# "DESIGN AND ANALYSIS OF MULTI-STOREY EARTHQUAKE RESISTANT BUILDING"

A

PROJECT REPORT

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

*of*

**BACHELOR OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

*Under the supervision*

*of*

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**HIMACHAL PRADESH, INDIA**

**May-2021**

## STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Design and analysis of multi-storey earthquake resistant building"** submitted for partial fulfillment 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. Saurabh Rawat**. This work has not been submitted elsewhere for the reward of any other degree/diploma. We are fully responsible for the contents of our project report.

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Date: May, 2021

**CERTIFICATE**

This is to certify that the work which is being presented in the project report titled **Seismic Analysis of Multistorey Building** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Ashsih, Aditya and Dikshant** during a period from July, 2020 to May, 2021 under the guidance of **Dr. Saurabh Rawat**, Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

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**ACKNOWLEDGEMENT**

Every project big or small is successful largely due to the effort of a number of wonderful people who have always given their valuable advice or lent a helping hand. I sincerely appreciate the inspiration, support and guidance of all those people who have been instrumental in making this project a success.

It is my radiant sentiment to place on record my best regards, deepest sense of gratitude to Dr. Ashok Kumar Gupta, Head of the Department Civil Engineering, Jaypee University of Information Technology for his precious guidance which was extremely valuable for my study both theoretically and practically.

Many thanks go to the project supervisor, Dr. Saurabh Rawat who has given his full effort in guiding the team in achieving the goal as well as his encouragement to maintain our progress in track. I would like to appreciate the guidance given by other supervisors as well as the panel especially in our project presentation that helped us improve our presentation skills.

## ABSTRACT

In recent years extensive consideration has been paid to innovative work of structural control gadgets with specific accentuation on alleviation of wind and seismic response of structures.

In recent years, vibration-control measures have been developed, i.e. passive, active, semi-active and hybrid vibration control methods. During major earthquakes, passive vibration management tends to maintain the building effectively elastic and its fundamental frequency is smaller than both its fixed base frequency and ground motion frequencies. Base isolation is a passive vibration management device that leads to a large-scale reduction of seismic forces.

Forced vibration research was carried out by using and experimentally validating the computer software ETABS 2019 on the framed structure.

The isolation mechanism eliminates the inter-storey drift by a factor of at least two and often by a factor of at least five in the superstructure. Acceleration responses are often decreased by a quantity in the structure, but the amount of reduction depends on the isolator's force deflection characteristic. In recent years, ground-breaking work on structural control gadgets with a particular focus on wind relief and seismic response of structures has been given comprehensive attention. For contrast, the building is built with a fixed foundation and a base insulator, and all systems compare floor drift, displacement, velocity and acceleration. Then the isolator's manual configuration is completed and the isolator is evaluated in the ETABS software.

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# 1 INTRODUCTION

## 1.1 BACKGROUND

### 1.1.1 What is an earthquake:

In the earth's crust, there is an enormous amount of elastic strain energy which during an earthquake gets released suddenly in the form of seismic waves. The unexpected ground shaking caused by the release of these seismic waves is known as earthquake.

In simpler words, say, one block of earth suddenly slips over another one at their interface thus earthquake happens. These blocks are the tectonic plates which comprises of elastic but brittle rocky material. The interface where the movement or 'slip' has taken place is known as fault or fault plane.

The scientific study of earthquake and the propagation of elastic waves through the earth is called as seismology. (In Greek: "Seismos" =earthquake and "logos" = science)

### 1.1.2 How our earth is constructed

There are multiple layers associated with the earth. Seismologists have shown that most of the earthquakes occur in the lithosphere. In other words, earthquakes occur in the upper 200 kilometers of the earth.

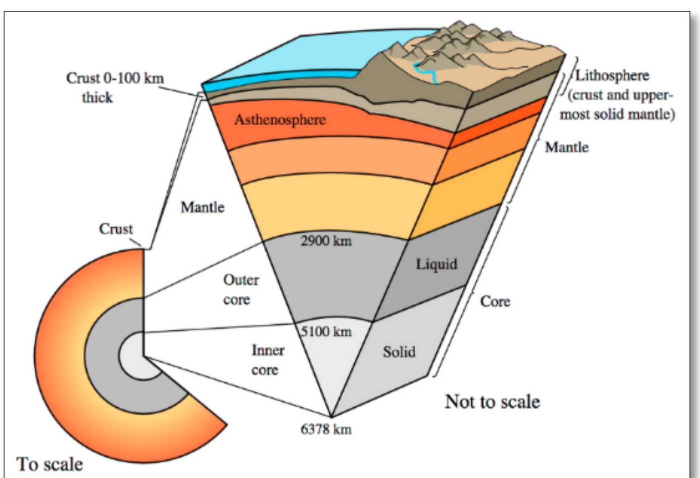


*Figure 1 Different layers constituting earth's structure*

| Typical thickness | (km) |
|---|---|
| Oceanic crust | 5 |
| Continental crust | 25-75 |
| Lower lithosphere | 50-120 |
| Asthenosphere | 200 |
| Lower mantle | 2500 |
| Outer core | 220 |
| Inner core | 1278 |

*Table 1 Typical thickness of different layers*

Some earthquakes may occur in the Asthenosphere and in the upper portions of the mantle however no earthquakes have been ever recorded below depths of about 1700 kilometers.

### 1.1.3 Why earthquake happens:

**Theory of plate tectonics:**

According to this theory, the lithosphere or the crust of the earth is divided into different portions, called as, plates and these plates, because of the moments and the convections happening in the mantle beneath the lithosphere, are constantly interacting (bumping or grinding) against each other.

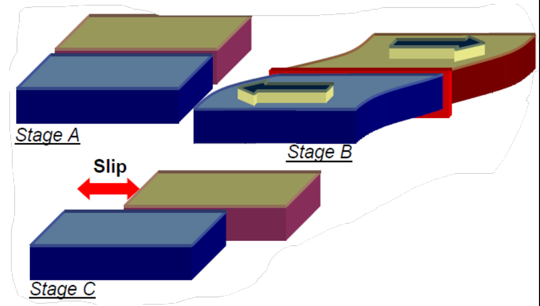


***Figure 2*** *Theory of plate tectonics*

**Theory of convections:**

This is the most accepted theory for the explanation of the plate tectonics or the continental drift which states that hot material that rises up (from the core, 2500°C) to top of the mantle (or the earth's crust, 25°C) and the cooler material gets pushed down or sinks to the bottom of the mantle which gets heated up and gets back to the top giving rise to a circular current within the mantle. This circular current creates friction between the mantle due to which the aesthenosphere and lithosphere drags and creates movement in the crust itself and hence continental drift happens.

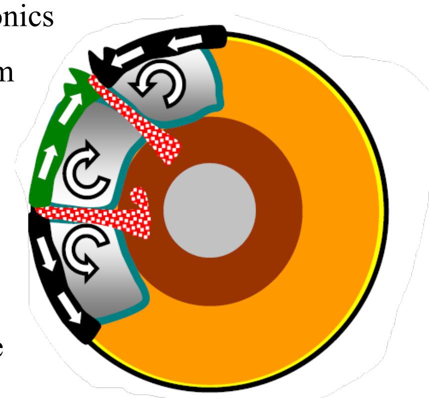

***Figure 3*** *Flow of convection currents*

**The Elastic Rebound Theory**

When the locked-up fault still trying to move the ductile rock slowly starts to deform and energy or stress starts building up eventually there is a sudden fracture of a rock leading to a big strain. This elastic strain energy gets released in all directions and it propagates outward from the point where the rock is broken and the slippage which occurs then is what we called as an earthquake.

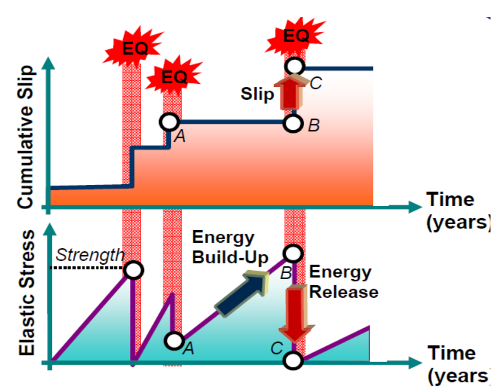


***Figure 4*** *Elastic Rebound Theory*

### 1.1.4 Earthquake Resistant Structures

Nowadays structures are being designed in such a way that they're able to withstand all forces of nature and the structure (building, bridge) which is capable of withstanding the lateral forces of an earthquake is known as Earthquake resistant structures.

The term "earthquake resistant" is often confused with term "earthquake proof" despite having a major difference that in former one building show signs and warnings when there is a ground motion (e.g., cracks) with some amount of damage to life and property whereas an earthquake proof building claims to have zero damage or not even a single crack in the building. Examples of such structures includes Nuclear containment cells.

Major disadvantage of earthquake proof structures is that their design is based on a specific range of intensity of ground motion hence the term "Earthquake Resistant" is commonly used in seismic design and earthquake engineering.

For a long time the traditional methods that are used for earthquake resistant design involves improving the stiffness, strength and ductility of the structures. Such kind of structures are more expensive due to increased sections of structural members. Moreover, with decreased flexibility seismic responses have higher values. To resolve these limitations of this customary strategy, concept of structural control come into play which incorporates various vibration control measures have been considered.

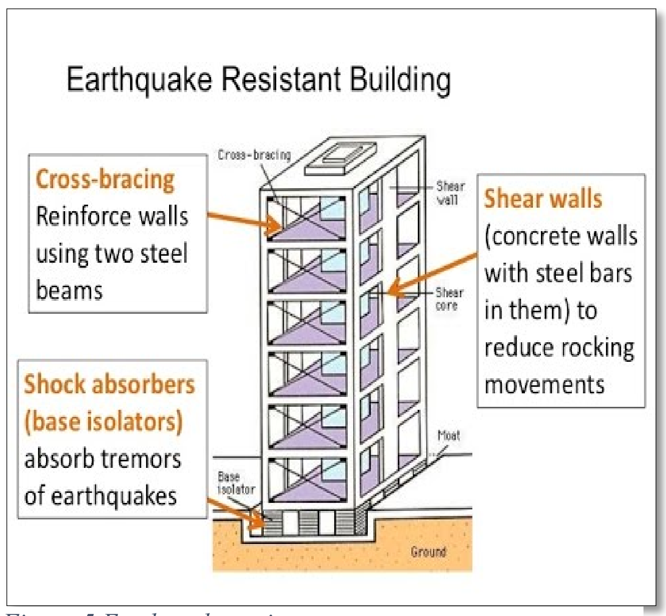


*Figure 5 Earthquake resistant structure*

Structural control is a vast and very demanding field of study. A lot of researches are still going on and various advancements are being done to reduce the response of any structure due to quakes (earthquakes or aftershocks) or strong winds.

## 1.2 IMPORTANCE OF PRESENT STUDY: NEED FOR SEISMIC ANALYSIS

Safety, reliability and durability of any structure in its designed life cycle are the major concerns of a structural engineer. Any compromises in any of these factors can cause a huge loss to life and property.

Seismic analysis, in the same way, encompasses the methods to analyze the peak response of a structure to ground motion during an earthquake to ensure safety, reliability and durability. It ensure that the designed structure will be resist any lateral forces acting on it due to an earthquake. This is called Seismic resistance.

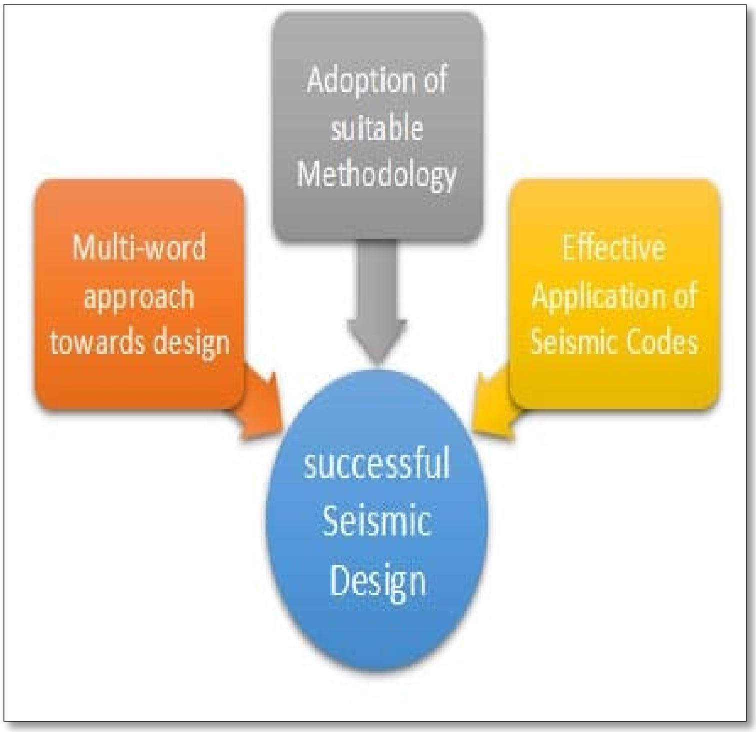


***Figure 6** Seismic design methodology*

Basically seismic analysis are of two types:

**<u>Static Analysis</u>**: Nowadays, this analysis is not considered in practical life applications because it does not consider the dynamic properties of ground motion i.e. variation of ground acceleration with time.

**<u>Dynamic Analysis</u>**: It includes time-based analysis and both space and time-based analysis. Further it is divided into two subcategories:

i) Time History method

ii) Response spectrum method.

### **Time History method**

Time history method involves a step-by-step analysis of seismic response of a structure subjected to dynamic earthquake loading. This structural response to seismic events may vary with time. This analysis can be either linear or nonlinear depending on the structural strength and stiffness.

### **Response spectrum method**

Spectrum in seismology implies that structural response to dynamic loading whether elastic or in-elastic having a vast range of fundamental time periods can be represented in a single graph. For a given value of ground acceleration and a percentage of critical damping, this response spectrum provides a plot of different responses related to earthquake motion like graphs of acceleration, displacement and velocity versus time periods.

**Elastic dynamic analysis or Linear dynamic analysis**: only material linearity is considered. E.g., Behavior of steel in elastic region in considered.

**Inelastic dynamic analysis or Non-linear dynamic analysis**: Non-linearity or residual strength of material is also taken into account. This analysis is reserved more for research purposes.

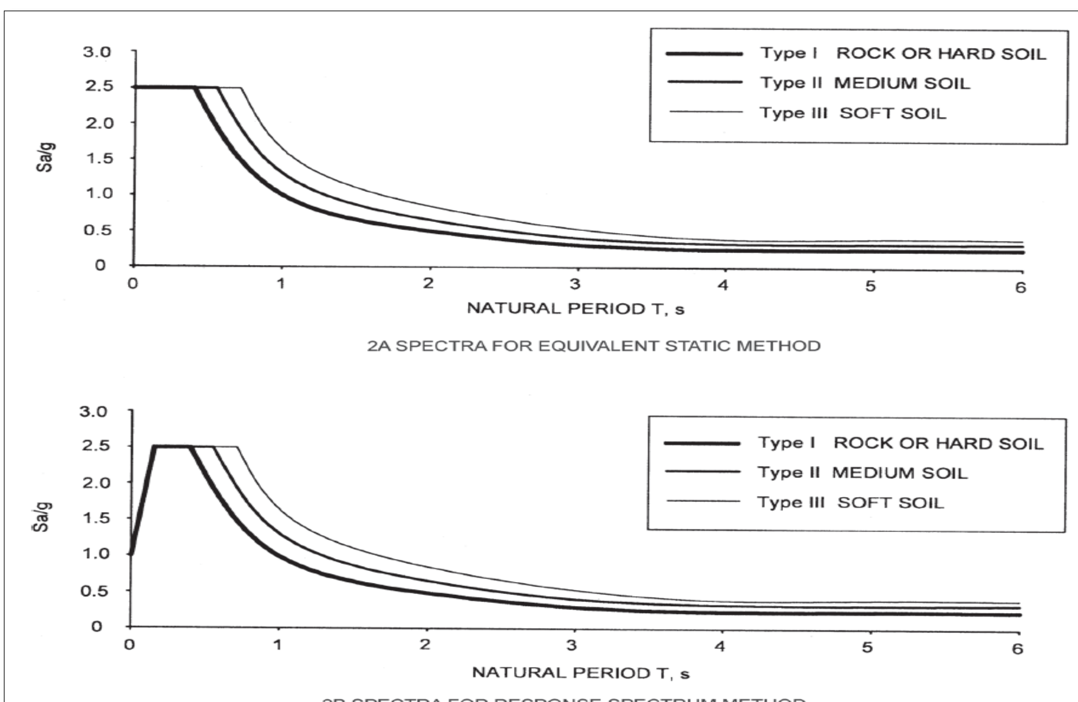


***Figure** 7 Design Acceleration Coefficient (Sa/G) (Corresponding To 5 Percent Damping)*

We mainly stick to the elastic dynamic analysis in this project as it is more convenient or less complicated as compared to the later one. In recent years, more and more advancements in seismic design are being done considering non linearity rather limited to research work.

Seismic analysis and thereby the design is very crucial for any structure so that its functionality is not at all hindered and it serves its purpose even after it gets hit by an earthquake. Seismic resistance, as stated earlier is the resistance generated within the structure against any lateral forces coming to it due to the sudden ground movement. There are various methods of increasing this resistance or dissipating lateral forces such as base isolation system, energy dissipation system like dampers, and active and passive control system which helps in improving the overall seismic response of a structure.

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## 1.3 FIVE IMPORTANT ELEMENTS OF AN EARTHQUAKE-RESISTANT BUILDING

### 1.3.1 Diaphragms

Diaphragms are the structural elements usually located in horizontal direction beneath the floor slab. These are designed to resist lateral forces by transferring all in plane base shear to shear resisting structural elements placed vertically such as shear walls. A roof with a slope is also an example of diaphragms.

Diaphragms improves rigidity by connecting exterior walls of building thus making it less susceptible to torsion and over turning.

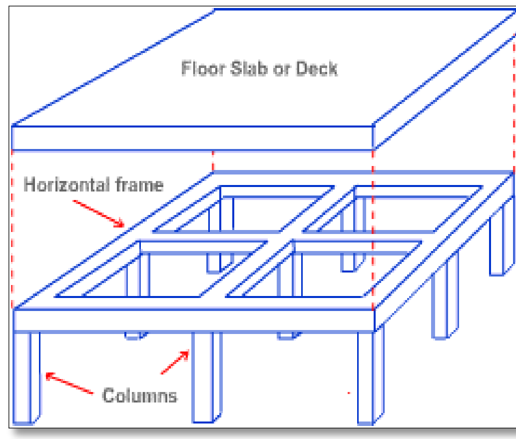



*Figure 8 Diaphragms*

Examples: In wood construction, ply wood is recommended and for RCC structure, slabs are provided as diaphragms.

