SEISMIC DEMAND CALCULATIONS FOR AN ELEVATOR

A

Project Report

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

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

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To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN-173234

HIMACHAL PRADESH, INDIA

MAY,2022

DECLARATION

I hereby declare that the work presented in the Project report entitled **"SEISMIC DEMAND CALCULATIONS FOR AN ELEVATOR"** 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 **Dr. Sugandha Singh**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible fot the contents of my project report.

Madhvender Singh(181611) Abhay Kanwar(181618)

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"SEISMIC DEMAND CALCULATIONS FOR AN ELEVATOR"** 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 **MADHVENDER SINGH(181611) and ABHAY KANWAR (181618)** on May 2022 under the supervision of **Dr. SUGANDHA SINGH** (Assistant professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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We would like to express our sincere gratitude to Mr. Rohan Singhal (Assistant Professor) for his valuable guidance.

We would like to extend our sincere thanks to sir. We are highly indebted to all of them for their guidance and constant support.

Date:_______________

ABSTRACT

In past several years many disasters had occurred damaging the constructions as well as human lives. In a building best way to exit in case of emergency are elevators.

Elevators are non-structural components which gets damaged in case of earthquake as the shaking and disturbance caused by earthquake provides excess of loads along different directions and axis.

The case studies have been discussed in this report to analyse the damage and how it can be prevented. Among all the case studies several damages were there but in Taiwan(due to 921 and 1022 earthquakes) proper analysis was done on the elevators where five teams investigated the elevators and the elevator system.

Several reasons were there for the failure of elevators but it was found that among both of the earthquakes entanglements of CW derailment and governor ropes were the two most frequent damage patterns.

Among the case studies it can also be analysed in Chile most earthquake damage occurs as their traditional construction style don't use steel constructions due to which their constructions are unable to take much loads due to earthquakes.

Therefore, to deal with these situations proper construction measures must be taken and good quality material must be used properly.

After measures for a building elevators must be installed in such a way that they can bear the load of earthquake and it must bear all the shakings and forces.

In this report we have done analysis of a building and elevator in STAAD Pro, in which a elevator is designed by applying the several loads to it which are necessary for it's working.

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Introduction

1.1 Tectonic plates and Indian Tectonic plates:

Inside Earth there are tectonic plates. They are also called lithospheric plates. They are very giant or massive plates which are like slab of solid rock and irregularly shaped and therefore they are generally composed of both continental lithosphere and oceanic lithosphere.

Continental and oceanic lithosphere varies only for their thickness between them. Oceanic lithosphere has thickness typically about 50-100 km,whereas continental lithosphere is thicker than oceanic lithosphere and is about 150 km thick. Continental lithosphere consists of about 50 km of crust and 100 km or more of the uppermost mantle.

The tectonic plates are the moving plates which moves in three types of tectonic boundaries, which are-

- **Convergent-** in this case two plates move into one another.
- **Divergent-** in this case two plates move apart from each other.
- **Transform-** in this case two plates move sideways with respect to each other.

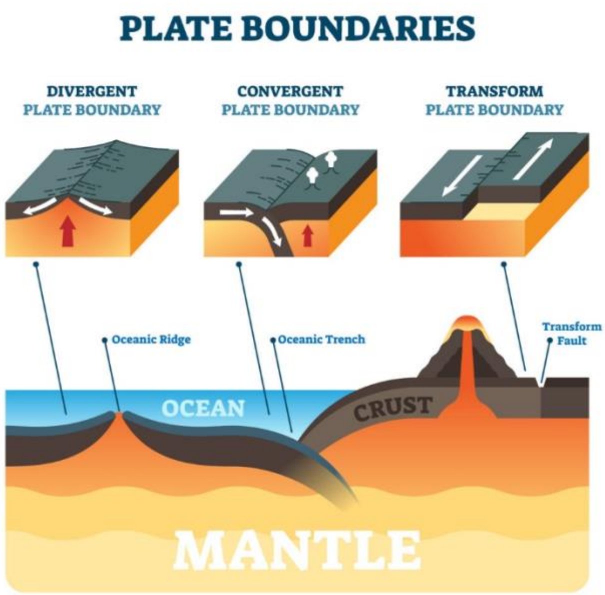

Fig 1.1 *Tectonic plate boundaries*

These are the causes of seisemic activities like earthquakes.

The Earth's crust is made up of 15 to 20 shifting tectonic plates that look like bits of broken shell resting on hot, molten rocks in the mantle and fitting tightly against one another.Therefore, India is bounded by 4 major tectonic plates:

- **The Eurasian plate-** This tectonic plate is bounded for the North.
- **The Australian plate-** This tectonic plate is bounded for the South East region.
- **The African plate-** This tectonic plate is bounded to the SouthWest region.
- **The Arabian plate-** This tectonic plate is bounded to the West.

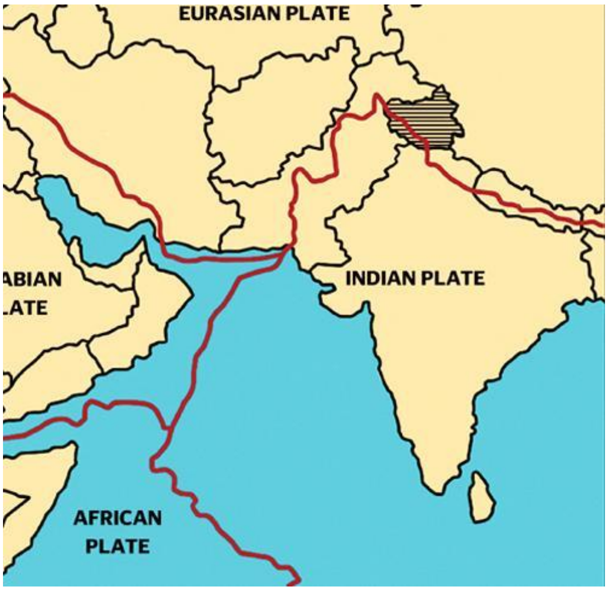

Fig 1.2 *Geographical view of Indian tectonic plates*

The Indian plate or the India plate is a minor tectonic. This plate is straddling the Equator in the Eastern Hemisphere. It was originally a part of the ancient continent of Gondwana. Approximately,100 million years ago India broke away from the other fragments of Gondawa and began moving north.

Tectonic plates are the reason of occurance of seismic activities. The biggest earthquake recorded in India is known as “Gujarat Earthquake” or “ Bhuj Earthquake” which was a 7.7 magnitude earthquake. Gujarat lies between the plate boundary of The Indian plate and The Eurasian plate.

1.2 Earthquake and Damage

The movement of tectonic plates sometimes makes contraction or slip between them due to which plates stress across their edges when overcomes friction releases energy in form of waves. These waves travel through the Earth’s crust and causes sudden shaking which we feel and we call as an earthquake.

The energy released which cause an earthquake can by released due to several reasons such as gravity, chemical reactions etc.

Occurance of seismic activities and earthquakes sometimes doesn’t make any major impact on the constructions and society but varying to high magnitude sometimes earthquakes make a huge disaster not only to buildings but to lives of people as well. Several damages had already occured due to earthquakes in several parts of the world as well as in India also.

