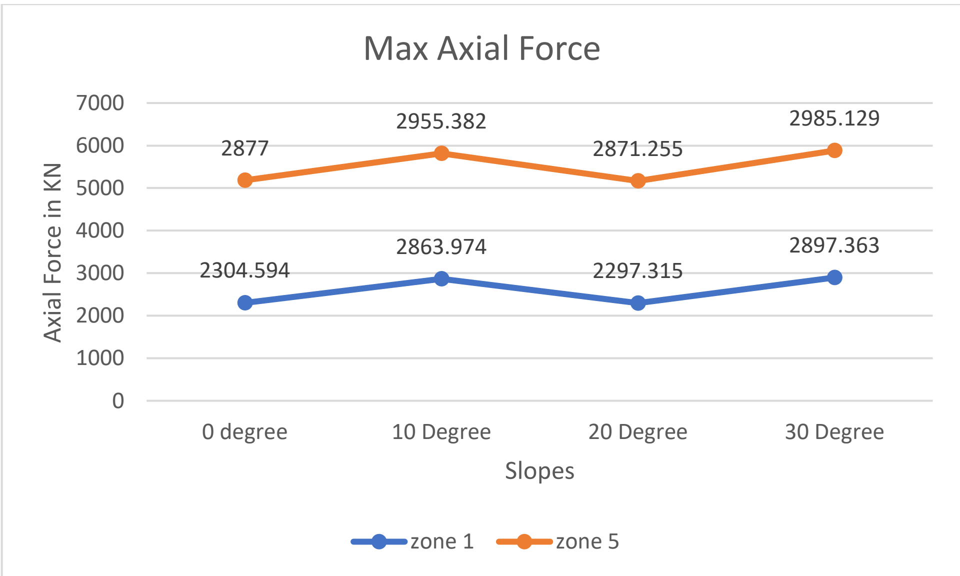

Figure 29 Max Axial force with respect to slopes

- **Max Bending Moment with respect to Slopes: -**

The graph given below shows the change in bending moment with the change in slope from 0^0 to 3^0 for Seismic zone I and Seismic Zone V.

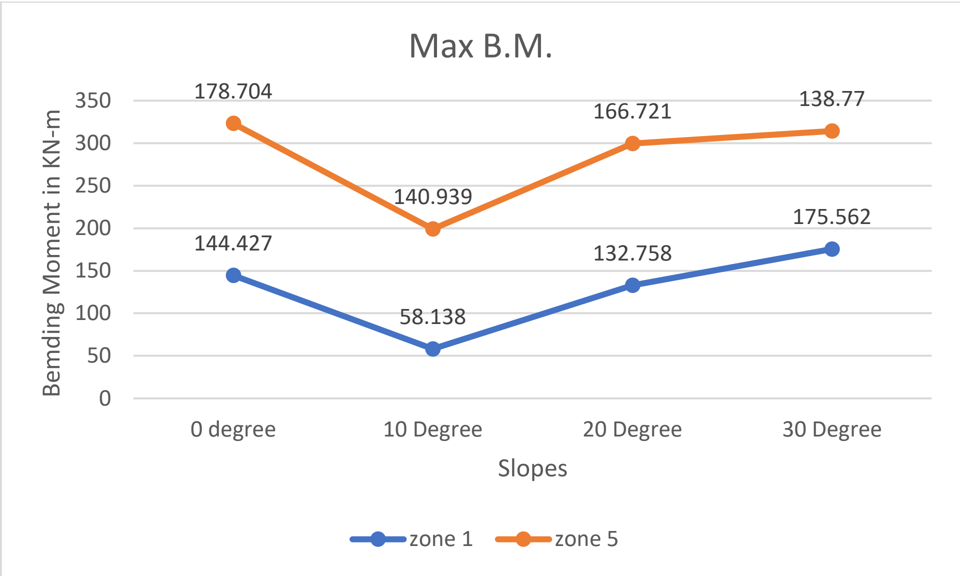

Figure 30 Max Bending Moment wrt. slopes

- **Max Shear force with respect to Slopes: -**

The graph present below shows the change in Max Shear force with the change of slope for Seismic zone I and Seismic Zone V.