### 1.3.2 Shear Walls

These are the diaphragms placed vertically in a structure. Like the diaphragms, shear walls also help in dissipating the vibrational energy and thereby reducing shear or lateral forces coming to building. Shear walls also helps in reducing sway in transverse direction by increasing stiffness of the building.

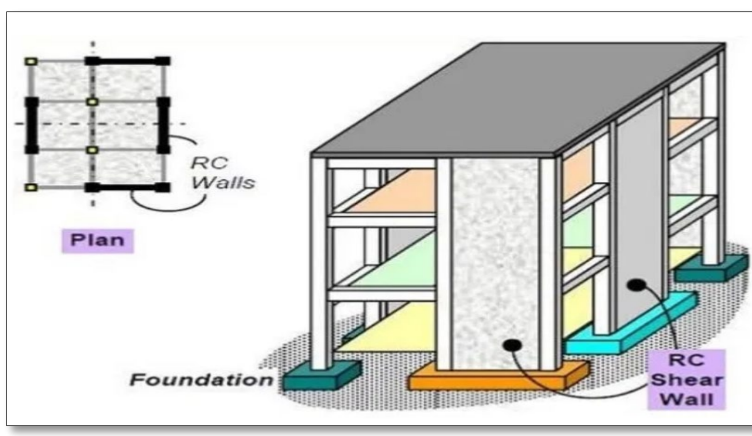



*Figure 9 Shear Wall*

These are usually provided at the corners of a building because of cost effectiveness and are made up of concrete of same or lower grade as the building. Shear walls are generally designed for high rise building.

### 1.3.3 Cross-Bracing

Also known as X-bracing which employs two structural members crossing each other diagonally. This system requires participation of beam column and bracing in order to transfer shear loads back to the ground.

***Figure 10*** *Cross-Bracing*

### 1.3.4 Trusses

- A truss can be imagined as the web of triangles where these triangles depict the structural elements made up of steel. This web-like structure is created to have a uniform distribution of loads and to manage continuously varying tension and compression without any damage to building.

***Figure 11****: Roof Truss*

- This arrangement helps reducing bending and shearing witin the building. The truss is organized in such a way that the whole structure as a whole will act as a single object.
- Trusses are more common in bridges, towers and roof of buildings. They also add strength to the building in areas here diaphragms are weak.

### 1.3.5 Moment-Resisting Frames:

These frames may be defined as the rectilinear assemblage having flexible beam attached rigidly to the columns. By developing shear force and bending moment in members and joints in the frame, this provides both vertical and lateral resistance against vertical loads and seismic loads. Columns and beams can move flexibly but the joints or connectors remains intact and rigid. There are two types of MRF: *Ordinary Moment Resisting Frames (OMRF)*

*Special Moment Resisting Frames or SMRF (ductile behaviour IS 13920 or sp6)*

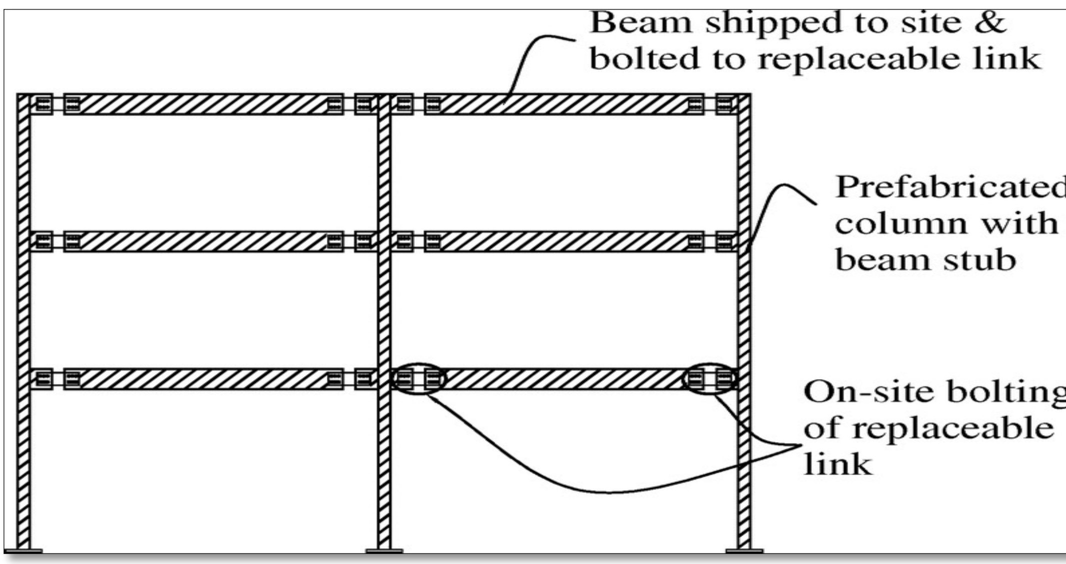



***Figure 12**: Moment Resisting Frames*

## 1.4 IMPORTANT CHARACTERISTICS FOR EARTHQUAKE-RESISTANT BUILDING DESIGNS THAT AFFECTS THEIR STRUCTURAL INTEGRITY:

### I <u>Stiffness and strength</u>

For an earthquake resistant structure sufficient strength and stiffness especially in lateral direction should be there.

### II <u>Regularity</u>

Earthquake caused lateral movement of a building

Regularity ensures energy dissipated should be uniformly distributed instead of focusing on one side only.

Irregular building sway more leading to huge amount structural damage.

### III <u>Redundancy</u>

In terms of safety, it is one of the most important characteristics that incorporates alternative strategies in case of failure of the previous one.

Very Reliable but expensive. It adds to the cost of a structure or building.

### IV <u>Foundations</u>

For every high rise building it is must for them to have a stable foundation.

It is the most significant characteristic and choice of foundation for a building depends on the intensity of ground motion. Generally, for seismic design, deep foundations and driven piles are recommended.

Important to analyze response of a foundation to lateral forces coming to it.

### V <u>Continuous Load Path</u>

This proposes to have an interconnected hub of structure and non-structural elements.

The idea is to dissipate the lateral or inertial forces by the structure as a whole rather by its components independently. Independent responses can lead to structural collapse.

It should be ensured that the path remains intact.

## 1.5 BASE ISOLATION OF STRUCTURES

### 1.5.1 Concept of Base Isolation and the Principle behind it:

This method is one of the most accepted and implemented method to protect a building against a tremor.

Seismic base isolation or simply base isolation as the name suggests is isolating the base of a structure from the ground itself. So, mitigation of effects like base shear, inter-storey drift and displacements due to the ground acceleration by isolating the whole structure and its components from that ground motion is known as base isolation technique.

***Figure 13*** *Tomb of Cyrus, Iran (the oldest base-isolated structure in the world)*

Traditional design approach involves strengthening of structure which was based on increased resistance philosophy whereas seismic isolation concept focuses on reducing earthquake load at the base itself.

This technique mainly focused on reducing the floor accelerations and inter-storey drifts in a cost-effective manner.

**Principle:** The basic principle of base isolation is that it makes the structure more flexible, thus uplifting its natural time period, and improves its energy dissipation capability which is well achieved by inserting proper isolating material (or isolator) like lead rubber bearing (LRB) or High damping rubber bearing (HDRB) between superstructure and the foundation.

This method is most effective for low rise buildings and buildings on stiff soils with large mass and not for high rise building because of large overturing moments. The base isolation concept is practically complex and somewhat costly to implement.

### 1.5.2 Suitability checks

Structure assessment for the suitability of base isolation should be done on the following basis:

**1. Weight of the structure:**

Suitable for heavyweight buildings and not for light ones because this method is not cost effective for the later. Moreover, cost of isolators (if provided) will be more than the initial cost of building.

**2. Time period of structure:**

Suitable for structure with short natural time period preferably less than 1s.

In practical case, an isolator increases the time period to range of 1.5 to 3.5 s. So, buildings already having time period in this range are not recommended to opt for base isolation.

**3. Subsoil conditions**: Base isolation works for soil having rocky and stiff texture.

In soft soils, earthquake waves get modified such that long period motion increases which will affect by reducing the effectiveness and efficiency if base isolator is provided.

**4. Near Fault Effect:**

The near-fault ground motions are accompanied by long duration pulses, with very large displacements such that an oversized isolation system is required. Therefore, due to high cost and complex evaluation, it is not recommended to provide base isolation in near fault locations. All the evaluations of structures near fault are done on account of "fling effect".

**5. Configuration of structure.**

Recommended for horizontal sites and not suitable rather complex (need both horizontal and vertical separation planes)

Most efficient for buildings having basement because it enables base isolator to distribute load more effectively through a diaphragm.

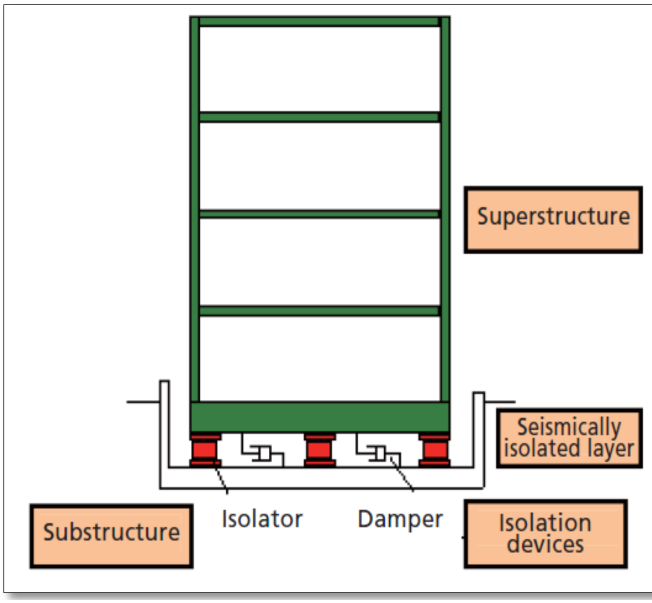



*Figure 14* Concept of Base Isolation

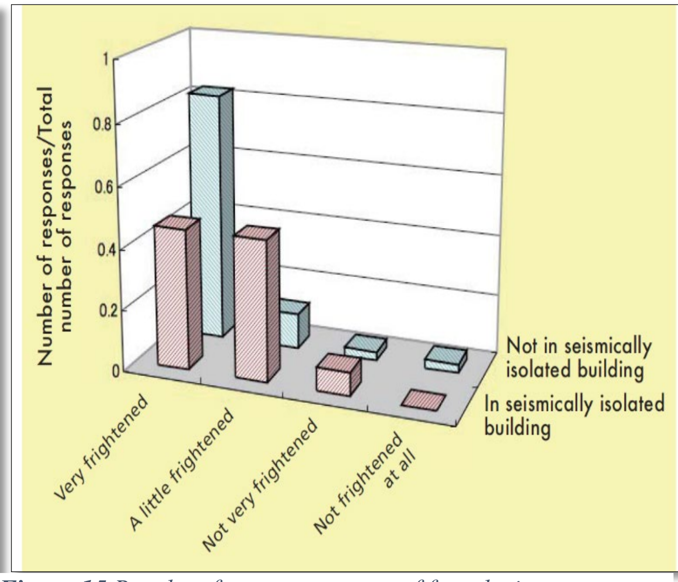



*Figure 15* Results of survey on sense of fear during an earthquake

A new strategy: Concept of "**smart base isolation**"

This concept incorporates a strategy such that the buildings can be protected against extreme earthquake or maximum considered earthquake (MCE) without compromising its performance during more frequent or moderate events.

The strategy involves use of conventional lead rubber bearing (elastomeric bearing with low damping) and smart controllable semiactive dampers. Magnetorheological fluid damper is an example of smart damper.

As a result of smart base isolation, significant decrease in base drift without increase in superstructure motion can be observed as compared to traditional LRB systems.

## 1.6 ADVANTAGES OF BASE ISOLATION:

Its purpose is to enable a structure to withstand a potentially annihilating seismic effect by means of a proper initial plan or subsequent changes. The use of base isolation can sometimes dramatically improve both a structure's seismic execution and seismic supportability. The following are the main benefits of using this base isolation mechanism:

- Aside from seismic exercises, base isolation protects structures from blast loads by reducing the overall impact of the blast on the structure due to their ability to move.
- When compared to conventional structural components, structures with base isolation are unsurprising. As a result, their dependability is extremely high.
- Because earthquake forces are transmitted to the building in such a small amount, strengthening measures such as frames, bracing, and shear walls are not given as much weight, making seismic analysis easier.

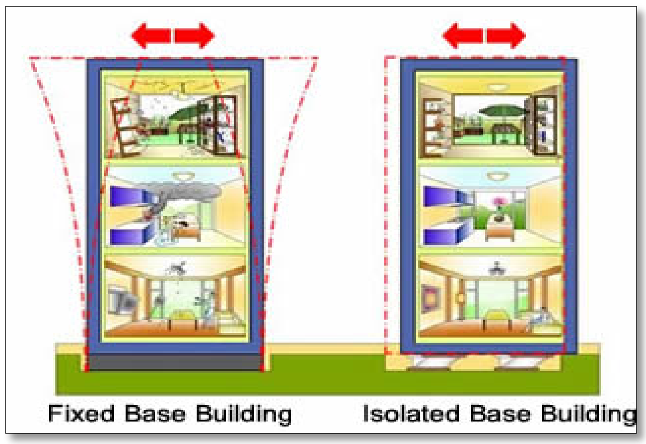



***Figure 14*** *Base isolation technique*

- In the event of massive unanticipated seismic activity, the damage is simply accumulated in the isolation system, where components can be effectively replaced.
- Base isolation can also be retrofitted to existing structures that are reasonable. In addition, the structure can remain fully operational during construction.

## 1.7 TYPES OF BASE ISOLATION SYSTEM

Base isolation depends on two factors: Damping and Flexibility

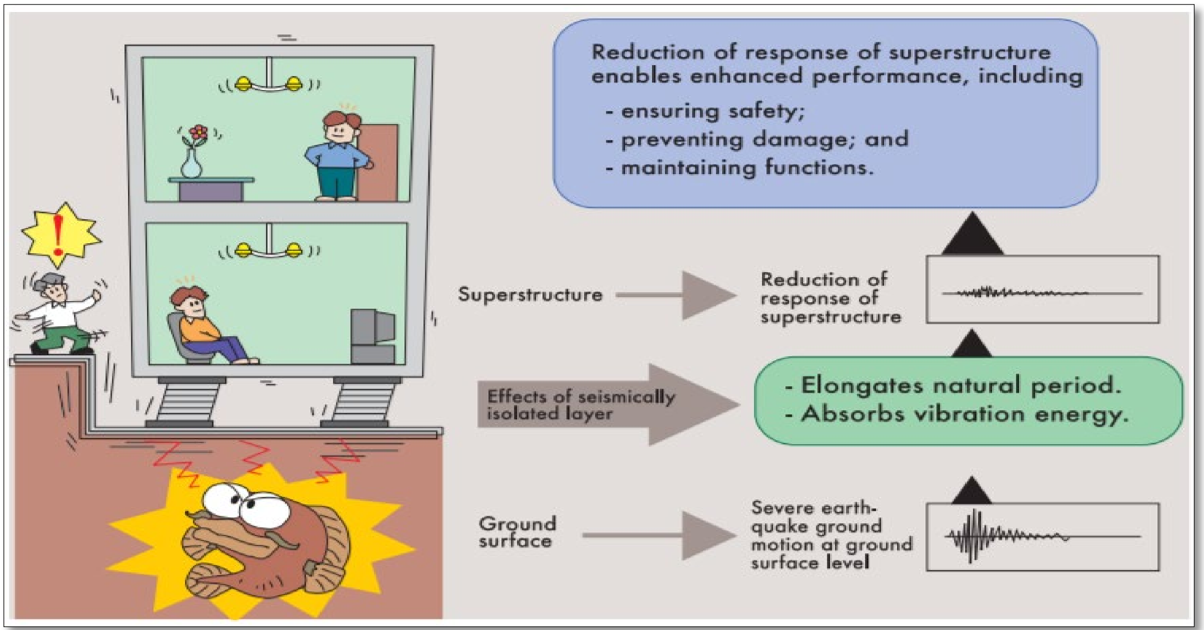



***Figure 15:*** *features of base isolation*

- Flexibility is the most important factor in adjusting a seismic response.
- Viscous (hysteretic) dampers are commonly used to improve seismic isolation.
- Dampers reduce response without relying on structural stiffness.

### 1.7.1 LEAD RUBBER BEARING

As shown in the diagram, a lead rubber bearing consists of a laminated elastomeric bearing pad, sealing at the top and bottom with connecting plates, and a lead plug inserted in the middle.

This is a very practical and cost-effective method of base isolation.

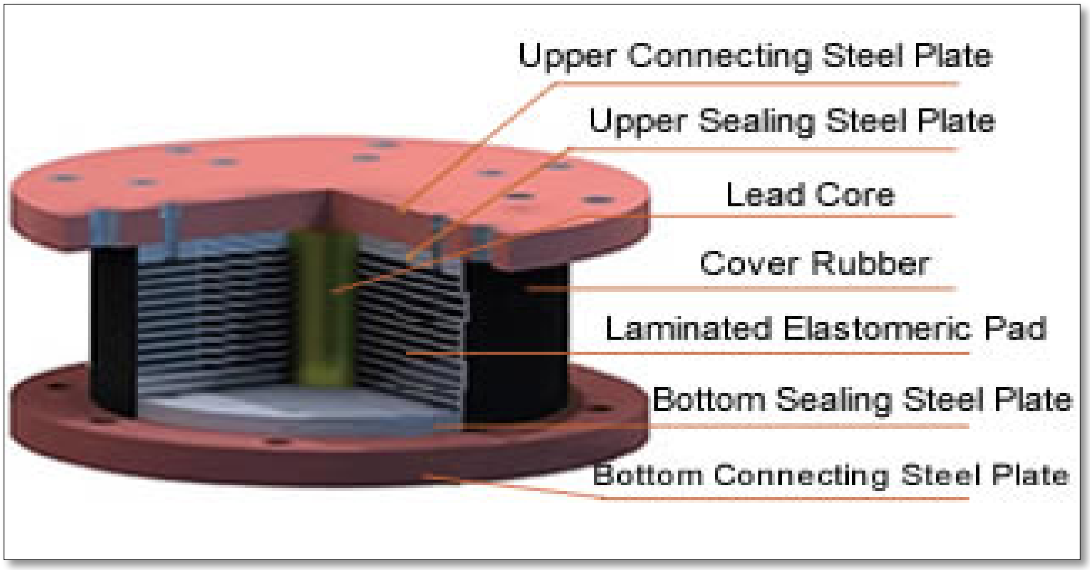



***Figure 16*** *Elastomeric Rubber Bearing*

## Features:

- In the vertical direction, it is firm and solid, but in the horizontal direction, it is flexible.
- Change the shape of the bearing to absorb the force generated during an earthquake.
- The rubber part is very durable and has a high elasticity, so it will not be damaged during an earthquake.
- Change the amount of damping simply by changing the number of lead plugs.
- Allow the structures to maintain their distinct shapes and positions as a result of the high elastic rubber force.
- Exceptional vertical load limit, ranging from 5 to 2000 tonnes.
- Ground acceleration is reduced by increasing the structure vibration period.
- Installation is simpler because there is no need for a separate damper.
- Low maintenance cost.