1.2.1 Seismic waves

Large amount of energy generated by the earthquake starts travelling through the Earth's layers as seismic waves in all directions which usually is reflecting and refracting in nature at each interface . there are mainly four types of waves .Primary waves and Secondary waves which are mainly known as body waves ,while Rayleigh &Love waves are the surface waves. P waves are the primary body wave and is the first wave detected by seismographs, and are able to move through both liquid and solid rock .s wave -secondary wave that oscillates the ground perpendicular to the direction of wave travel and they usually travel about 1.7times slower than the p waves liquid doesn't sustain shear stresses . ray leigh waves have surface waves that move in an elliptical motion, producing in both horizontal and vertical directions while, love waves surface waves that move parallel to the earth surface and perpendicular to the direction of wave propogation.

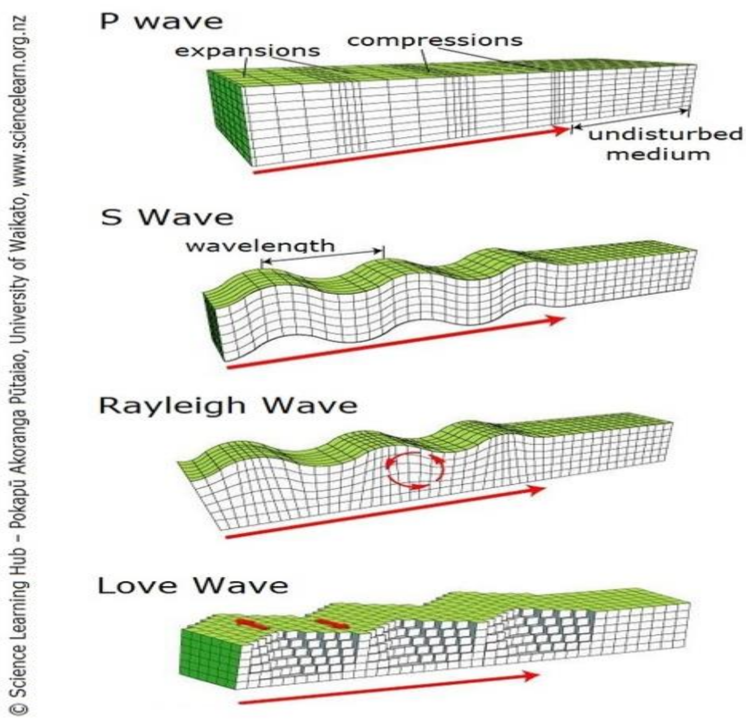

Fig (i) *Seismic Waves*

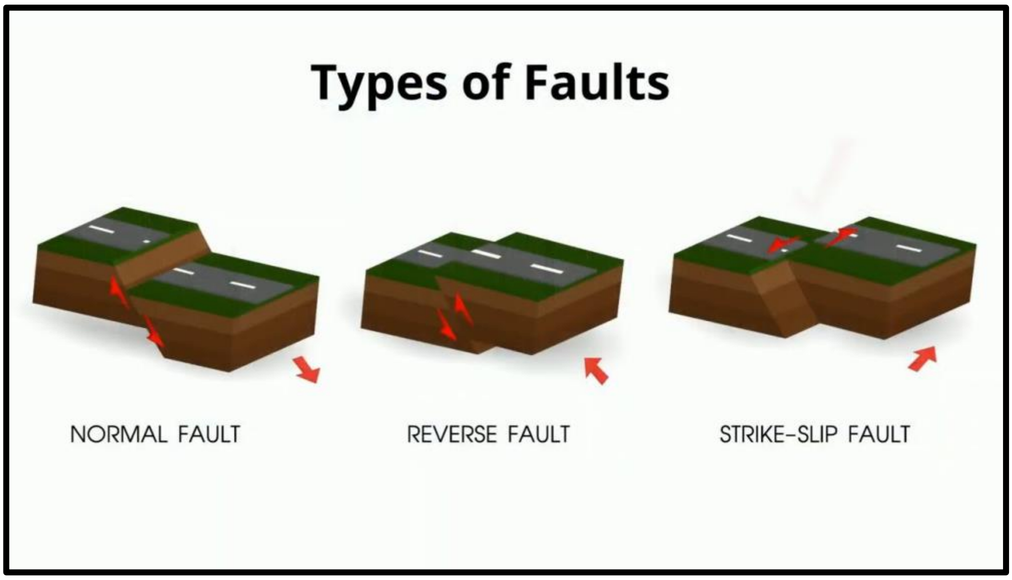

Fig 1.2.1 *Three types of faults caused by earthquakes*

The Bhuj earthquake which occured on 26 January, 2001(52nd Republic Day of India) was the biggest earthquake recorded in the history of India. It was a 7.7 magnitude earthquake which led to a very great damage to the society, buildings as well as people. More than 20000 people died and more than 150000 people were injured during the earthquake and 340000 buildings were damaged including houses, huts and several multi story buildings like hospitals, schools etc.

A impact on a building due to earthquakes occurs as when a earthquake hits a structure it generates inerta force which has a very destructive impact on building by causing deformations, horizontal and vertical shaking. By this when the building is unable to retain its original shape the structure fails.

Fig 1.2.2 *Damage caused due to Bhuj earthquake*

Not only the outer structure or the major part of structure is damaged but a earthquake has a great damage to components which are not major parts of building, which are non-structural components such as ceilings, elevators etc. Falling of ceiling in case of earthquake can risk life as well as unfunctionality of elevators can risk many lives at same time.

During this situation the fastest method to exit a multi story building are elevators. But when a seismic activity occurs with a great magnitude than the impact on the building also have as great chance to destroy elevators installed in the building.

Elevators must be made in such a way that they must survive in critical conditions and must work properly in serismic conditions and provide people a safer and faster exit from the building which can always benefit people to rescue themselves.

After concluding all the measures for a multi story building to bear all the loads of whole structure the place where elevator car and elevator system has to installed could be made in such a way that it could bear conractions, shakings, and vibrations along all axis and have minimum impact from the building dur to seismic activity.

Many studies have been conducted after the occurance of earthquake, in India as well as all over the world in which many people were killed as they didn't get any faster exit and the damage to non-structural components were more. Three cases have also been discussed.

1.3 Overview: Case Studies:

1.3.1 Taiwan Case Study:

Two earthquakes occurred in 1999 which are known as the 921 and 1022 earthquake, near large population in Taiwan. In this a study was conducted in Chia-Yi city. Both the earthquakes were very strong and they registered strong ground motion. In this the impact due to earthquakes are analysed and the factors are considered due which the elevator and elevator system failed. It was observed that the elevators were not properly constructed accoding to the seismic conditions.

Chia-Yi city was chosen to analyse the impact of earthquake on elevator because the city is large enough to have an ensemble of elevators and the ground motions were not big enough to create great structural damage. As well as, this city had a population of about 260,000 and it was 10 km away from the 1022 eartquake epicenter and 55 km away from the 921 earthquake epicenter.

There were several reasons due to which the elevators and the elevator systems failed to survive during 921 and 1022 earthquake like-

1. Damage to CW shoes.

2. Damage to CW rail.

3. CW cage derail.

4. Control cable damage.

5. Governor rope entanglement.

6. Speed governor damage.

7. Damage to the extrusions in the hoistway.

8. Compensating chain damage.

CW derailment and governor rope entanglements were the two most common damage patterns among the recorded elevator damage in both earthquakes. In Chia-Yi city, there were around 1600 elevators. In both earthquakes, the overall number of elevators destroyed was roughly equal..