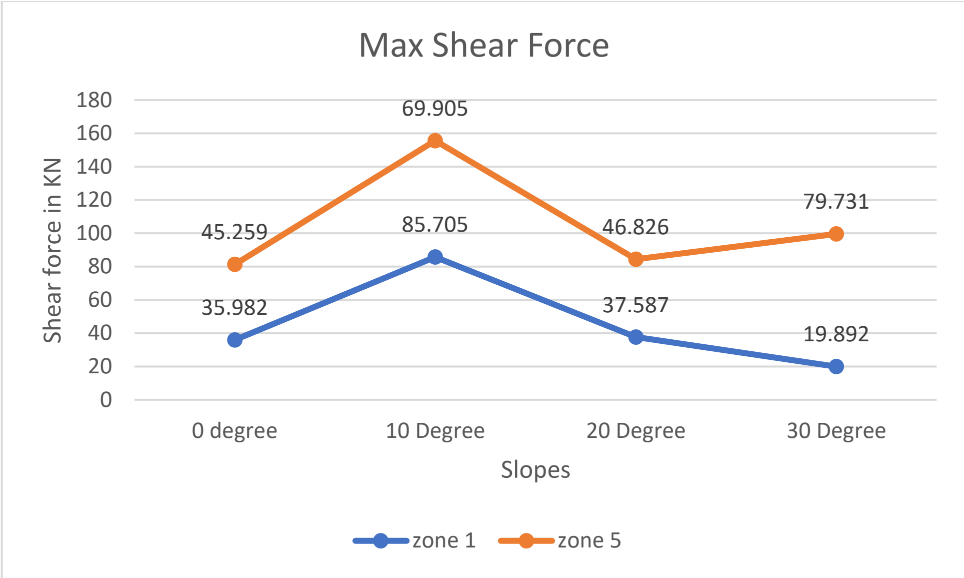

Figure 31 Max Shear Force w.r.t. slopes

CHAPTER 6: CONCLUSION

6.1 GENERAL

Previously we have modelled the (G+B+4) storey building. For four sloping grounds and two Seismic zones total of eight builds were modelled. For each building structure the results were collected. The precise final results are separated and graphically shown in previous chapter. In Conclusion we are going to see the percentage of change or how many times the building in Zone V is venerable than the Building in Zone I.

6.2 INCREASE IN DISPLACEMENTS

The displacement of structure with zero-degree slope and seismic zone I is increased by 29.87% in zone V. For structure on 10-degree slope, the displacement is increased by 2.4 times for zone V as compared to zone I. Similarly for structure on 20-degree slope, the increase in displacement is 2 times for zone V as compared to zone I. And for structure on 30-degree slope, the increase in displacement is 2.4 times in zone V as compared to zone I.

6.3 INCREASE IN FORCES

There is average 12.78 % increase in Max axial force for zone V as compared to zone I. Max Bending moment is increased by 22.36 % in zone V. Also, average increase in Max Shear force is 34.91% in zone V as compared to zone I.

REFERENCES

[1] Bureau of Indian Standards (2005). National Building Code, Bureau of Indian Standards New Delhi, 2005.

[2] National Disaster Management Division (2007). Ministry of Home Affairs Additional Provisions in Building Regulations/Byelaws for Structural Safety- In Natural Hazard Zones of India; IA.

[3] Bureau of Indian Standards (2000). I.S. 14804, Siting, Design and Selection of Materials for Residential Buildings in Hilly Areas-Guidelines, BIS New Delhi.

[4] Menon M., Kapoor M., Kohli K. (2009). India's Notified Ecologically Sensitive Areas (ESAs): The Story so far…, Kalpavriksh, Delhi & WWF-India, New Delhi.

[5] Mr Tamboli Nikhil Vinod (2017): Study of Seismic Behaviour of Multi-Storied RCC Building Resting on Sloping Ground.

[6] Kumar A. (2016). Impact of building regulations on Indian hill towns. HBRC Journal, 12(issue 3), 316–326.

[7] Dr. Ramya, A.V.S. Sai Kumar "Comparative Study on Design and Analysis of Multi-storeyed Building (G+10) By STAAD. Pro and Etabs Software's." IJESRT, ISSN: 2277-9655 (I2OR), (October, 2015)

[8] R. S. Malik, S. K. Madam, V. K. Sehgal "Effect of Height on Seismic Response of Reinforced Cement Concrete Framed Buildings with Curtailed Shear.

[9] Building Construction in Hilly Regions: Site Selection, Planning and Design, [Online] available from

[10] Deshmukh R., Earthquake consideration in hilly areas, Architecture Time Space & People, 7(9), September 2007.

[11] Satish Kumar and D.K. Paul., "Hill buildings configuration from seismic consideration", Journal of structural Eng., vol. 26, No.3, October 1999, pp. 179-185.

[12] IS:1893 (I)-2002., "Criteria for Earthquake Resistant Design of Structures" BIS, New Delhi.

[13] S.S. Nalawade., "Seismic Analysis of Buildings on Sloping Ground," M.E. Dissertation, University of Pune, Pune Dec-2003.

[14] IS: 13920-1993, Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces-Code of Practice, Bureau of Indian Standards, New Delhi, India, 1993.

[15] IS: 456-2000, Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi, India, 2000.

[16] BIS (Bureau of Indian Standards). (1987a). "Indian standard—Code of practice for design loads (other than earthquake) for buildings and structures (dead loads)." IS 875 Part 1, New Delhi, India, 1987.

[17] BIS (Bureau of Indian Standards). (1987b). "Indian standard—Code of practice for design loads (other than earthquake) for buildings and structures (live loads)." IS 875 Part 2, New Delhi, India, 1987.

[18] Bureau of Indian Standards (1995). I.S. 14243 Part 2, Guidelines for Selection and Development of Hill Sites, BIS, New Delhi.

[19] Bureau of Indian Standards (2000). I.S. 14804, Siting, Design and Selection of Materials for Residential Buildings in Hilly Areas-Guidelines, BIS New Delhi.

[20] Bureau of Indian Standards (2005). National Building Code, Bureau of Indian Standards New Delhi, 2005.

[21] Chief Architect (J&K) (2010). Building Regulations and Bye-Laws (Kashmir Division) 2010.

[22] Sachin Kumar Gandhi and Saleem Akhtar (2019), "Seismic Analysis of a RC building on sloping ground with shear wall at different position", AIP Conference Proceedings, https://doi.org/10.1063/1.5127154

[23] Ravindra Navale, Dr. Sandeep Hake & Pramod Khar male (2017), "Analysis of Unsymmetrical Building Resting on Sloping Ground by Dividing In 2D Frame", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072

[24] A. S. Swathi, G.V. Rama Rao & R. A. B. Depaa studies (2015), "Seismic Performance of Buildings on Sloping Grounds", International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization), ISSN(Online) : 2319 – 8753, ISSN (Print) : 2347 – 6710