**Working:** During an earthquake, this lead rubber bearing will effectively dissipate a significant amount of inertial or lateral force, extending the building's vibration period and reducing its acceleration.

### 1.7.2 TUNED MASS DAMPER

A tuned mass damper (TMD) is a vibration-reduction device that is attached to a structure and consists of a mass, stiffness elements (spring), and a damper to reduce the amplitude of vibration to an acceptable level during an earthquake. Pneumatic or hydraulic dashpots, viscoelastic materials, and magnetic dampers are the most common types of dampers used in TMD.

## Features:

- Tuned mass dampers are known for their stability and ability to function even during major earthquakes.
- A TMD dissipates a significant amount of vibration energy from the main structure without requiring any ground connection.

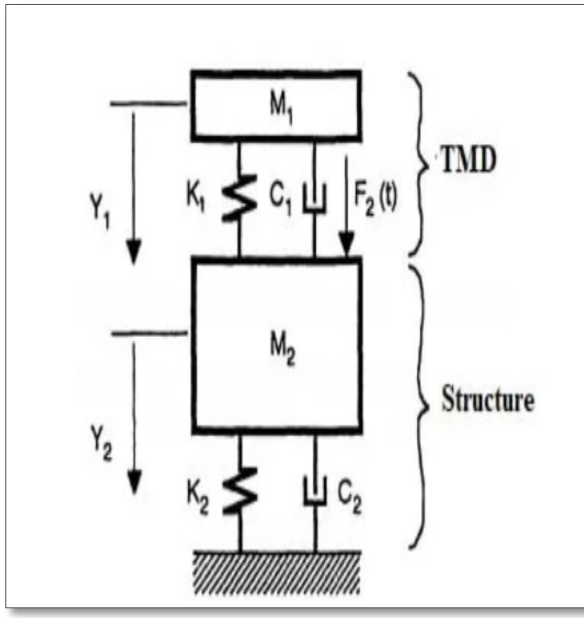



***Figure 17**: Tuned mass Damper*

**Working**

In this system, the mass and spring are adjusted (tuned) to the structural mode; in other words, the damper's frequency is tuned to a specific frequency (close to the natural frequency) of a structure in such a way that when that frequency is excited, the damper will resonate out of phase with the structural motion. The damper inertia force acting on the structure dissipates energy in the form of heat.

The effectiveness of a TMD is determined by three factors:

- **Mass ratio:** The Ratio of mass to TMD to that of structure or building.
- **Frequency ratio:** The ratio of the TMD's frequency to the structure's or building's natural frequency.

- **Damping coefficient of TMD**: The TMD's ability to dissipate energy is measured (lower the value of coefficient means better will be the damping).


***Figure 18*** *Enormous pendulum (TMD) helps keep Taiwan's tallest building, Taipei from swaying*

### 1.7.3 SIMPLE ROLLER BEARING

***Figure 19*** *Simple Roller Bearing*

The cylindrical rollers and balls used in this base isolation method are primarily used to resist service movements and damping. The purpose of this system is to protect various structures from the potentially damaging lateral effects of major earthquakes. With specific safety measures in place, this metallic bearing support could be used as a seismic isolator for high-rise buildings and structures on soft ground. The bearing's primary function is to reduce friction or resistance that occurs when moving an object.

## 1.8 TYPES OF BASE ISOLATORS

The major types of base isolators are as follows:

### 1.8.1 ELASTOMERIC RUBBER BEARING

- Horizontal thin layers of natural or synthetic rubber are sandwiched between steel plates in these bearings.
- These rubber bearings can withstand high vertical loads while exhibiting very minor deformations.
- These bearings remain flexible even when subjected to lateral loads.
- The steel plate that is provided aids in the prevention of bulging of the corresponding rubber layers.
- Lead cores are included to improve damping capacity.
- Elastomeric bearings are stiff in the vertical direction but soft in the horizontal.

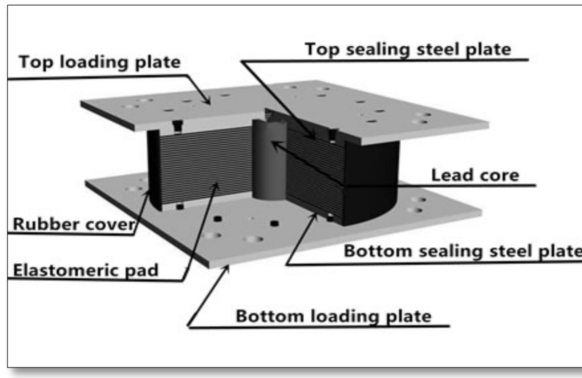



***Figure 20**: Elastomeric bearing pad*

### 1.8.2 ROLLER AND BALL BEARING

- The base isolation system in these bearings is based on cylindrical rollers and balls.
- Generally used in the machinery isolation.
- These bearings provide adequate damping as well as sufficient resistance to service movements (may vary material to material).

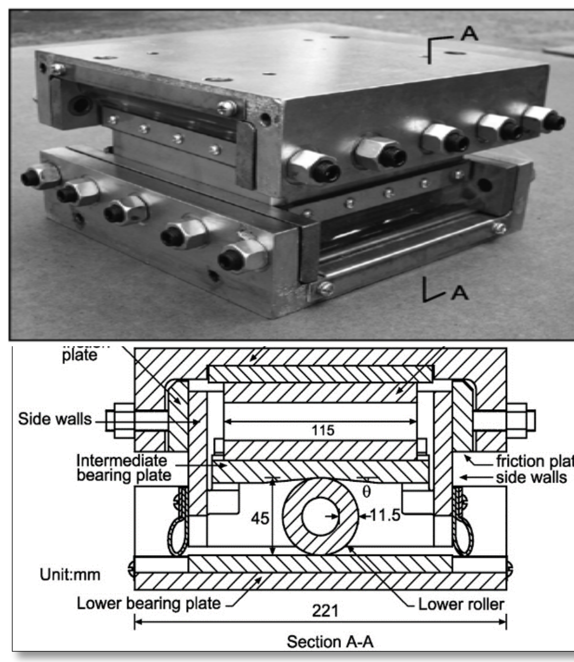



***Figure 21:** Roller and ball bearing assembly and section*

### 1.8.3 SPRINGS

- These bearings are typically used in mechanical applications, such as reducing noise, shock, and vibration generated by mechanical or industrial equipment within a structure.
- Apart from being one of the base isolators, this type of system is not commonly used for structural applications due to its flexibility in both horizontal and vertical directions, which causes an increase in service deflections.

***Figure 22***: *Springs*

### 1.8.4 SLIDING BEARING

- With the help of its predefined friction coefficient, a sliding bearing provides base isolation by limiting the acceleration as well as the transferred forces.
- The Sliders provide flexibility and resistance.

- Sliding movements can be used to achieve bearing force-displacements in this case.
- To avoid displacements with aftershocks, formed or spherical sliders are usually preferred over flat sliders due to their restoring effect.

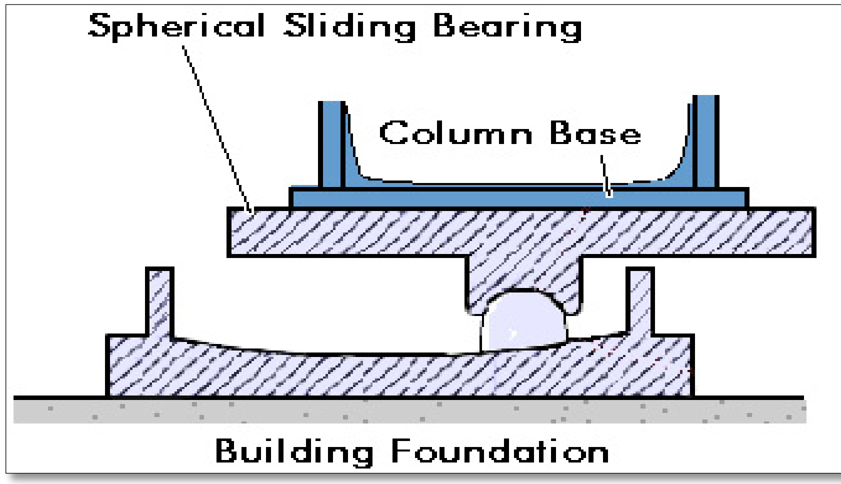



***Figure 23***: *Spherical Sliding Bearing*

- During an earthquake, bearing pads with a curved surface and a lower friction coefficient support the structure in this spherical sliding.
- Buildings can freely slide on spherical sliding bearings when subjected to lateral forces.

## 1.9 CLASSIFICATION OF BEARING

Classification of bearing depends on two criteria:

- Degree of freedom.
- Manufacturing material used for the bearing.

| • *Sl. No.* | *Type* | *Translation* | *Rotation* |
|---|---|---|---|
| I. | Fixed | Not allowed | Allowed |
| II. | Free | Allowed | Allowed |
| III. | Rocker and Roller | Roller end free | Rocker end fixed |

Based on the materials used in manufacturing

1. Steel
2. Rubber (i.e. elastomer)
3. Poly Tetra Fluro Ethylene (PTFE)
4. Combination of any of the above.

## 1.10 BEARING PAD:

The laminated elastomeric bearing is the most widely used of the various types of bearings discussed above. This bearing pad is made up of multiple layers of rubber, with steel plate reinforcement provided by sulphuration and adhesion.

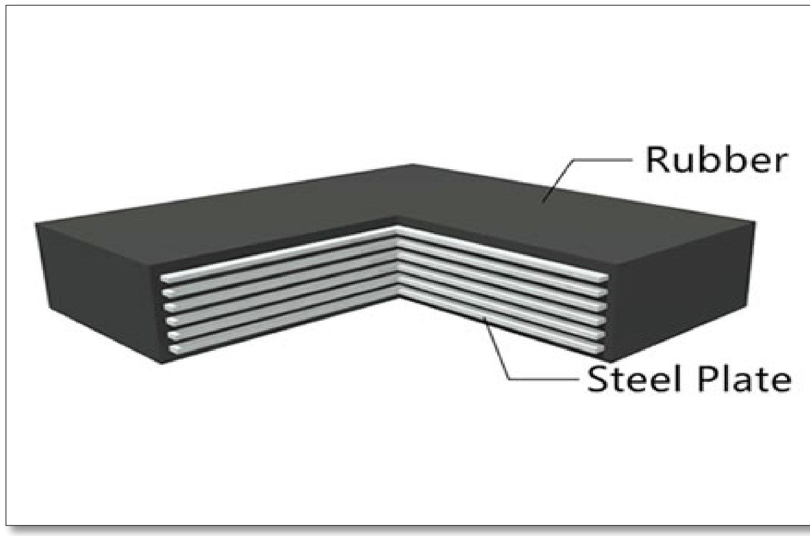



*Figure 26: Laminated Elastomeric bearing pad*

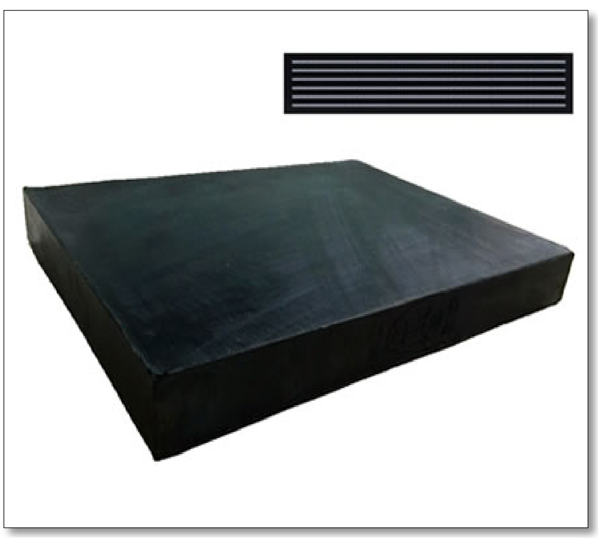


*Figure 27 Rectangular laminated elastomeric bearing pad*

*Figure 28 Round laminated elastomeric bearing pad*

In contrast to non-reinforced ones, laminated elastomeric bearing pads have sufficient vertical rigidity to easily transmit concentrated vertical loads and impact or lateral loads of a structure to both sides of the foundation. Because of its fine elasticity and high shearing deformation capacity, it is frequently used in steel and RC bridges.

**Features**

- **Great flexibility-** This term refers to the ability to adapt to any type of rotation at the beam's end.
- **Adequate shear deformation-** This means that a building's horizontal displacement can be easily mitigated.
- **Enough vertical rigidity-** Vertical and lateral forces are easily defensible.
- **Great isolation effect-** Easily withstands earthquakes and other live loads.
- **Versatility in range of application-** In earthquake-resistant bridges and structures.

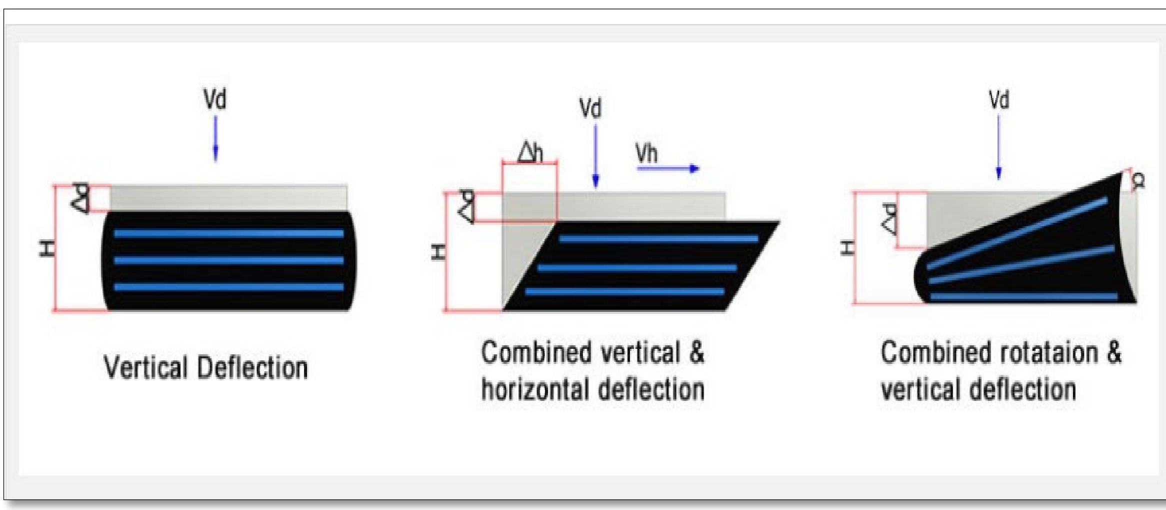



*Figure 24: Load distribution and movement resistance*

## 1.11 SHEAR WALL

Shear wall is a concrete wall made to resist shear forces due to seismic activities. It comprises of hard concrete and braced panel. These walls are excellent means of providing earthquake resistance to multistoried or high rise reinforced concrete buildings.

Earlier these walls were considered as of brittle nature but now with proper ductile detailing they can behave in a ductile manner. Proper ductile detailing enables walls to stably dissipate seismic energy in flexural mode.

## 1.12 Design provisions for ductile detailing of a shear wall

These provisions are applicable for shear walls that are a resisting lateral load in a structure.

1. Thickness of any part of the shear wall shall not be less than 100 mm

2. the designed effective flange width shall be smaller of (a) half the distance of an adjacent shear wall web (b) $1/10^{th}$ of the total wall height.

3. Shear walls are to provided uniformly with lateral and longitudinal reinforcement and minimum reinforcement should be 0.0025 of the gross area in both directions.

4. Reinforcement shall be provided in two curtains if (a) wall thickness exceeds 200 mm (b) factored shear stress exceeds $0.25\sqrt{f_{ck}}$.

5.Diameter of any bar to be used in any part shall not exceed 1/10 th of the thickness of that part.