Another reason for elevator failure in Taiwan was an insufficient seismic code. Because many elevator systems in buildings were set up so that when they weren't in use, the passenger car had to wait on the first floor. As a result, several CW cages were on the top floor when the earthquake struck in 921. As a result, the most of the CW damage occurred on the building's highest storey.

The goal of this study is to show that certain variables or provisions must be considered before establishing an elevator in a specific place. All essential variables that are needed to run an elevator normally and properly must be assured that they are capable of bearing all seismic loads and shaking induced by the earthquake..

Fig 1.2.3 *Damage due to 921 and 1022 earthquakes*

1.3.2 Case Study 2: Barlavento Algarvio’s Hospital

This case study describes an elevator system installed in the Barlavento Algarvio's Hospital in Portimão. Here, according to EC-8. to analyze the response of the elevator guide rail system when requested to a seismic action.

- **EC-8:** “EC-8” is defined as 'Eurocode 8'. It is a design of structure for earthquake resistance.
  It describe how to design structure in seismic zones. It was approved by European Committee for standardization(CEN),on 23 April 2004. Its purpose is to ensure that in the event of earthquake.

This study described a multi-story building of hospital in which the building is divided into 7 independent structural bodies and the object of study is the highest one with 7 upper floors and two buried and it is the one with vertical accesses (stairs and elevators).

Reinforced concrete frames of C20/25 concrete grade and C12/15 for the foundations. The motive for this analysis is not to evaluate if the elevators that were installed in the hospital are well designed, but rather to study its methodology referred by EN81-77.

- **EN81-77 :** refers to special provisions and safety rules for good passenger lifts where these lifts are permanently installed in buildings.

Six elevators were installed on the block which were electrical traction lifts with machine rooms devided into two groups, where bigger one are for passengers and strechers and the smaller one for passengers only.

The numerical model was performed in the SAP 2000 where the structural elements (pillars, beams and walls) were modeled as frame elements.

- **SAP 2000:** SAP 2000 stand for Structural “Analysis Program 2000”. It is a structural analysis and design software produced by CSI(Computer and Structures, Incorported. CSI is a structural and earthquake engineering company.

The interaction of the structural walls with the remaining structure is carried out by connecting it with rigid sections (with a very high modulus of elasticity).

1.3.3 Case Study 3: Chile Earthquake-

"Chile earthquake 2010" was the earthquake which occurred on 27 february, 2010. This earthquake occurred off the coast of south-central Chile. This earthquake caused widespread damage on land as well as it initiated a tsunami that devastated some coastal areas of the country. This disaster overall caused a death ratio of around 500 people.

It was a very heavy earthquake with magnitude of 8.8 and the epicenter of the earthquake is located around 325 km southwest of the Chilean capital of Santiago.

Buildings in the city has been constructed strictly under building codes instituted in the wake of 1960 earthquake and had been revised several times during 1990s due to which the buildings in the area has sustained damage but still around 400,000 homes were destroyed.

All engineered buildings in the area survived well in the area as compare to others. To bear the seismic actions in Chile, the Chilean Code(NCH 433 1996) is used.

- sites, using soil parameters mainly associated with their resistance, from a seismic point of view to deal earthquakes. This code was only operative before the 2010 eathquake.

The Chilean Code (NCh433 1996) permits the use of either equivalent static load analysis or dynamic spectral modal analysis for the computation of the seismic design base shear.

Fig 1.2.4 *Disaster in Chile due to earthquake*

1.3.4 Performance of steel buildings in Chile:

Therefore, steel buildings survived well during the disaster but steel construction are not common in Chile to cost effectiveness and are more relevant to other construction materials.

Pallets were used to construct temporary supports for the structure that was on the verge of collapsing. At the bottom chord, near nodes, and some distance from the columns, local buckling caused considerable deformation of the chord element. Both the columns and an infill braced the undamaged masonry wall between the trussed columns for out-of-plane movement.

In the perpendicular direction, however, the in-filled masonry and boundary element columns completely failed in the out-of-plane direction due to the top concrete beam's lack of lateral support. The construction was constructed in the mid-1960s with exceptional detailing for earthquake resistance.

1.3.5 Performance of Non-Structural elements in Chile:

In Chile, brick masonry walls are commonly used as non-structural walls, and people use them as infill and partition walls in concrete and steel frames for both older and newer buildings. This is also why nonstructural elements such as brick infill walls, suspended ceilings, partition walls, architectural features, and other operational and functional components of buildings suffered substantial damage.

As these walls interact with the enclosing frame parts, they frequently experience diagonal tension cracking and (or) diagonal compression crushing.

As a result, in most new buildings with shear walls, the brick infill walls preserved their integrity. They suffered considerable damage in structures with poor drift control.

Chapter-2

Methodology

Earthquakes makes critical emergency situations for the people inside a building. As the fastest way to exit a building is elevator, they must be made in way that they provide safest exit or entry for the people inside the elevator.

Three case studies:

- Taiwan Case Study
- Barlvento Algarvio's Hospital
- Chile Earthquake

have been described on how earthquakes made damage to the constructions and people.

Damage was analysed on the basis of contruction, material used etc.

The damage to the buildings must be lesser and elevators must provide and safe source of exiting a building. All the loads and accrelations caused by an earthquake must to stablised to make elevator work properly under emergency conditions.

2.1 Earthquake:

An earthquake is the sudden movement on Earth's surface caused when two tectonic plates of earth collides with each other or when they have slip on between each other.

On greater scale earthquakes are very disastrous and have greater damage to contructions and people. Several earthquakes have been occurred which had a great damage overall.

The destructions caused in a earthquake occurs in faults. Mainly they are classified as:

- **Convergent:**
- **Divergent:**
- **Transform:**

Most of the earthquakes occurs among the geologic faults which are a kind of narrow zones where rock masses moves in relation to one another. In the world the major fault lines are are located at the corner or fringes of the huge tectonic plates.

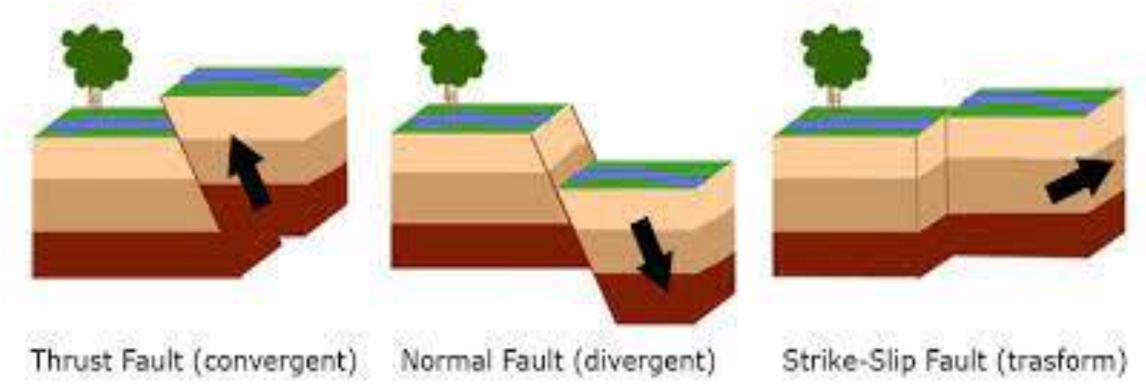

Fig 1.2.5 *Thee types of tectonic faults*

2.2 Causes of Earthquakes:

There are several reasons behind a earthquake to occur. Main reasons that could be targeted for a earthquake could be as:

- **Coinciding the margins of Tectonic plates.**
- **Natural forces inside Earth's crust.**

2.3 Case Study 1: Taiwan Case Study

ABSTRACT :

There were two major earthquake at Taiwan on the year 1999 which were known by the 921 and 1022 earthquakes. The earthquake affected area was densly populated. There were mainly structural damage and also additional equipment damages. After the earthquake the research were conducted where Field investigation were done at Chia-yi city, both Earthquakes were strong here. In this investigation elevator service were interviewed and damage to the elevators were analyzed. The research examines the

cause of these damage types and proposed several measures to improve seismic capacity of elevators.