## 1.13 TYPES OF SHEAR WALL

### 1.13.1 Cantilever Shear Wall

1. **Tall walls with rectangular cross sections:** This is a single cantilever wall having height to depth ratio of over 2. It behaves as a flexural member. It is recommended to have a sufficient width to avoid instability. Conventional load-moment relationship can be used to determine the strength of such walls. Flexural steel concentration near the extreme end of this shear wall helps

in increasing the rotational ductility. In shear strength evaluation, contribution from the

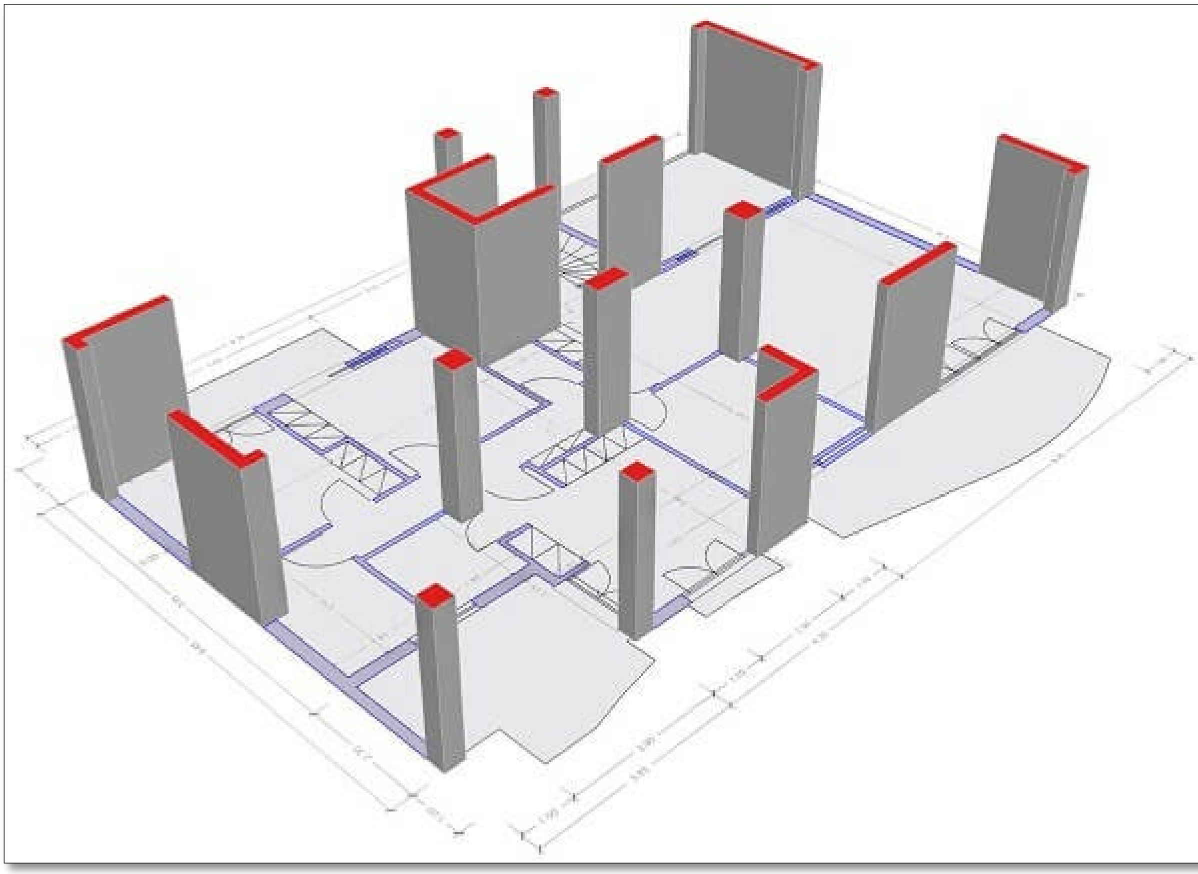


*Figure 25* *Different shapes of cantilever shear walls*

cracked concrete must be neglected and horizontal shear reinforcement i.e. ties or stirrups should be provided for total shear evaluation. For longitudinal reinforcement minimum of___$p_v = 0.25\%$ vertical steel should be provided.

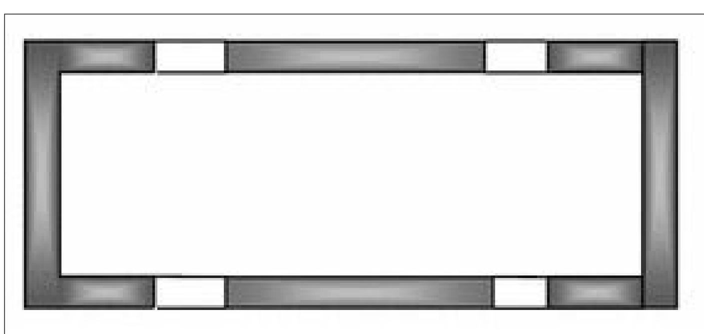


*Figure 26* *Core Type Shear wall*

2. **Squat shear walls with rectangular cross sections:** Cantilever shear walls having comparable height and depth i.e., $h_w/l_w \approx 1$ so that design considerations for flexure and shear for such walls are same. Since large flexural capacity of walls may lead to total collapse by attracting more shear forces hence it is recommended to design these walls for shear strength first.

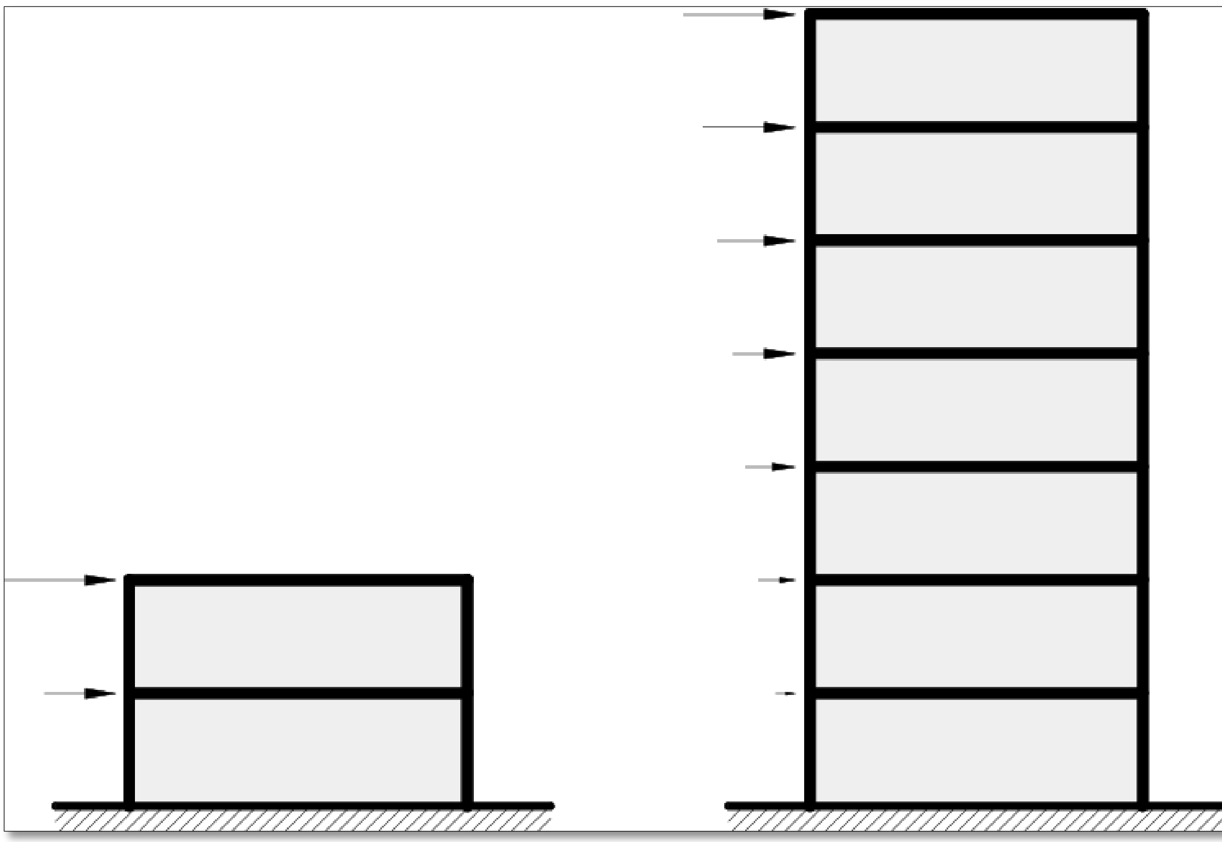


*Figure 27(a) Squat shear wall (b) Cantilever shear wall*

No reliance should be there on contribution from concrete because of flexural failure related with large cracks.

3**. Flanged cantilever shear wall :** Since steel reinforcement is provided in each of their flanges therefore this cantilever shear wall ensures adequate flexural ductility. Thickness of wide flange

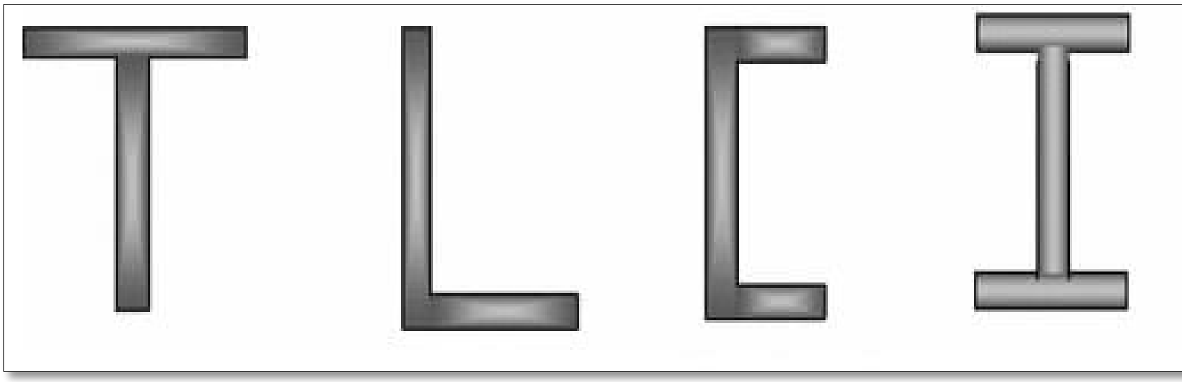


*Figure 28 Types of flanged shear wall*

also contribute in flexural ductility. Flanges helps in improving moment capacity whereas web helps in providing shear strength by employing use of steel of higher yield strength.

### 1.13.2 Shear Walls With Opening

As a matter of fact, that we cannot avoid opening in a building for various requirements like doors, windows it is sometimes become must to introduce an opening in as shear wall too. But it should be done in such a way that rotational ductility of walls is not compromised.

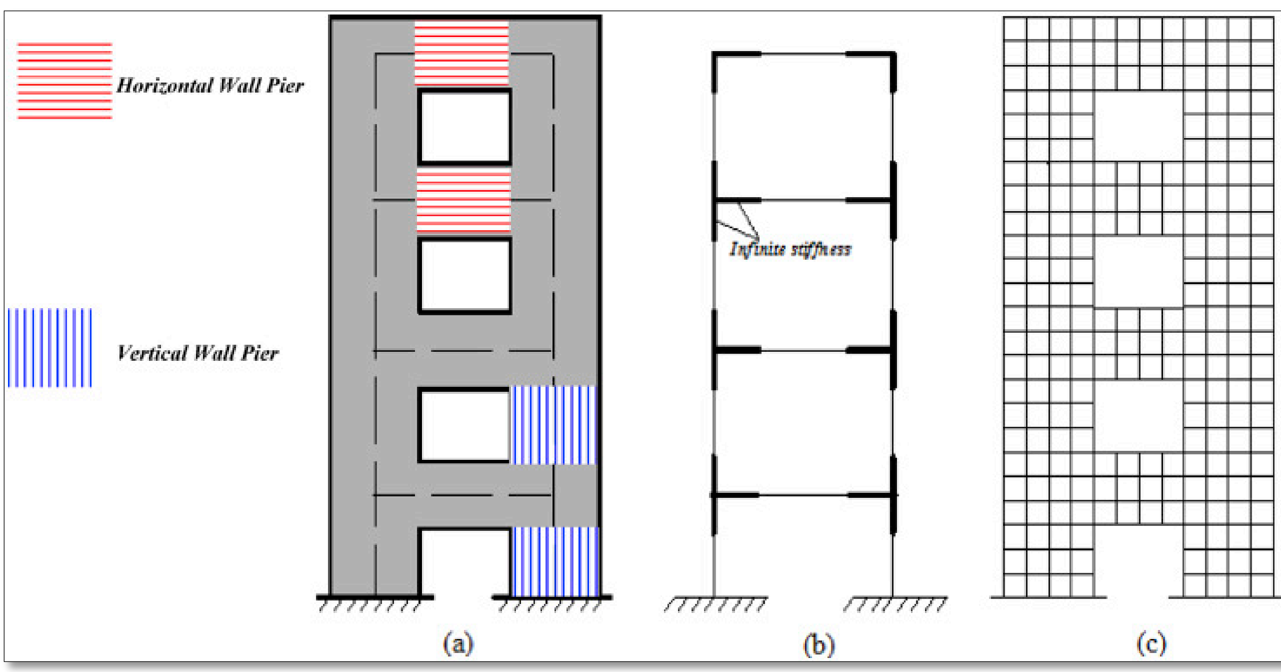



*Figure 29 Shear wall with opening*

**Effect of an opening in a shear wall**

Shear wall sometimes may have to contain an opening in order to meet the functional requirements of a building

Due to this opening, there is a discontinuity in reinforcement and concrete area gets reduced leading to reduction in strength and stiffness of the wall.

Strength and stiffness of a shear wall may also get reduced because of improper stress concentration which means stress concentration is more around the corner of opening leading to early induced cracks at loading stage.

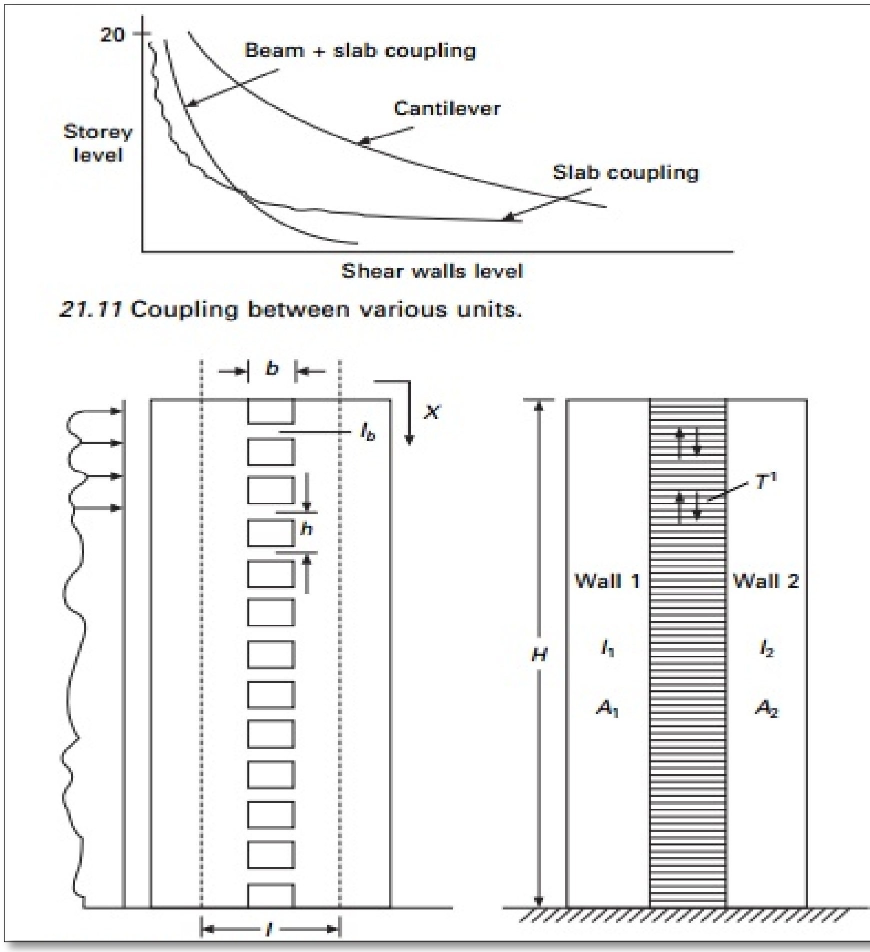
Ductility and shear strength of a shear wall get highly affected due to reinforcements around opening. Strength gets decreased to 20 % of it yield strength for vertical and horizontal reinforcement and it becomes 40% of yield strength for diagonal reinforcements.

Such structures sometimes attract more disaster (more lateral forces) due to concentration of absorbed energy in few specific positions only. If this happens, in such case ductility requirement may not be fulfilled by that element leading to shear failure.

### 1.13.3 Coupled Shear Walls

This is a prototype structure which emanates when there are regular openings within the shear wall. In this shear wall, two or more flanged cantilever shear walls are interlinked with the help of short and moderately deep *coupling beams.* Analysis of such walls should include shear failure of these coupling beams along with the axial deformation of shear walls. Therefore, software based computations should be done since manual computations are inadequate without proper modelling. This concept of coupled shear wall is based on "laminar analysis' or "continuum approach" which states that internal moments generated in walls are related to each other and also to the axial forces and over turning moment.

### 1.13.4 Elastoplastic response of coupled shear wall




*21.11* Coupling between various units.

***Figure 30*** *Coupled shear wall*

The ultimate strength of coupled shear walls, subjected to seismic loading, is achieved through an acceptable mechanism having adequate rotational capacity possessed by each of the required plastic hinges. To avoid further shear each of the coupling beam are required to have two plastic hinges. In addition, each of the cantilever walls should have one plastic hinge generally developed at their base, to complete the collapse mechanism. The sequence of hinge formation in any component is based on the relative strength and stiffness of that component.

The behavior of some coupled shear walls that are subjected to earthquake motion showed that all or most coupling beams failed before reaching the ultimate strength of the coupled shear wall.

# 2 LITERATURE REVIEW

## 2.1 INTRODUCTION

To consider the framed structure's behavior under applied dynamic loading, a modal study of the framed structure is of considerable technical importance. It is necessary to compare the reaction analysis technique (Experimental or Analytical) of a base-isolated framed structure with a fixed base or otherwise identical framed structure in order to determine the efficacy of base isolation using rubber bearings. "Earthquake resistance structures" refers to structures that can withstand an earthquake while maintaining and sustaining their functions. The main points for their architecture are selecting good ground for the location, making them light, solid, and ductile, shifting the natural duration of the structures from the prevailing period of earthquake motion, and increasing the damping potential.

Izumi Masanory reviewed the remaining literature, and Kawai proposed the first foundation-free structure in the Architecture and Building Science Journal in 1981, following the Nobi Earthquake (M=8.0). At its base mat of logs, he has rollers mounted on several levels by manually lengthwise and crosswise. During the San Francisco Earthquake (M=7.8), J.A., an English doctor, was killed. Calantarients patented a building in 1909 by placing talc between the foundations. R designed and built the Fudo Bank Buildings in Himeji and Simonoseki, Japan, which are the world's first isolated base structures. During World War II, the Oka was used by the US GarevskiAetal. Built in 1969, the Pestalozzi Elementary School in Skopje was the first building in the world to use natural rubber isolators to protect against extreme earthquakes. The Foothill Neighbourhoods of Law and Justice Center, completed in 1985, has four floors, a full basement, and a sub-basement for an insulation scheme consisting of 98 multilayered natural rubber bearings filled with steel plates, making it the first foundation-free structure in the United States. The house's superstructure has a structural steel framework stiffened by braced frames in some bays. The base isolation technique was first demonstrated in India after the 1993 Killari (Maharashtra) earthquake [EERI, 1999]. Two single-story buildings (one school building and another retail complex building) with rubber base isolators resting on the hard ground were constructed in the newly relocated Killari area. They were both made of brick and had a concrete roof.

Following the 2001 Bhuj (Gujarat) earthquake, the four-story Bhuj Hospital was built using a foundation isolation technique. The Base isolation method has been adopted in several dynamic engineering texts, and the number of scholars worldwide is increasing. Constantinou et al. identified an empirical model and algorithm for analyzing several buildings on a standard isolation scheme in this article, and the results are used to demonstrate the importance of analyzing the unified system rather than individual buildings.

For buildings with 10 to 20 levels, Jain and Thakkar discussed the idea of stiffening the superstructure to improve base isolation efficiency. If the base is isolated, the stiffening of the superstructure may result in a smaller fixed base span, and such buildings may develop a smaller seismic response. Jangid and Kulkarni compared the seismic response of a multi-story base-isolated structure in this report by idealizing the superstructure as rigid and fluid. Naharajaiah and Sun conducted an analysis during the 1994 Northridge earthquake to determine the seismic response of the base-isolated USC Hospital Building and Fire Command Control Building in Los Angeles. The earthquake responses of multifunctional vibration-absorption RC mega frame structures are reduced significantly when compared to normal mega frame structures, with a 60-80% reduction in the main frames and a 70-90 percent reduction in the minor frames, according to Hanget al.

Mazza and Vulcano compared various base-isolation techniques to see how they affected the structural reaction and applicability limits of near-fault earthquakes. The logical approach for the Base Isolated Structures (BIS) code to determine behavioural variables was identified by Palazzo and Petti. The method used in this study is to directly extract q-factors using a 2 d.f. nonlinear reaction analysis. According to the EC8 nature spectra, isolated models are subjected to artificially induced intense seismic excitations. Dutta and Jangid investigated the stability of base-isolated and fixed-base steel building frames in the event of a first-passage collapse caused by earthquake ground motion and discovered that base-isolated systems are more stable than fixed-base frames. Mei[13] used Classical theories to model in-plane motions in planar frame systems. Analytical solutions were obtained using a wave vibration technique. The propagation, reflection, and transmission matrices, as well as the matrix relations between the pumped waves and externally imposed forces and moments, are obtained using classical vibration theories.

Haringx's 1947 study on the technical aspects of helical steel springs and rubber rods used for vibration mountings resulted in the buckling isolation bearings principle. This work was reported in a series of papers, the third of which (Haringx 1948) deals with the durability of solid rubber rods. The Haringx principle (1964) was later applied to the dilemma by Gent.

Gent and Lindley in 1959 and Gent and Meinecke in 1970 conducted the first studies using an energy method. Rocard made further advancements in 1937. Kelly's "pressure solution" method, developed in 1997, is a condensed version of these earlier studies. In this process, the elastomer is assumed to be completely incompressible. Strain approximates the typical components of stress. Any individual elastomeric layer in the bearing deforms horizontal planes remain planar, and points on a vertical line lie on a parabola after loading, according to two kinematic assumptions. The extensive versatility of the fiber reinforcement is integrated into the "pressure solution" process in this article to evaluate the bending stability of fiber-reinforced circular isolators. The bending stiffness formula for fiber-reinforced circular isolators is calculated. It investigates how the versatility of fibers affects the mechanical properties of fiber-reinforced insulators.

A series of devastating structural collapses have occurred in recent years as a result of extreme, impulsive seismic activity. Some studies, such as Hall et al. 1995 and Heaton et al. 1995, have raised concerns about the feasibility of seismic isolation in such situations. Based on observations from the January 17, 1994 Northridge earthquake, these researchers hypothesised that base-isolated buildings are vulnerable to strong impulsive ground motions produced at near-source locations. Furthermore, new updates to the ICBO 1997 Standardized Building Code have made the criteria for base-isolation schemes more stringent than in previous iterations of ICBO 1994; Kelly 1999, making Kelly 1999b less commercially justified due to the increased difficulty and cost of base-isolated buildings.

Concept of “Smart Base Isolation” incorporates a strategy such that the buildings can be protected against extreme earthquake or maximum considered earthquake (MCE) without compromising its performance during more frequent or moderate events.

The strategy involves use of conventional lead rubber bearing (elastomeric bearing with low damping) and smart controllable semiactive dampers. Magnetorheological fluid damper is an example of smart damper.

As a result of smart base isolation, significant decrease in base drift without increase in superstructure motion can be observed as compared to traditional LRB systems.

Effect of an opening in a shear wall:

Shear wall sometimes may have to contain an opening in order to meet the functional requirements of a building

Due to this opening, there is a discontinuity in reinforcement and concrete area gets reduced leading to reduction in strength and stiffness of the wall. Strength and stiffness of a shear wall may also get reduced because of improper stress concentration which means stress concentration is more around the corner of opening leading to early induced cracks at loading stage.

Ductility and shear strength of a shear wall get highly affected due to reinforcements around opening. Strength gets decreased to 20 % of it yield strength for vertical and horizontal reinforcement and it becomes 40% of yield strength for diagonal reinforcements.

Such structures sometimes attract more disaster (more lateral forces) due to concentration of absorbed energy in few specific positions only. If this happens, in such case ductility requirement may not be fulfilled by that element leading to shear failure.

Elastoplastic Response of Coupled Shear Wall:

The ultimate strength of coupled shear walls, subjected to seismic loading, is achieved through an acceptable mechanism having adequate rotational capacity possessed by each of the required plastic hinges. To avoid further shear each of the coupling beam are required to have two plastic hinges. In addition, each of the cantilever walls should have one plastic hinge generally developed at their base, to complete the collapse mechanism. The sequence of hinge formation in any component is based on the relative strength and stiffness of that component.

The behaviour of some coupled shear walls that are subjected to earthquake motion showed that all or most coupling beams failed before reaching the ultimate strength of the coupled shear wall.

## 2.2 OBJECTIVES OF THE PRESENT WORK

The main aim of this project to design a suitable seismic-isolated multistorey building on ETABS and to find out effects on building upon any seismic activity. The building is designed in ETABS where load of the building at the end of the one column is taken and Isolator is manually designed to find out its dimensions. Then the model is generated in ETABS according to the manual design and efficiency of the isolator is calculated whether the designed isolator is safe for the building or not.

**Indian codes used in this study**

- **IS 1893: (revised in 2002)**—
  - Indian Standard Criteria for Earthquake-resistant Design of Structures (fourth revision)
  - Structures should be able to respond, without structural damage, to shocks of moderate intensities, and without total collapse to shocks of heavy intensities.
- **IS 456:2000**—
  - Indian Standard Earthquake-resistant Design and Construction of Buildings: Code of Practice.
  - This code is intended to cover the specified features of design and construction for earthquake resistance of buildings of conventional types.
  - Recommendations regarding restrictions on openings, provision of steel in various horizontal bands, and vertical steel in corners and junctions**.**
- **IS 13920: 1993 & IS 1893: 2016 part 1**
  - Indian Standard Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces: Code of Practice.
- **UBC 1997---**
  - The deficiencies in the design and detailing of RCC structures.
  - For providing adequate toughness and ductility provisions on detailing of beams and columns were revised.
  - Specifications on seismic design and detailing of RCC shear walls were included.

# 3 ANALYSIS OF 6-STOREYED BUILDING IN ETABS

### 3.1 Problem Definition

In this section, a Six-storey RCC building is modeled in ETABS 2019 (a) with its based fixed to the ground and (b) with its base isolated from the ground. This building example is taken from S K Duggal (2013) Design of Earthquake resistant building. The supports are modeled as Lead Rubber Bearing (LRB) isolator whose Effective stiffness is designed by the guidelines of UBC 1997 in Design of Isolated Seismic Structures by shows isometric view of the building considered, its properties are:

Number of storeys = 6

Storey height = 18m

Number of bays in X-direction = 4

Number of bays in Y-direction = 5

Size of beams = 0.35 ×0.55 m

Size of columns = 0.5 ×0 .5 m

Concrete Grade = M30

Steel reinforcement grade = Fe 500

Seismic zone = 5

Slab thickness = 0.125m

Importance factor = 1.2

Building frame type = SMRF

Dead load = 14.19KN/$m^2$

Live load = 3KN/$m^2$

Floor load = 1KN/$m^2$

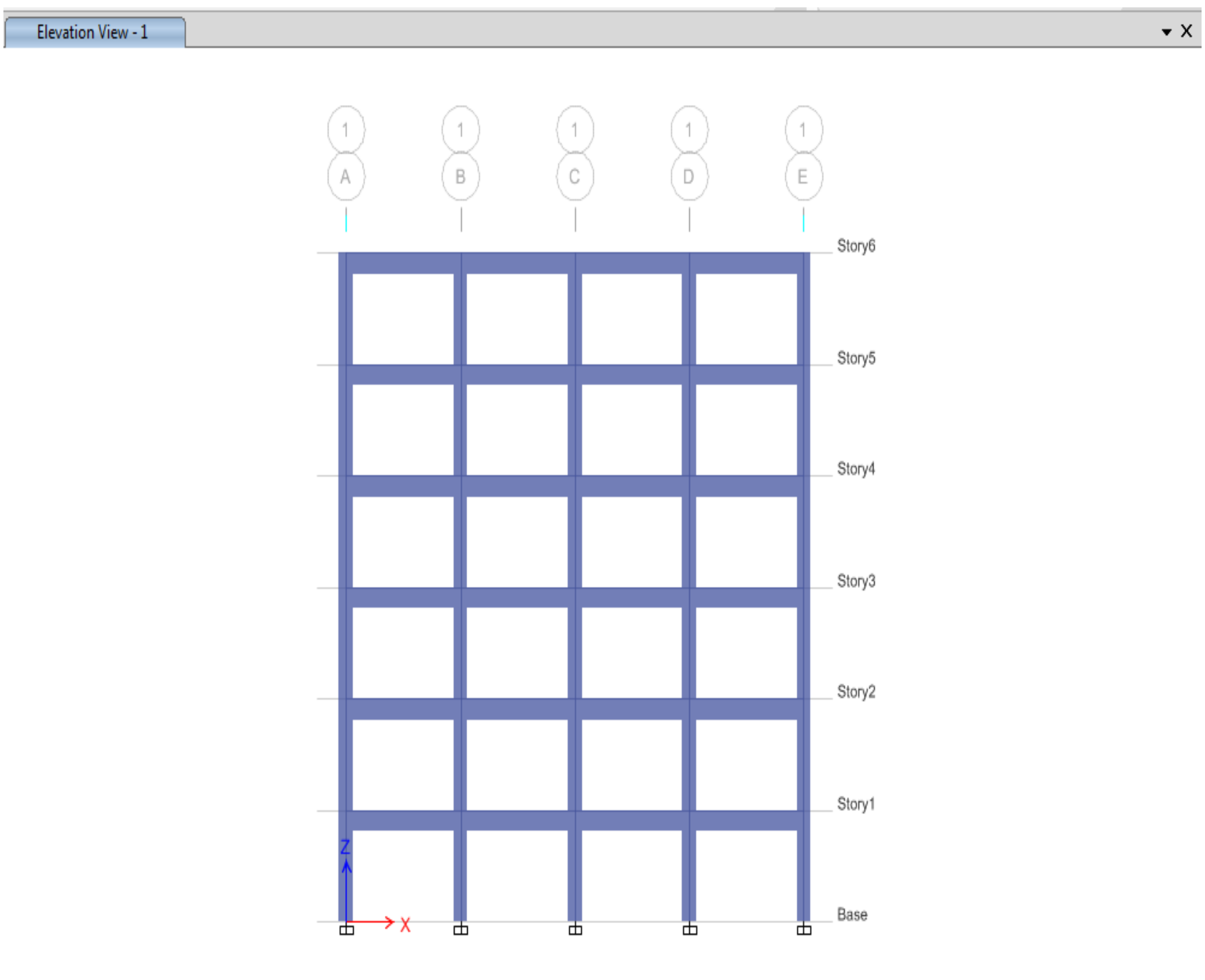



*Fig 3.1 Elevation view of structure*

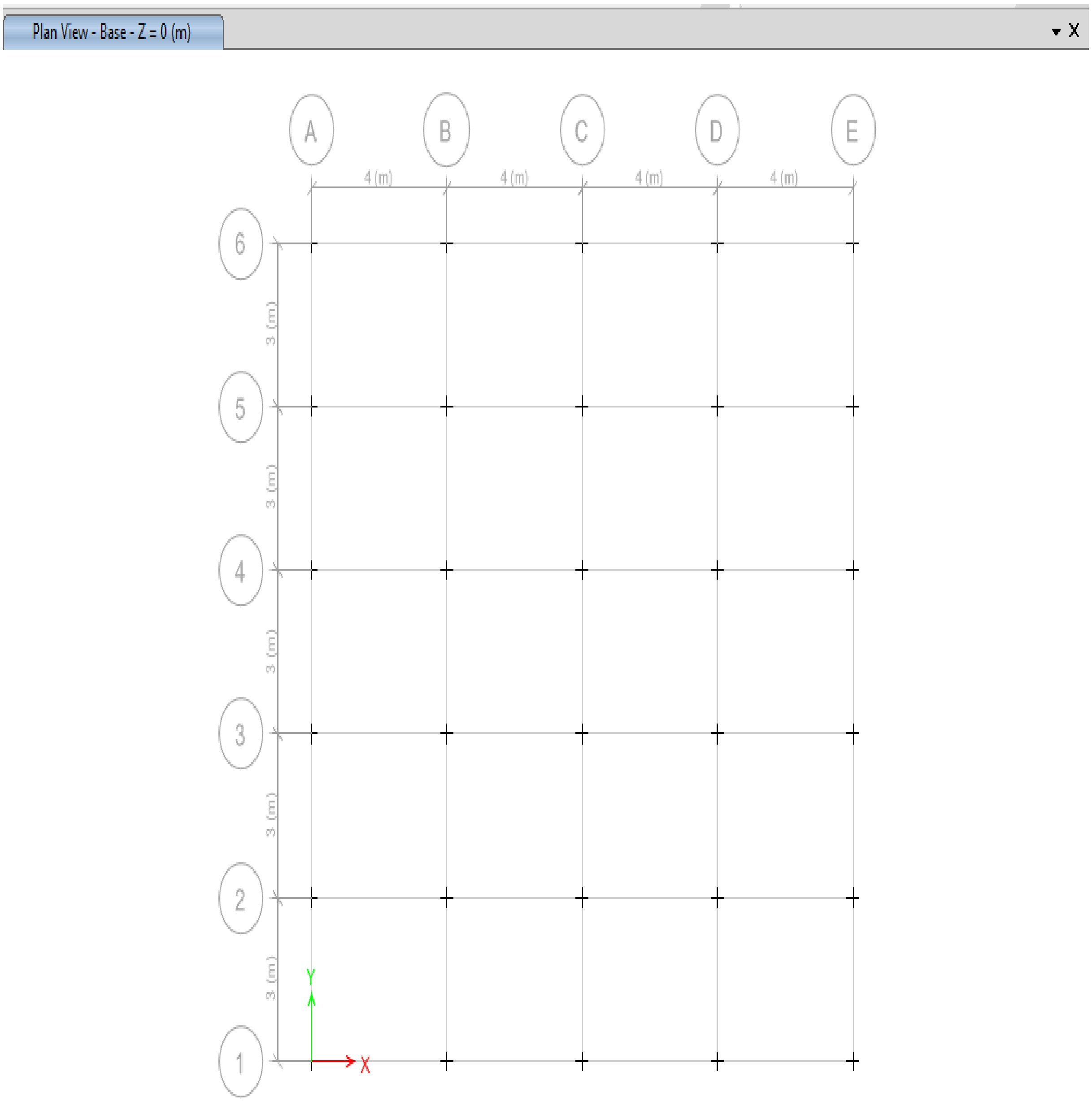



***Fig 3.2 Plan view***

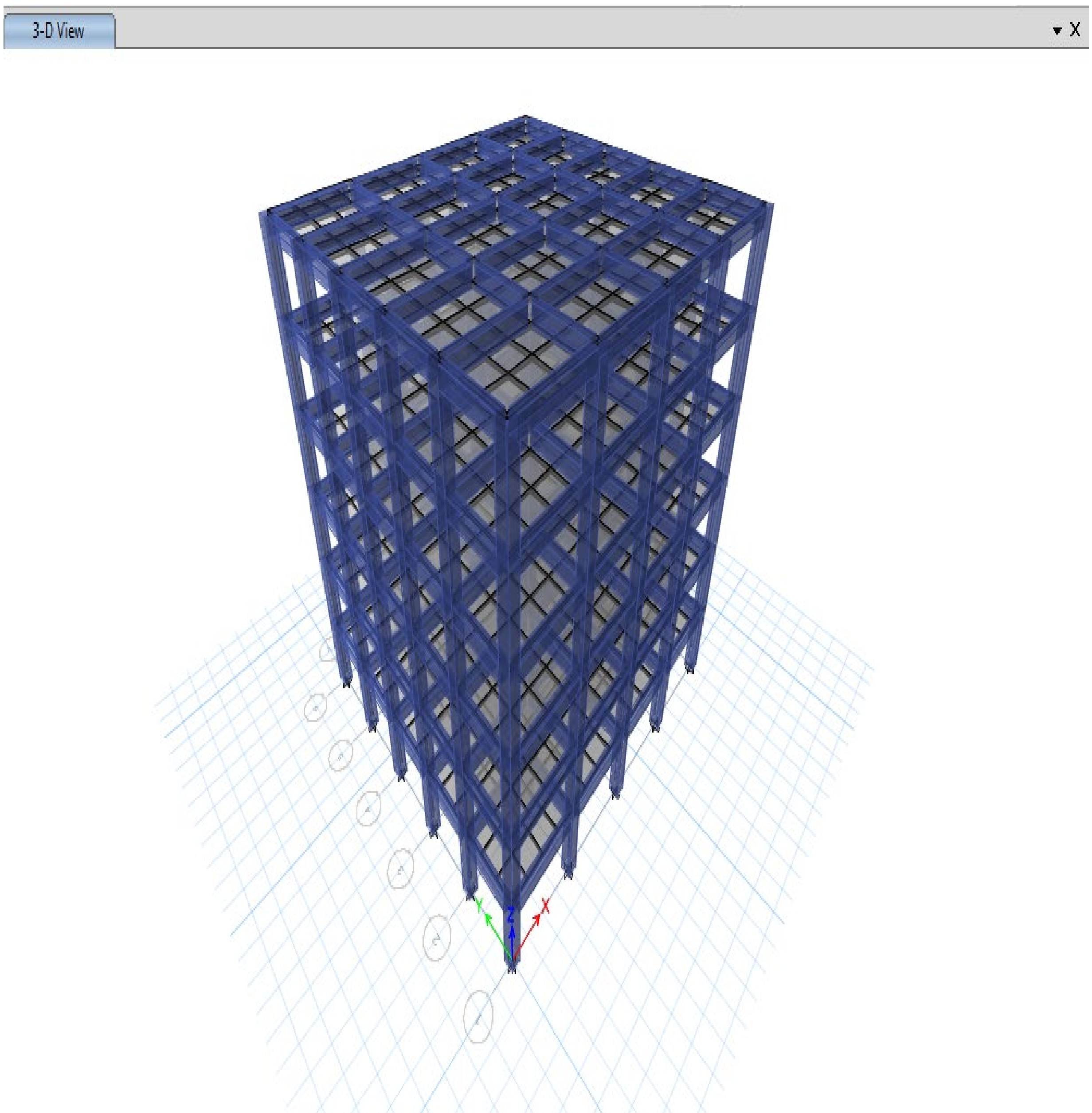



***Fig 3.3 Isometric view of structure***

RESPONSE SPECTRUM ANLAYSIS  IS DONE FOR THE STRUCTURE HERE

For design decision-making, response-spectrum analysis is more advantageous as it is based on dynamic performance for a selected structural type. Shorter-period structures experience higher acceleration, while longer-period structures incorporates larger displacement.