Researches or Studies done to understand the elevator damage:

-Chia-yi city was taken to study the elevator damage.

• Cha-Yi was having a population 260,000 and is about 55km away from 921 and 10km away from 1022 epicenter.

- City was chosen because of its large area and have an assemblence of elevators. The structural damage were mild and at the end of study we got knowledge of elevator demage and causes behind it.

MAJOR DAMAGE MECHANISMS OF ELEVATORS:

It was noticed that several major component were vulnerable to earthquake, following are the critical items in an elevator hoistway.

- CW cage Derailment.

• CW Block Detachment from the CW Cage.

- Damage to Landing Switch
- Control Panel Failure.

CONCLUSIONS:

1) The Insufficient seismic design should be improved.
2) The smallest PGA to initiate CW Cage derailment and governor rope were found from two earthquakes. It should be used for installment of seismic switches.
3) CW block detachment and CW cage should be
considered as most dangerous damage to human lives.

2.4 Case Study 2: Barlavento Algarvio's Hospital:

An elevator system was installed in Barlavento Algarvio's Hospital in Portimao which is located in Portugal. It was done to analyse the response of the elevator guide rail system when requested to a seismic action according to EC-8.

"EC-8" is defined as 'Eurocode 8'. It is a design of structure for earthquake resistance. It describe how to design structure in seismic zones. It was approved by European Committee for standardization(CEN),on 23 April 2004. Its purpose is to ensure that in the event of earthquake.

The motive for this analysis is not to evaluate if the elevators that were installed in the hospital are well designed, but rather to study its methodology referred by EN81-77.

EN81-77 : refers to special provisions and safety rules for good passenger lifts where these lifts are permanently installed in buildings.

Design and Structure:

Six eleators were installed on the block which were electrical traction lifts with machine rooms devided into two groups:

- Bigger one for passengers and strechers.
- Smaller one for passengers only.

Each elevators consisted of two sets of T-section guide rails that guide the car (T125B and T82A) and the counterweight (T70A and T50A).

The guide rails' total length was 33.8 meters and composed of mostly regular spans of 2.9 meters.

The vertical distance between the latter and the cab is 3.186 meters and 3.220 meters for the counterweight.

Car and counterweight guide rails were modelled with vertical frame elements.

The brackets were expressed by rigid bass of square section of dimension 0.1m*0.1m. For this the structural walls have been devided into several blocks to that theaxis coincides and the connection is made.

To analyse the X and Y directions for load situations were assumed during a seismic actions.

- For X direction both guide shoes may contact with the guide rails.
- For Y direction the car or counterweight can collide with the rails on both upper and lower guide shoe levels.

2.5 Case Study 3: Chile Earthquake-

This case study describes about the Chile earthquake which occured on 27 February,2010. In this case study the performance of Non-Structural components is evaluated. It was a magnitude 8.8 Maule Earthquake for which a team of structural engineers and aseismologist from Canada initiated reconaissance in Chile.

In Chile Steel construction is not commonly preffered by the people. The team that conducted reconnaissance in Chile also visited several other places also, like Santiago, Curico, Talca and Chillan along Highway 5 etc, where the peak ground accelerations of this subduction earthquake in the east-west and north-south directions were 0.65g and 0.78g in concepsion and melipilla respectively.

Performance of Non-structural elements-

Extensive damage was sustained by Non-Structural elements including masonry infill walls. The use of brick masonry walls as Non-Structural component is common in Chile. Older and new buildings also utilize this. These walls often suffer diagonal tension cracking and diagonal compression crushing as they interact. The non-Structural elements on the façade of the building were built using low density concrete, with polystyrene beats mind with concrete.

- The wall developed significant diagonal tension cracking while also experiencing the crushing of brick masonry under diagonal compression. It was observed that the brick infill walls maintained their integrity in most new buildings with shear walls, when used as exterior cladding the masonry walls either suffered out of plane failure or suffered damage along with the structural elements behind them, posing falling hazards

- Supreme Court building in Talca, which had a shallow reinforced concrete beam over the entrance as an architectural feature. The beam failed due to lack of sufficient anchorage to the building, and triggered additional damage to facade.

- The same building experienced extensive damage to the glass windows, ceilings and other contents. Similarly, a six story office building in Talca also suffered significant damage to its Non-Structural elements.

- The damage was more proned to buildings with little bracing elements and drift con

3.1 Objective of the present work

The primary objective of this research is to construct a suitable seismic building on staad pro software and to investigate impact of seismic activity on the structure The structure is constructed on Staad pro.