**Maximum storey displacement:** Absolute displacement on any floor relative to the ground and the overall allowable limit prescribed for buildings in the IS codes.

Here, we have maximum displacement in this 28.9 mm  at storey 6 as shown in the figure itself .

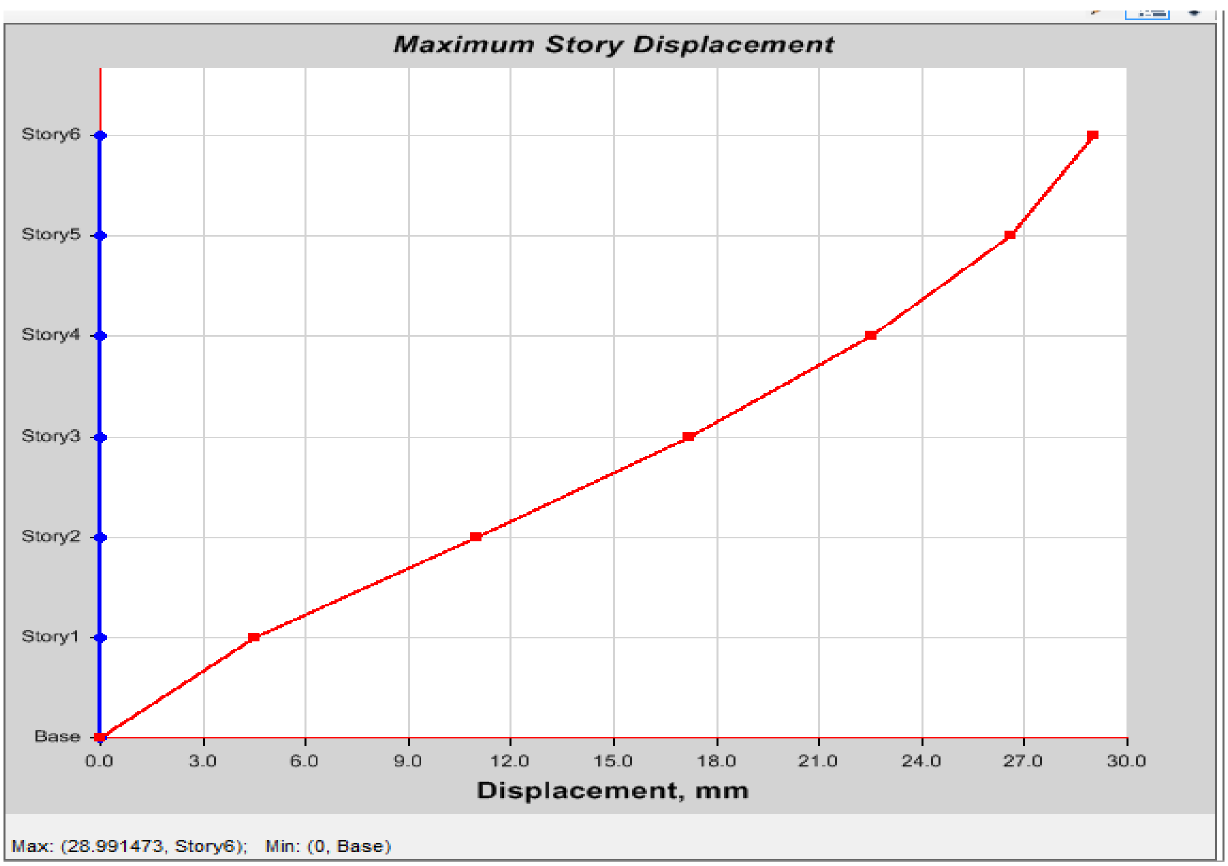



*Fig 3.4 Maximum Story Displacement*

**Storey Drift**: This is called the displacement ratio of two consecutive floors to the height of the building. It is a very relevant concept used in earthquake engineering for testing purposes.

Here we got maximum storey drift (0.002176, Story2).

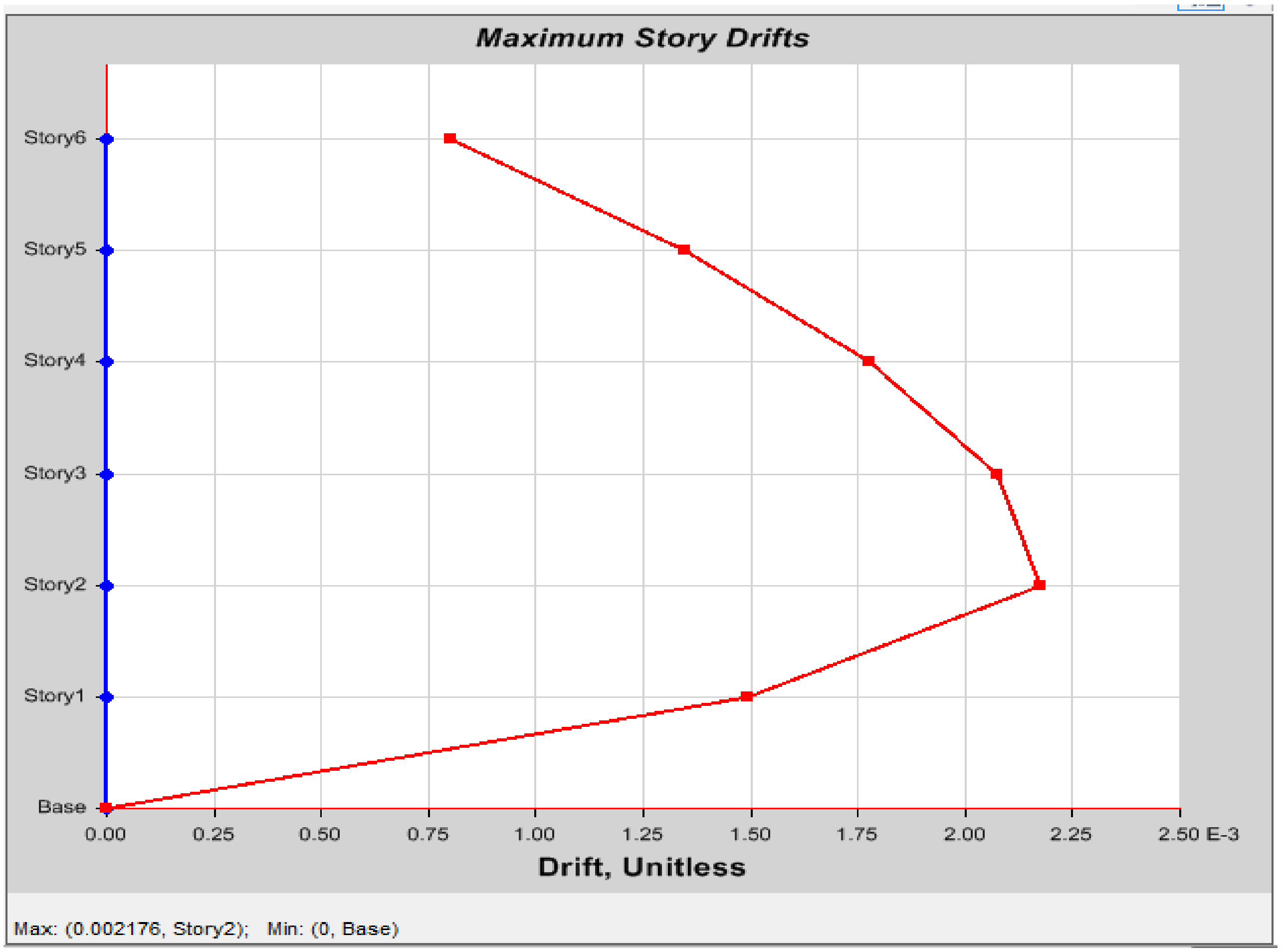



*Fig 3.5 Maximum Story Drift*

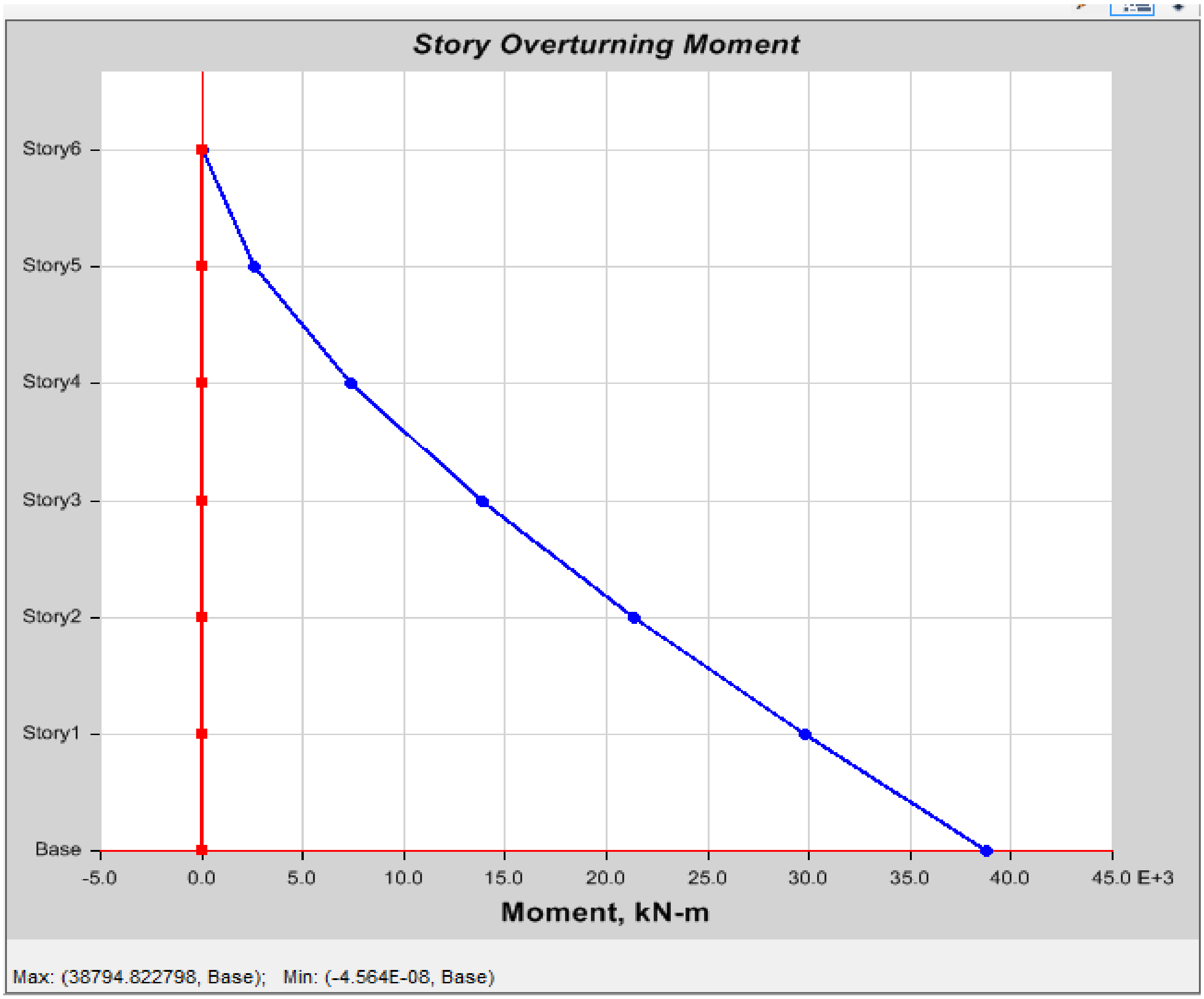



*Fig 3.6 Story Overturning Moment*

**Storey overturning moment**

The moments are discovered by multiplying the tale shear above the considered height by the distance to the centre of mass. These moment ratios exactly follow the equivalent shear ratios for each construction, thereby providing almost the same protection factor for shear and base overturning.

Max overturning moment (38794.822798, Base).

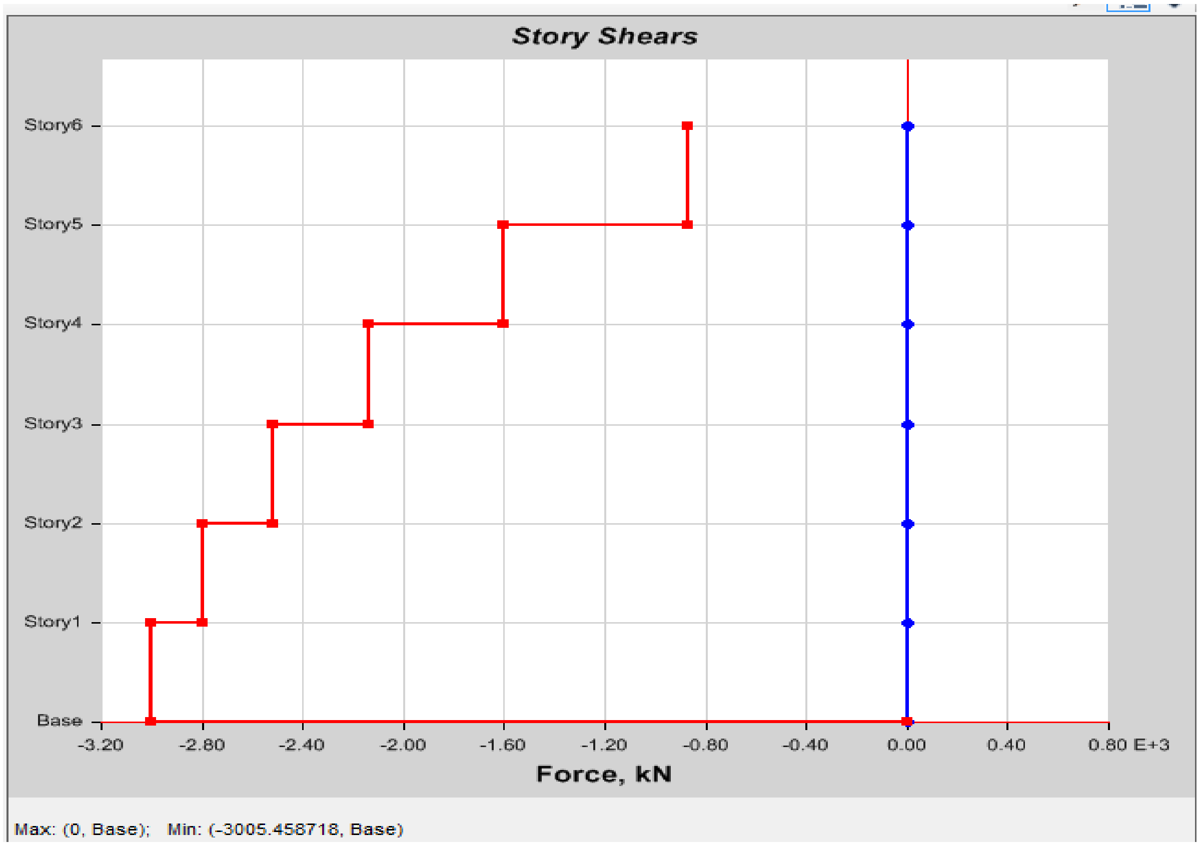



*Fig 3.7 Storey Shear*

**Story Shears** : It is the sum of the lateral forces of structure at all levels above the floor under consideration.

**MODE SHAPES** - The shape of the mode is the deformation that the part displays as the normal frequency vibrates.

In structural dynamics, the terms mode structure or normal vibration shape are used. The deformation that the part will present while vibrating at the natural frequency is represented by a mode shape.

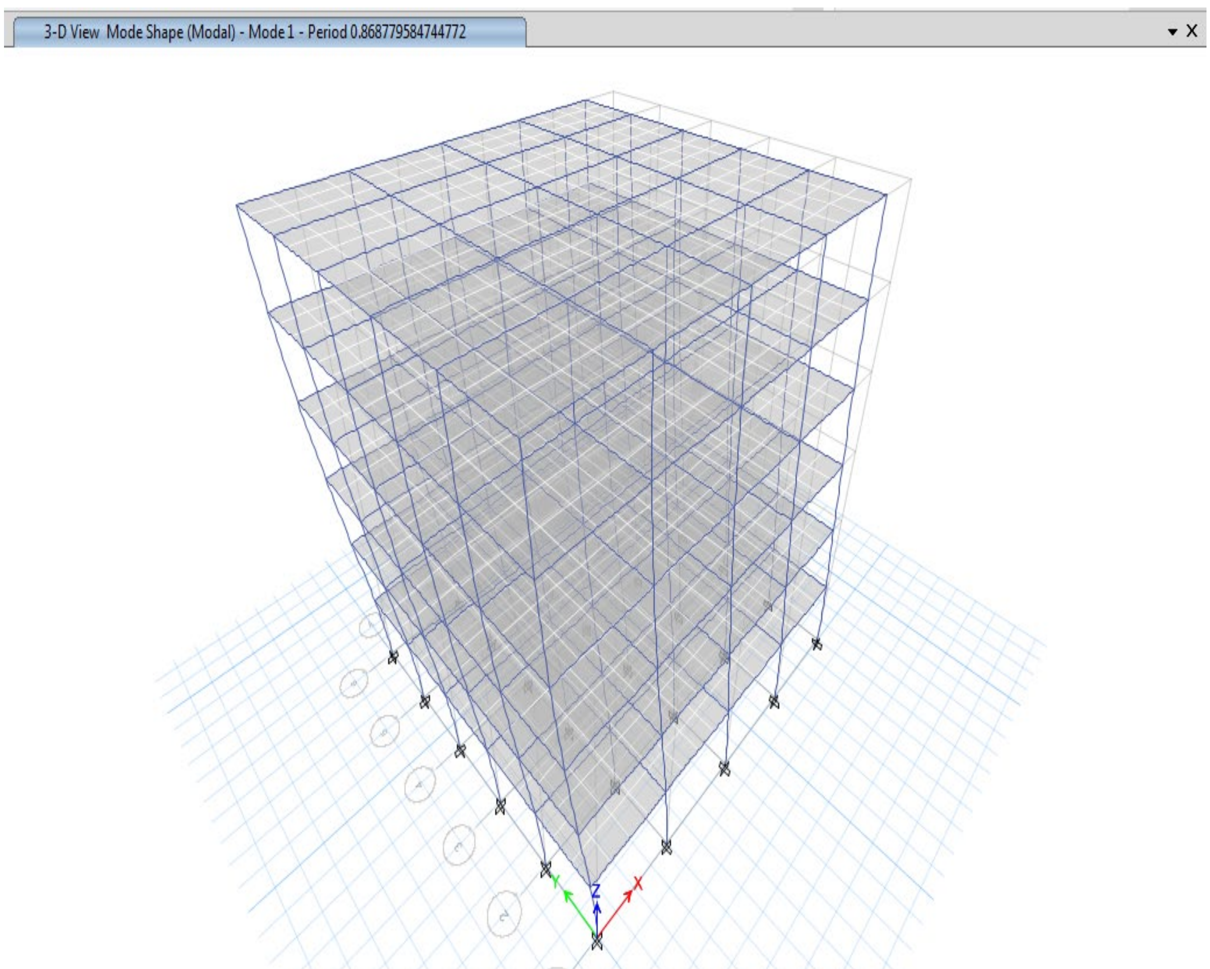



*Fig 3.8 Mode Shape 1*

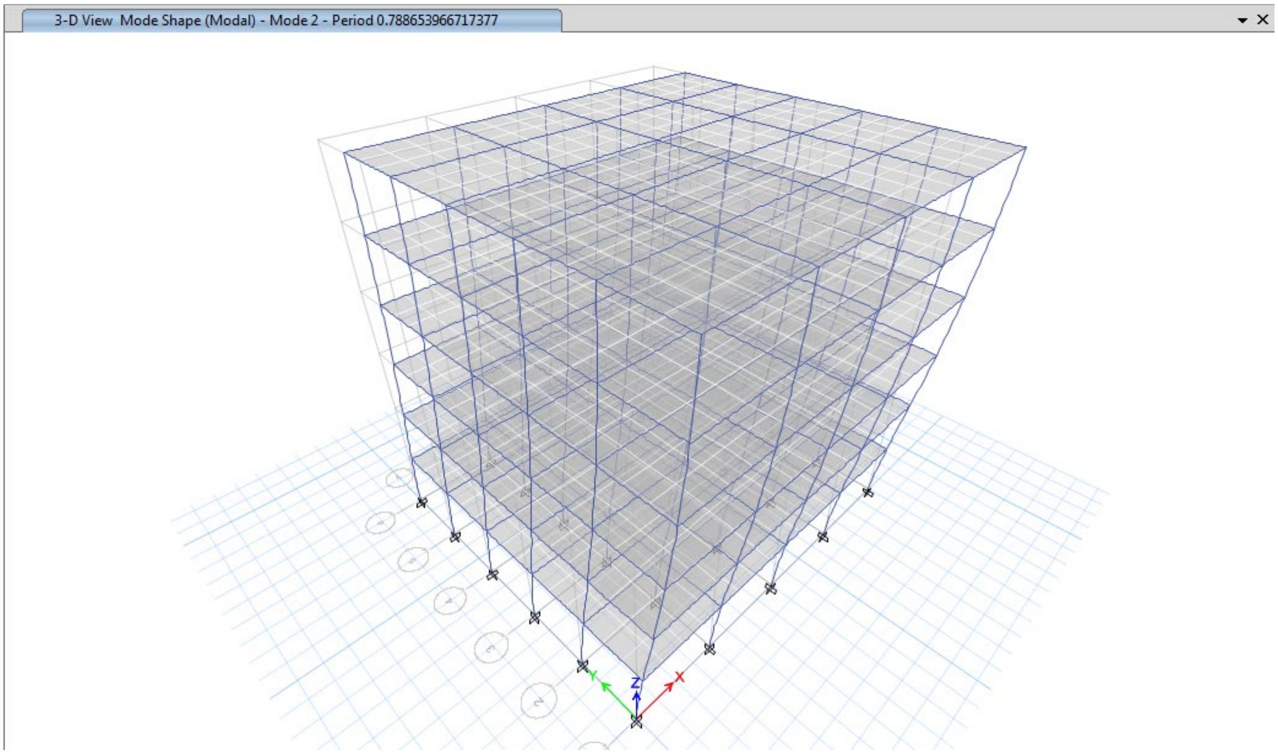



*Fig 3.9 Mode Shape 2*

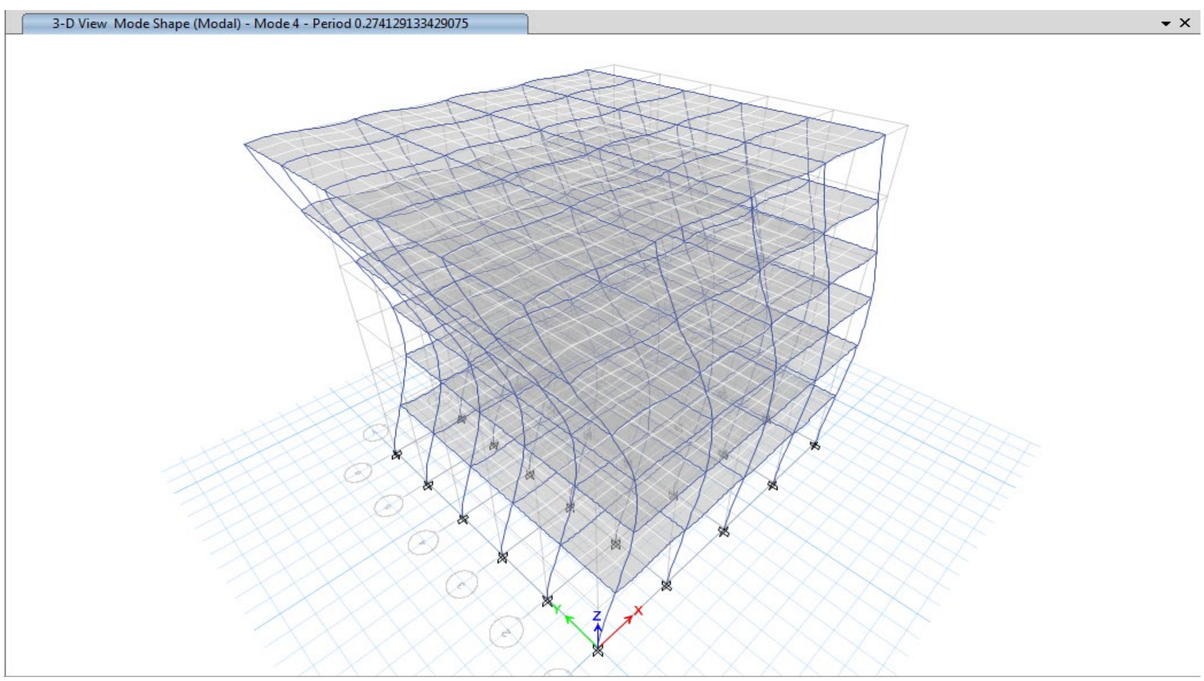



*Fig 3.10 Mode Shape 3*

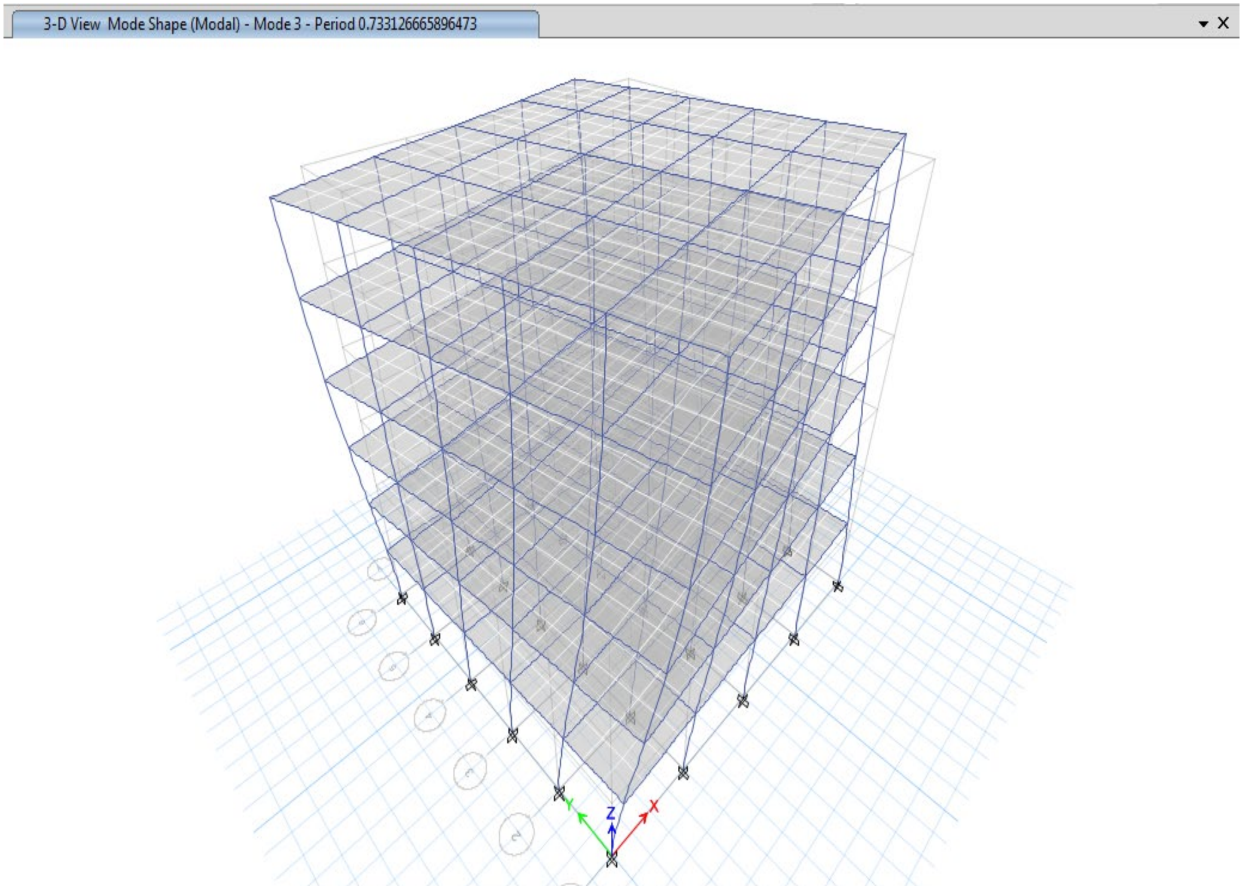



*Fig 3.10 Mode Shape 4*

**LEAD RUBBER BEARING ISOLATOR DESIGN**

| | | | | | |
|---|---|---|---|---|---|
| 1 | Maximum Vertical Load Column Support, W | | = | 1875.28 | kN |
| 2 | Shear Modulus, G | | = | 0.7 | $N/mm^2$ (Mpa) |
| 3 | Design Time Period, $T_D$ | | = | 2.5 | sec |
| 4 | Seismic zone factor, Z | | = | 0.3 | (UBC 97, Vol-2, Table 16-I & Zone Map) |
| 5 | Seismic Source Type | | = | B | |
| 6 | Near source factor, $N_a$ | | = | 1 | (UBC 97, Vol-2, Table 16-S) |
| 7 | Near source factor, $N_v$ | | = | 1 | (UBC 97, Vol-2, Table 16-T) |
| 8 | $ZN_v$ | | = | 0.30 | |
| 9 | Maximum capable earthquake response coefficient, $M_m$ | | = | 1.5 | (UBC 97, Vol-2, Table A-16-D) |
| 10 | Soil Profile Type | | = | $S_D$ | (UBC 97, Vol-2, Table 16-J) |
| 11 | Seismic coefficient, $C_v = C_{vD}$ | | = | 0.54 | (UBC 97, Vol-2, Table 16-R) |
| 12 | Seismic coefficient, $C_a$ | | = | 0.36 | (UBC 97, Vol-2, Table 16-Q) |
| 13 | Choose Response Reduction Factor, R for | *SMRF* | = | 8.5 | (UBC 97, Vol-2, Table 16-N) |
| 14 | For SMRF/IMRF/OMRF, Structural System Above the Isolation Interface, $R_i$ | | = | 2 | (UBC 97, Vol-2, Table A-16-E) |
| 15 | Effective Damping ($\beta_d$ or $\beta_m$) | | = | 5% | |
| 16 | Damping coefficient, $B_d$ or $B_m$ | | = | 1 | Interpolate (UBC 97, Vol-2, Table A-16-C) |
| 17 | Design Displacement, $D_d$ | | = | 0.3355 | m $D_D = \frac{gC_{VD}T_D}{4\pi^2 B_D}$ |
| 18 | Bearing Effective Stiffness, $K_{eff}$ | | = | 1175.42 | kN/m $K_{eff} = \frac{W}{g} \times \left(\frac{2\pi}{T_D}\right)^2$ |
| 19 | Energy dissipiated per cycle, $W_D$ | | = | 41.56 | kN-m $W_D = 2\pi K_{eff} D_D^2 \beta_{eff}$ |
| 20 | Force at Design Displacement or Characteristic Strength, Q | | = | 30.97 | kN $Q = \frac{W_D}{4D_D}$ |
| 21 | Pre Yield in Rubber, $K_2$ | | = | 1083.10 | kN/m $K_2 = K_{eff} - \frac{Q}{D_D}$ Where, $\frac{Q}{D_D}$ = Stiffness of lead core |
| 22 | Post Yield Stiffness to Pre Yield Stiffness Ratio(n) for Rubber | | = | 0.1 | $n = K_2/K_1$ |
| 23 | Post Yield Stiffness (Value for Non-linear Case also), $K_1$ | | = | 10831.01 | kN/m |
| 24 | Yield Displacement (Distance from End-J), $D_Y$ | | = | 0.0032 | m $D_Y = \frac{Q}{K_1 - K_2}$ |
| 25 | Recalculation of Force Q to $Q_R$ | | = | 31.2650 | kN $Q_R = \frac{W_D}{4 \times (D_D - D_Y)}$ |
| 25 | Yield Strength of Lead, | | = | 10 | Mpa |
| 26 | So, Are of Lead Plug required, A | | = | 0.0031 | $m^2$ $A_{PB} = \frac{Q_R}{10 \times 10^3}$ |
| 27 | So, Diameter of Lead Plug required, d | | = | 0.063 | m |
| | | | = | 63.1 | mm |
| 28 | Recalculation of Rubber stiffness $K_{eff}$ to $K_{eff(R)}$ | | = | 1082.22 | kN/m $K_{eff(R)} = K_{eff} - \frac{Q_R}{D_D}$ |
| 29 | Maximum Shear Strain of Rubber, γ | | = | 100% | |
| 30 | Total Thickness of Rubber, $t_r$ | | = | 0.3355 | m $t_r = \frac{D_D}{\gamma}$ |
| 31 | Area of Bearing, $A_{LRB}$ | | = | 0.5186 | $m^2$ $A_{LRB} = \frac{K_{eff(R)} \times t_r}{G}$ |
| 32 | Diameter of Bearing, $D_{LRB}$ | | = | 0.813 | m $\emptyset = \sqrt{\frac{4 \times A}{\pi}}$ |
| | | | = | 813 | mm |

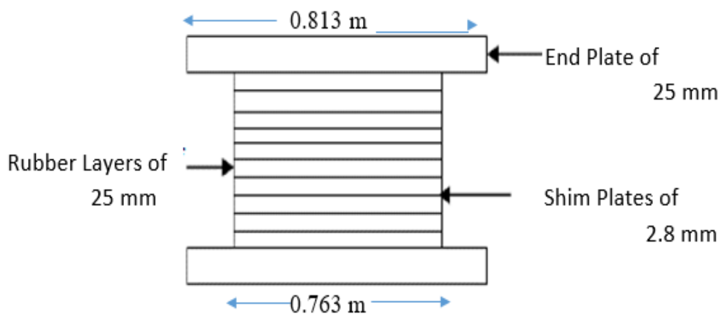
| | | | | | |
|---|---|---|---|---|---|
| 33 | Horizontal Time Period Consider | = | 2 | sec | Take horizontal period to be 2 sec |
| 34 | Horizontal Frequency, $f_h$ | = | 0.50 | Hz | $f_h = \frac{1}{2} = 0.5$ Hz |
| 35 | Set Vertical Frequency, $f_v$ | = | 10 | Hz | |
| 36 | So, Shape Factor, S | = | 8.33 | | $S = \frac{1}{2.4} \times \frac{f_v}{f_h}$ |
| 37 | Single Layer of Rubber, t | = | 24 | mm | $t = \frac{\emptyset_{LRB}}{4S}$ |
| 38 | So number of Rubber Layers, N | = | 13.76 | | |
| | | ≈ | 14 | | |
| 39 | So, Provide Single Layer of Rubber (Round up to nearest 5) | = | 25 | mm | |
| 40 | Let, Thickness of Shim Plates | = | 2.8 | mm | |
| 41 | Number of Shim Plates, n | = | 13 | n=(N-1) | |
| 42 | End Plate Thickness is between 19mm to 38 mm, Choose | = | 25 | mm | |
| 43 | So Total Height of LRB, h | = | 436.4 | mm | |
| | | | | | |
| 44 | Bulk Modulus, K | = | 2000 | Mpa | |
| 45 | Compression Modulus, Ec | = | 249131.9 | kN/m² | $E_c = 6GS^2\left(1 - \frac{6GS^2}{K}\right)$ |
| 46 | Horizontal Stiffness, $K_H$ | = | 1082.219 | kN/m | $K_H = \frac{GA_{LRB}}{t_r}$ |
| 47 | Vertical Stiffness, $K_V$ | = | 385164.667 | kN/m | |
| | | = | 385.165 | MN/m | |
| 48 | Cover from Lead to End Plate | = | 25 | mm | |
| 49 | Bonded Diameter | = | 0.763 | m | |
| 50 | Moment of Inertia,I | = | 1.660E+10 | kN/mm | Cir.: $I=\pi B^4/64$ |
| | | = | 0.016603 | kN/m | |
| 51 | Area of Hysteresis Loop, $A_h$ | = | 41.162 | kN-m | $A_h=4Q(D_d-D_y)$ |
| 54 | Yield Strength, $F_y$ | = | 34.703 | kN | $F_y=Q+K_2*D_y$ |

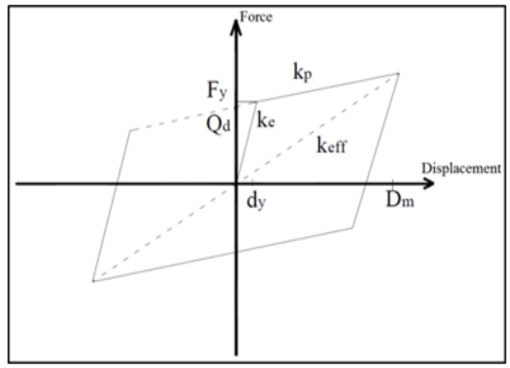
*Table 2 Design of LRB*

**Reference**: UBC-97 & DESIGN OF SEISMIC ISOLATED STRUCTURE FROM THEORY OF PRACTICE by JAMES M.KELLY and FARZAD NAEIM

Finally input values for ETABS/SAP2000:

| | | |
|---|---|---|
| Rotational Inertia1 | **0.016603** | kN/m |
| For U1 Effective Stiffness | **1175418.57** | kN/m |
| For U2 & U3 Effective Stiffness | **1175.42** | kN-m |
| For U2 & U3 Effective Damping | **0.05** | |
| For U2 & U3 Distance from End-J | **0.00318** | m |
| For U2 & U3 Stiffness | **10831** | kN/m |
| For U2 & U3 Yield Strength | **34.70** | kN |



# 4 ANALYSIS OF 6-STORYED BUILDING USING SHEAR WALL

We analyzed the same building in E-tabs 2019 but the difference is that this building was made with the help of the Shear wall.