3.2 Structure of the building

This is the basic structure of our building which we made on staad pro software

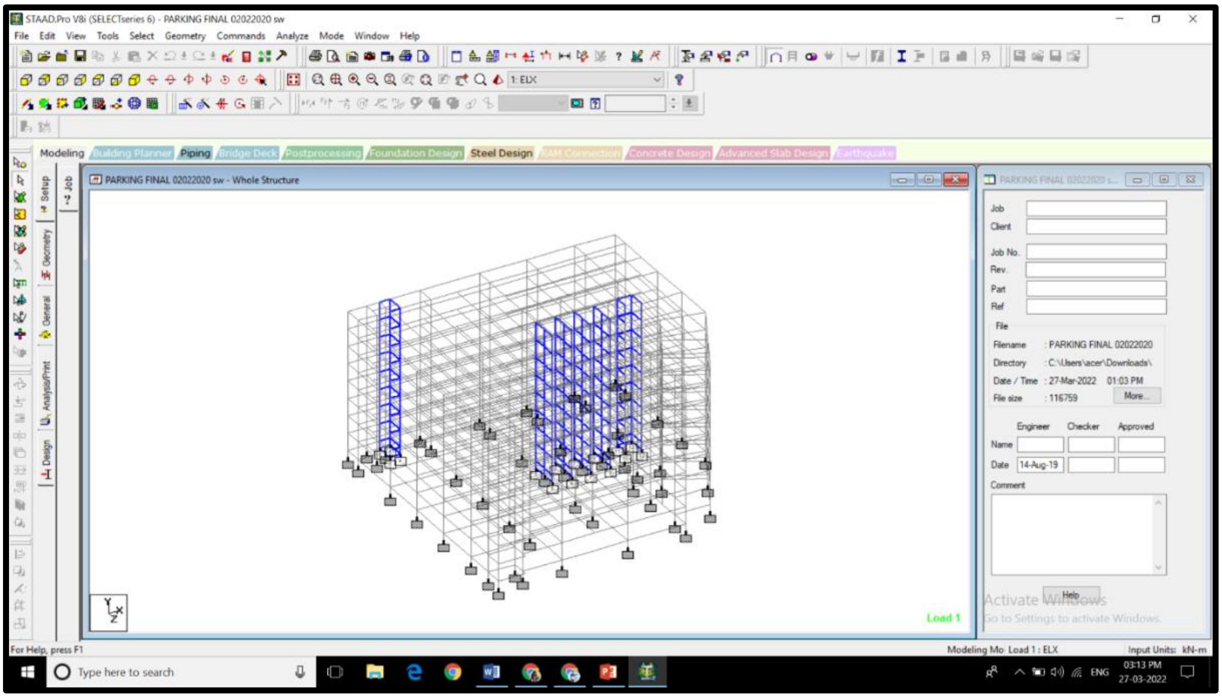

Fig 1.2.6 Structure of 10 storey building

3.3 3-d view of the building

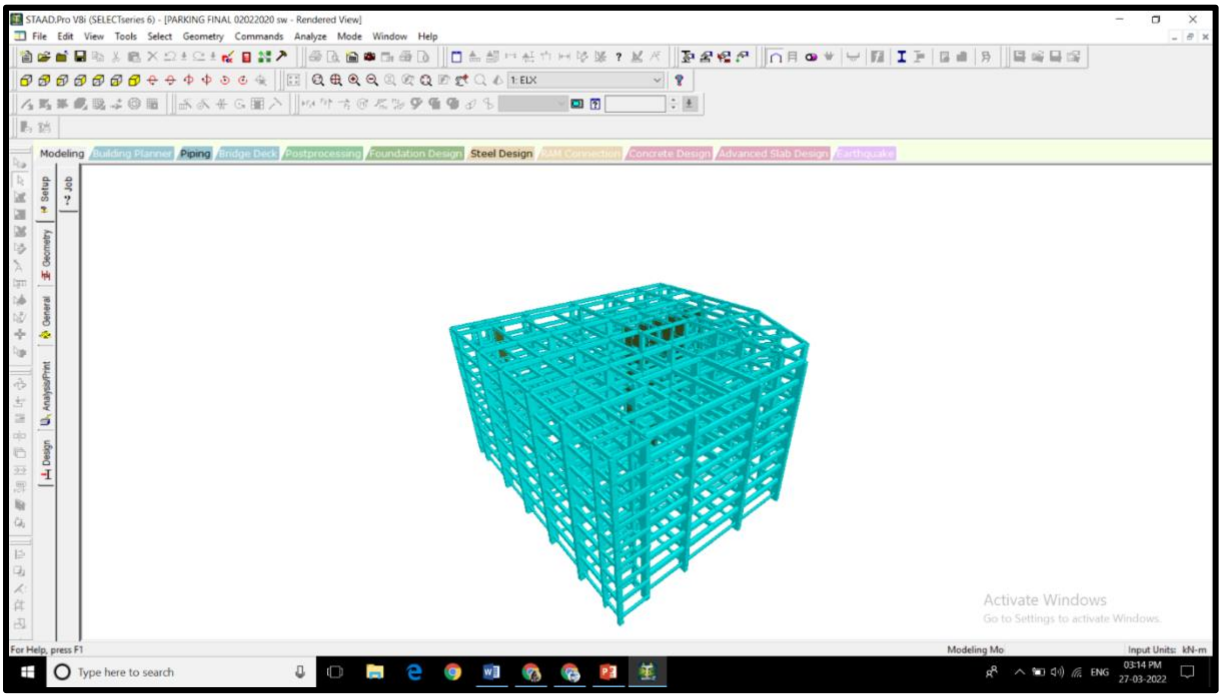

Fig 1.2.7 *3-d view of the building*

Chapter-4

RESULTS

4.1 Bending Moment Diagram

Bending moment diagram-it is the reaction that has been induced in a structural element when an external force or moment is applied to the element , causing the element to bend.

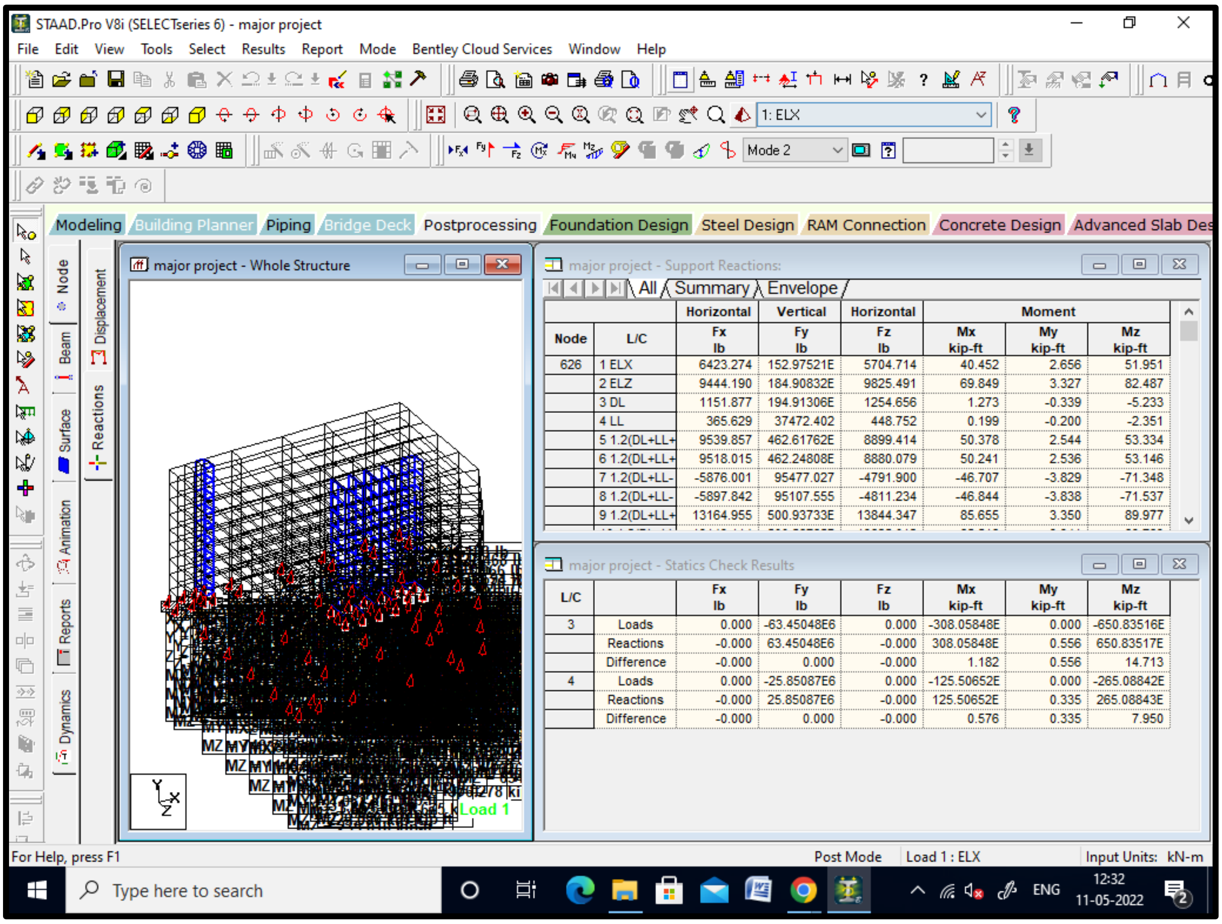

Fig 1.2.8 Bending Moment Diagram

4.1 Bending in Z and Y axis :

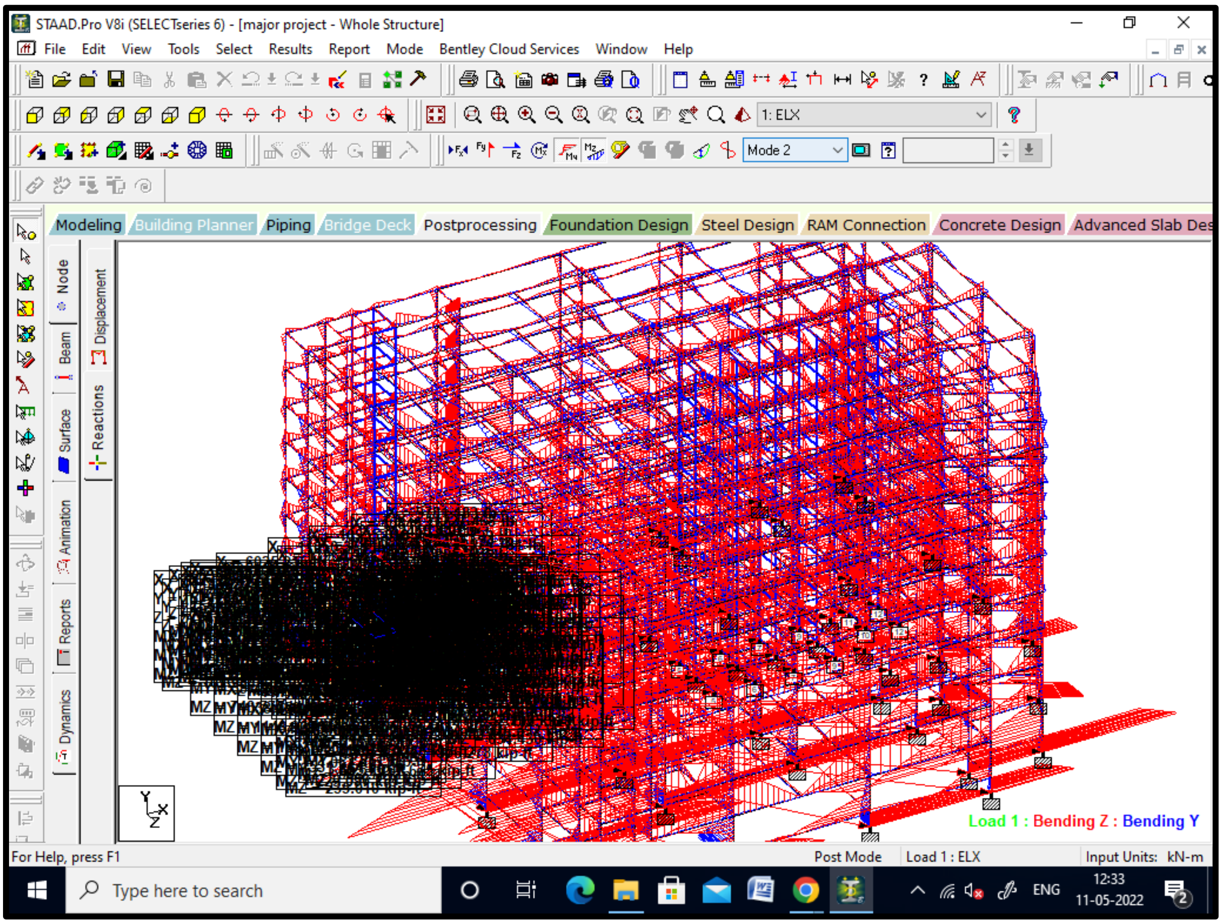

Fig 1.2.9 Bending in Z and Y axis

4.3 Displacement :

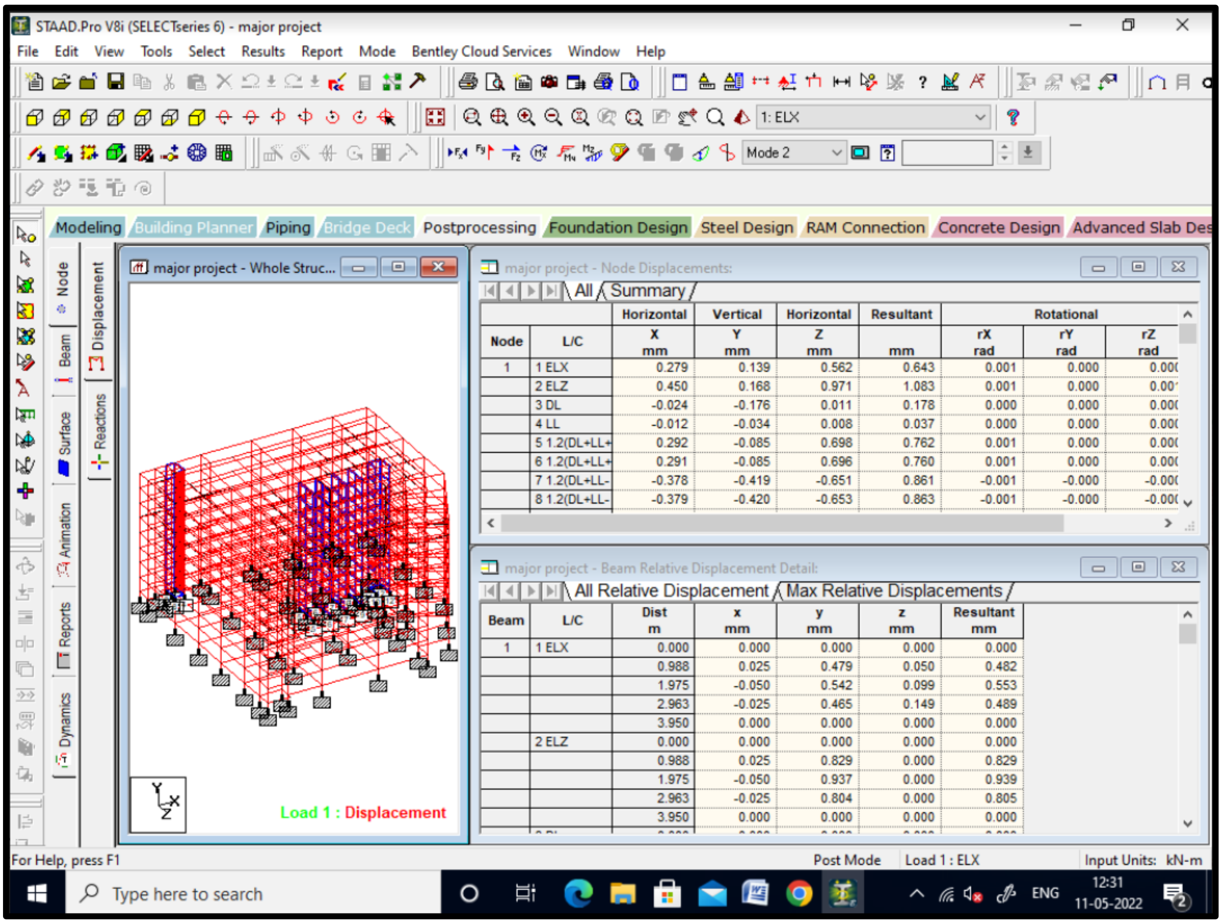

Fig 1.2.10 Displacement Diagram

4.4 Shear diagram :

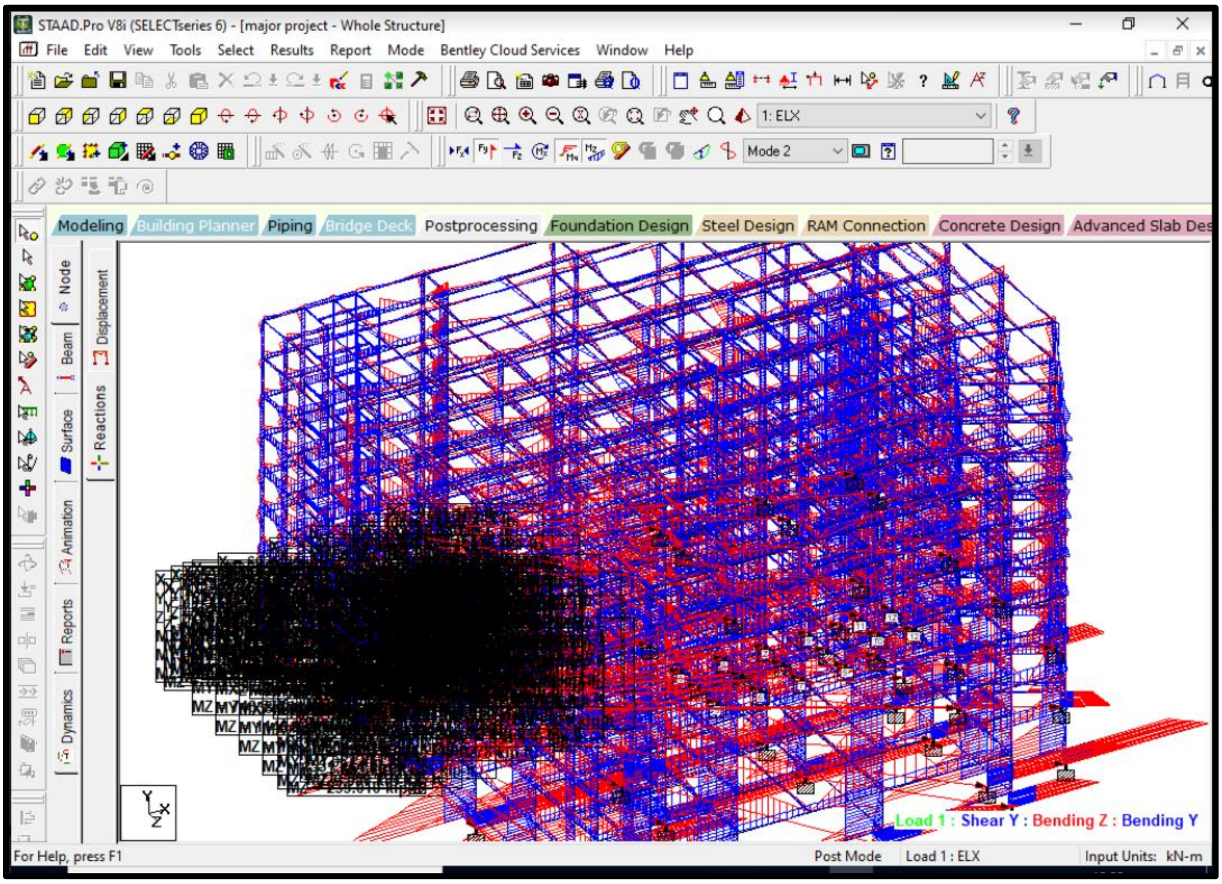

Fig 1.2.11 Shear Diagram

4.5 Axial forces :

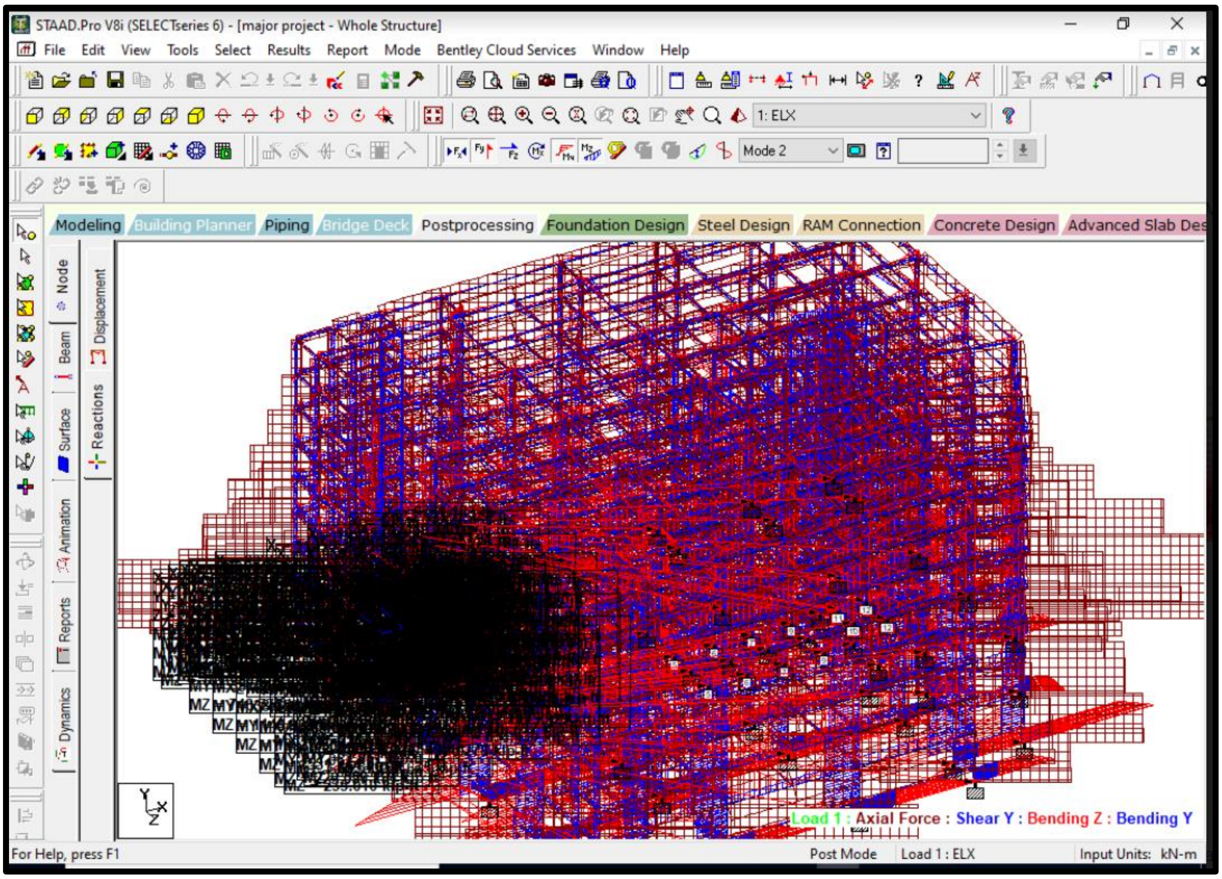

Fig 1.2.12 *Axial Forces*

4.6 Torsion diagram :

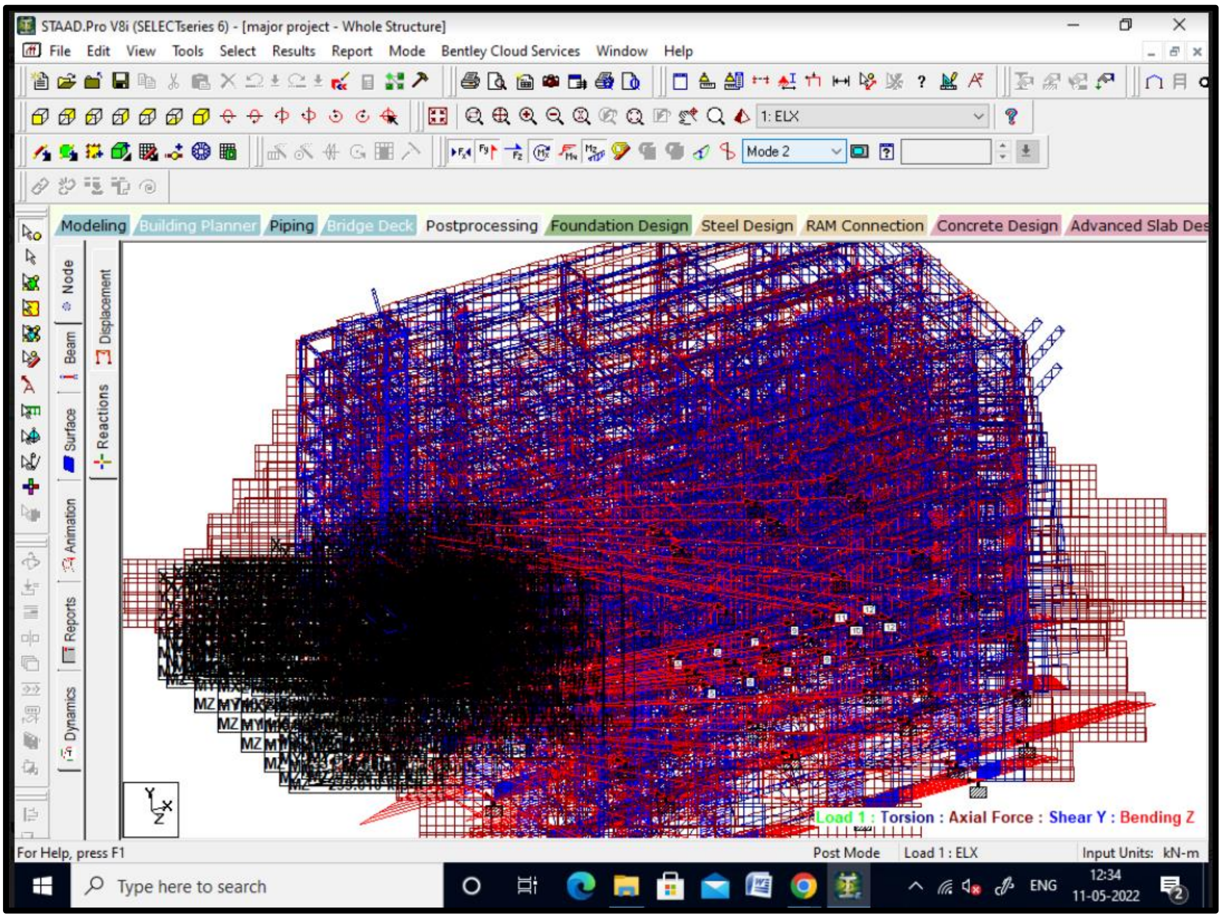

Fig 1.2.13 Torsion Diagram

4.7 Time vs acceleration graph :

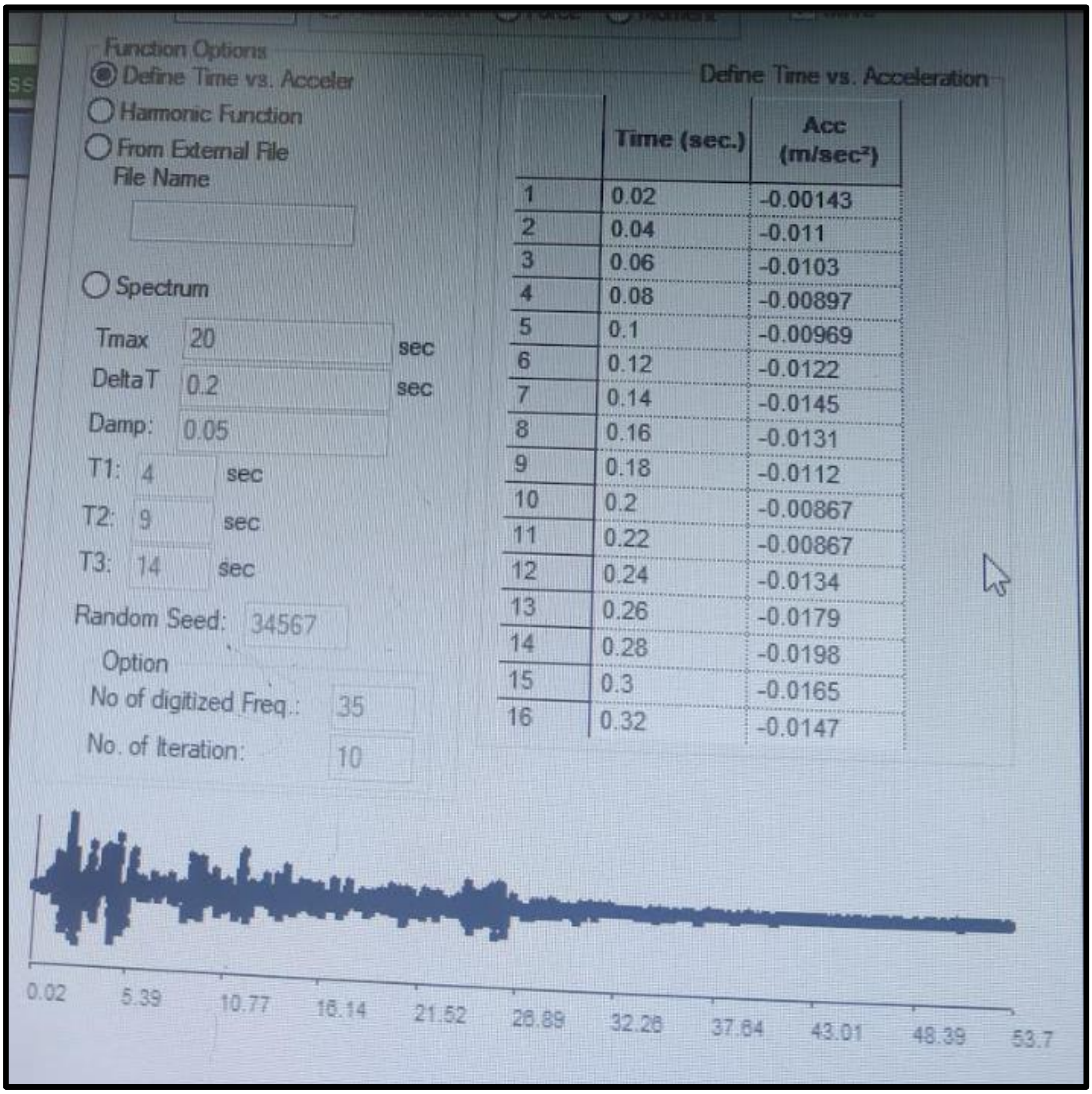

Fig 1.2.14 Time vs acceleration Diagram

Conclusions

1) Significant cost saving can be done by conducting more equivalent lateral force displacement
2) The simplified procedure is not worthwhile in practice due to use restriction and over conservative base shear values

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24. 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