Modeling of the building – From the model considered in this report mass distribution and stiffness distribution were analysed by considering dynamic interaction. Using Etabs detailing is done i.e. number of columns, beams, slabs, walls, etc. in the building were inputted. Calculation of storey loads were done by inputting fixed loads as well as loads on floors according to the purpose of each room.

| **Displacement Data** | | | | | | |
|---|---|---|---|---|---|---|
| | Roof | Floor 5 | Floor 4 | Floor 3 | Floor 2 | Floor 1 |
| Fixed Base (mm) | 28.99 | 26.58 | 22.55 | 17.22 | 11.01 | 4.47 |
| Shear Wall (mm) | 15.4 | 12.3 | 9.24 | 6.29 | 3.24 | 1.25 |
| **Velocity Data** | | | | | | |
| | Roof | Floor 5 | Floor 4 | Floor 3 | Floor 2 | Floor 1 |
| Fixed Base (mm/sec) | 221.71 | 202.99 | 174.65 | 137.75 | 92.69 | 40.56 |
| Shear Wall (mm/sec) | 36.15 | 27.65 | 30.27 | 28.44 | 20.98 | 9.73 |
| **Acceleration Data** | | | | | | |
| | Roof | Floor 5 | Floor 4 | Floor 3 | Floor 2 | Floor 1 |
| Fixed Base ($mm/sec^2$) | 1988.83 | 1690.8 | 1510.56 | 1370.85 | 1179.56 | 817.04 |
| Shear Wall ($mm/sec^2$) | 2529.52 | 1690.8 | 2248.9 | 1843.43 | 3060.52 | 2598.47 |
| **Storey Shear** | | | | | | |
| | Roof | Floor 5 | Floor 4 | Floor 3 | Floor 2 | Floor 1 |
| Fixed Base (KN) | 868.22 | 1600.83 | 2137.71 | 2522.14 | 2797.23 | 3005.45 |
| Shear Wall (KN) | 1328.11 | 2488.31 | 3318.35 | 3891.42 | 4280.65 | 4559.15 |

Table 3 Displacement, Velocity, Acceleration Data at a single node in Building

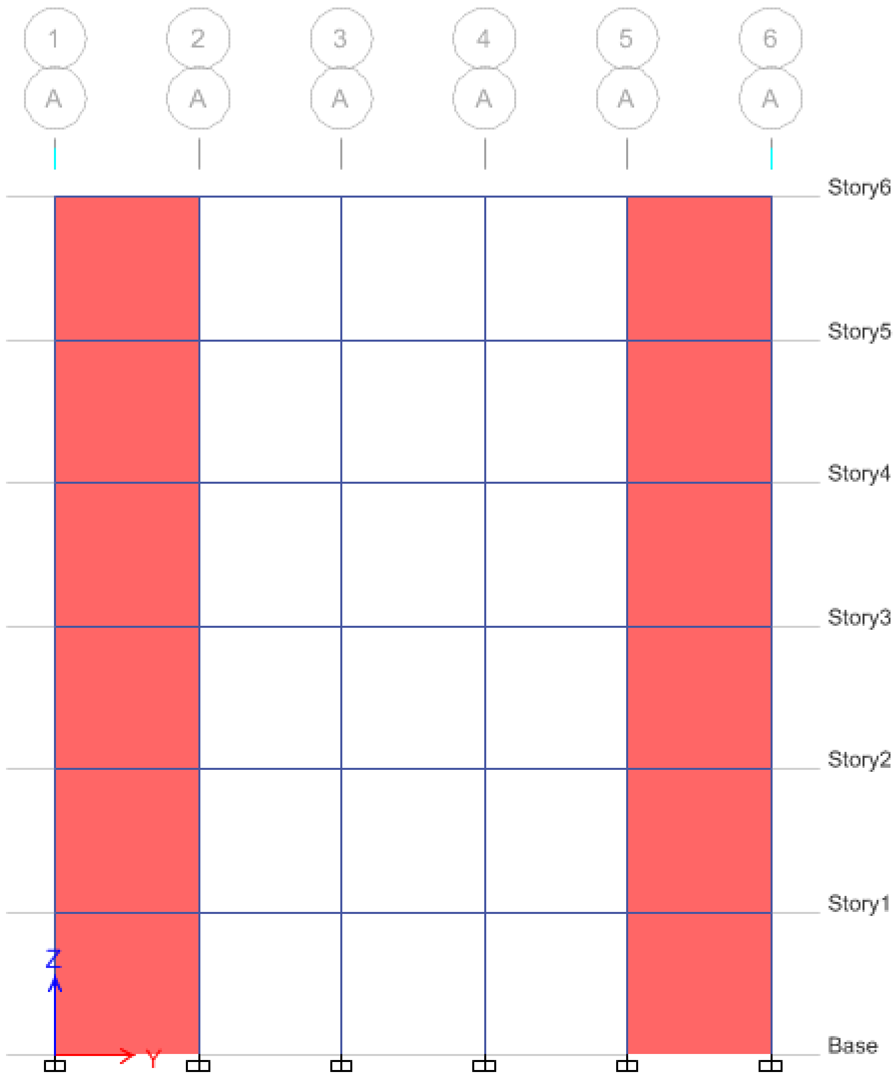



*Figure 4.1 Side View*

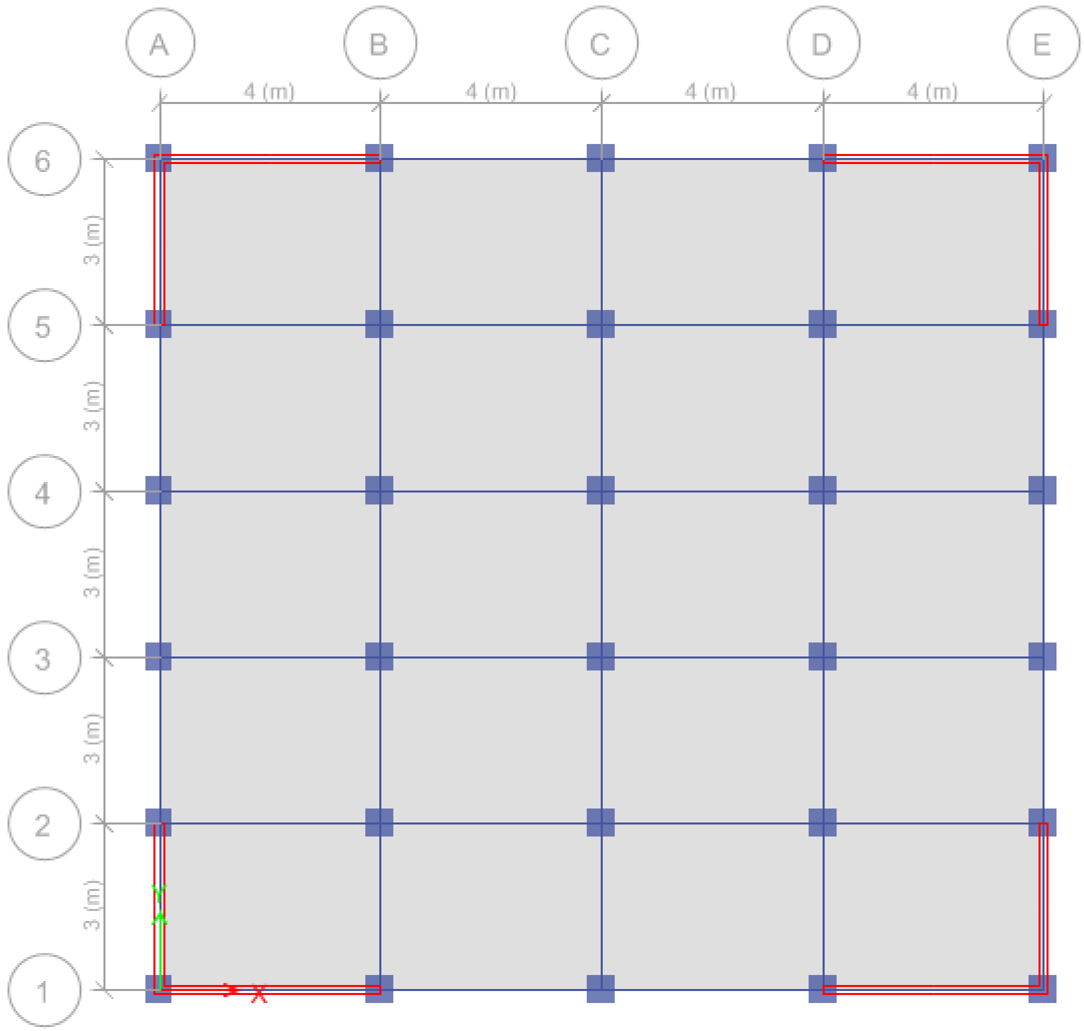



*Figure 4.2 Plan View*

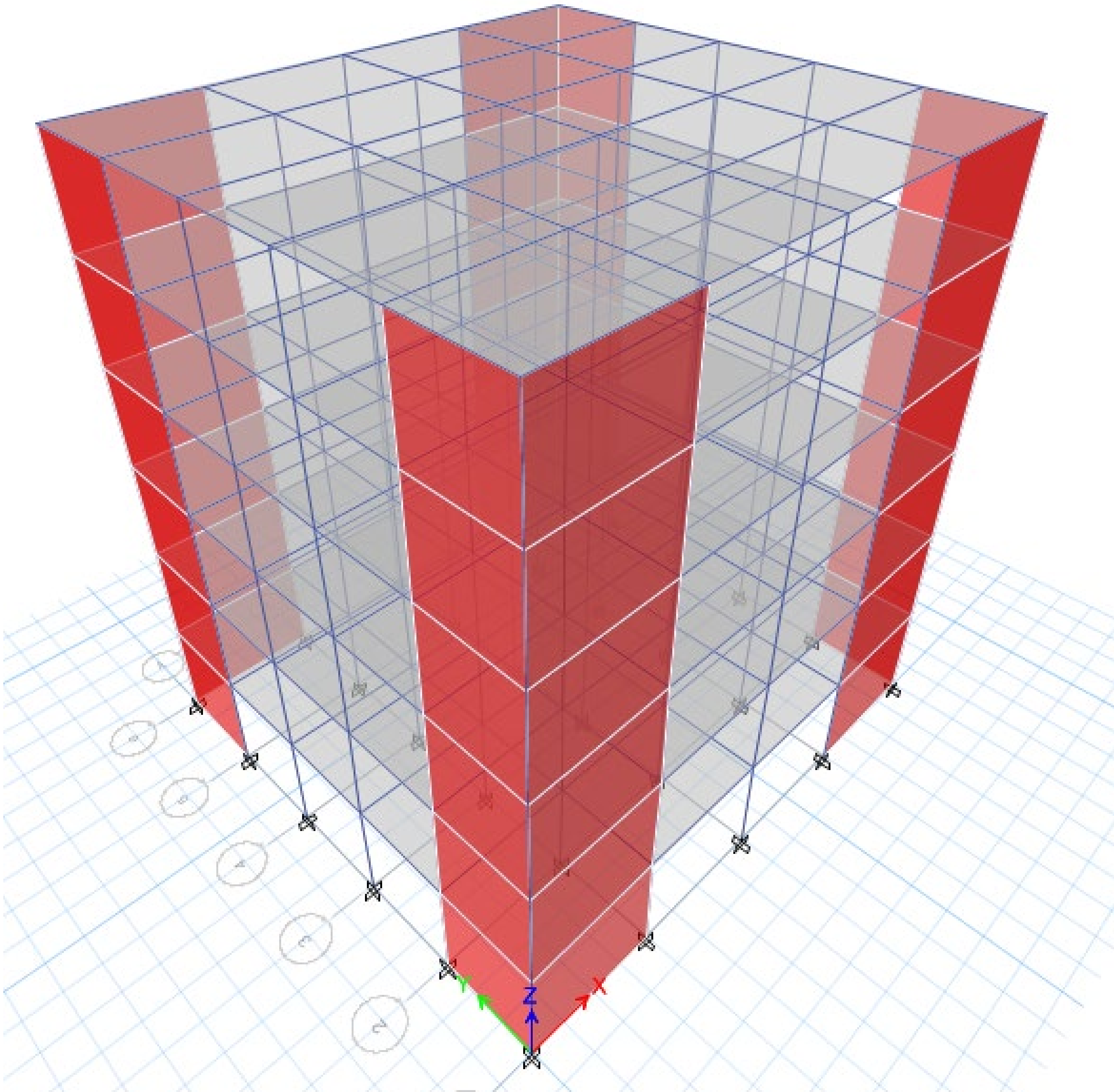



*Figure 4.3 Rendered 3D view*

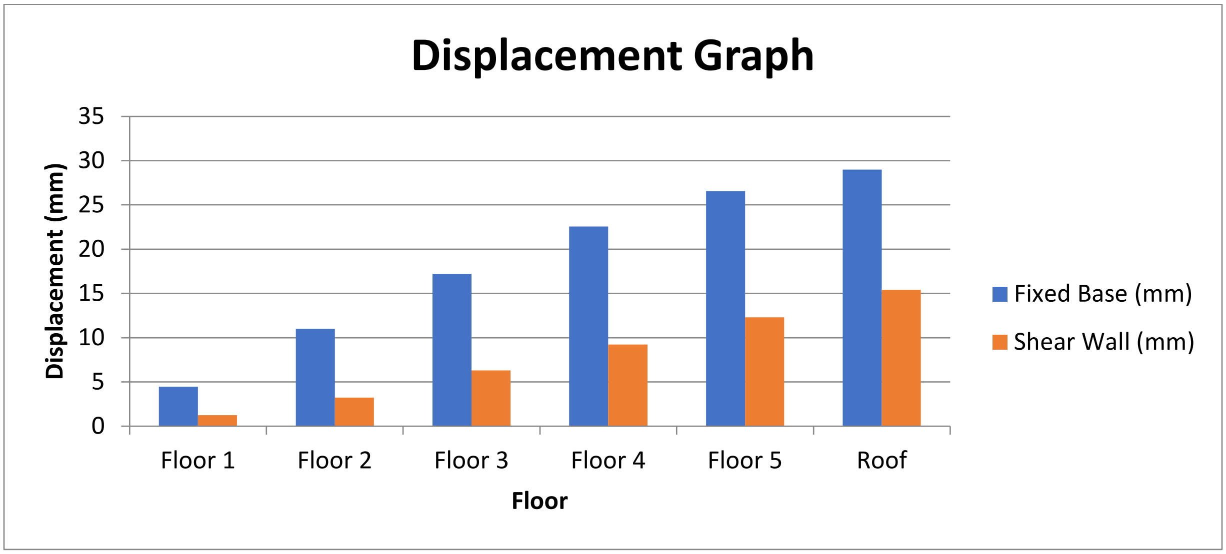



Fig 4.4 Displacement Graph (Fixed Base vs Shear wall)

This shows the total displacement on each floor with respect to the ground or a fixed base. As there is a certain value according to IS codes is only permissible if any building will cross that limit then that will leads to the failure of the structure.

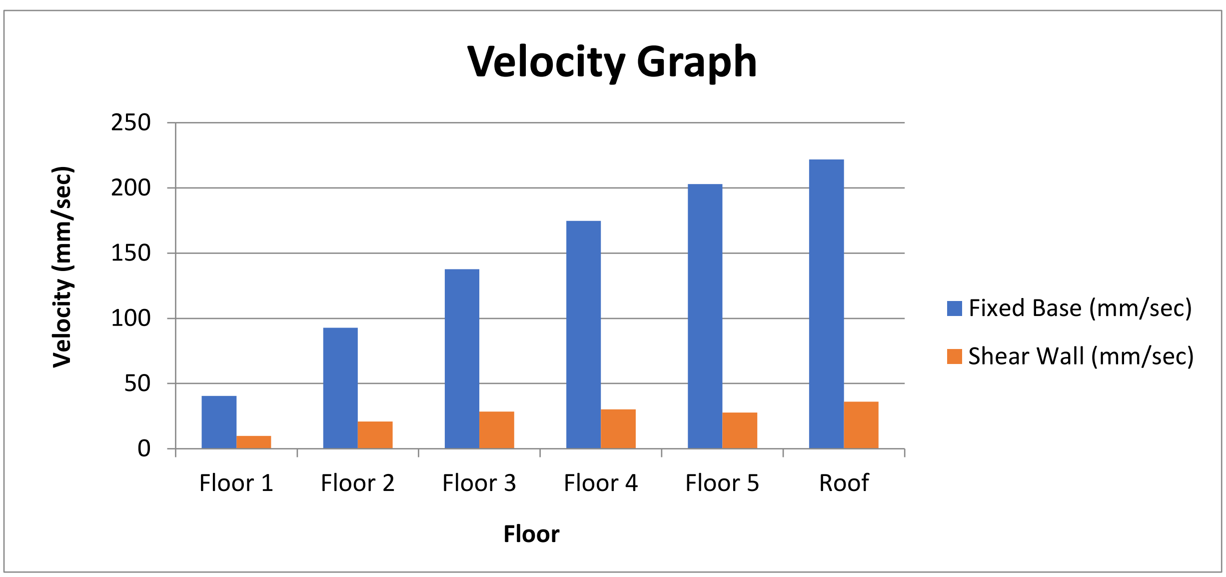



Fig 4.5 Velocity Graph (Fixed base vs Shear wall)

About velocity graph

Velocity in every direction is different as we are analyzing the structure in 3D . We have a graph comparison here we can clearly see the change.

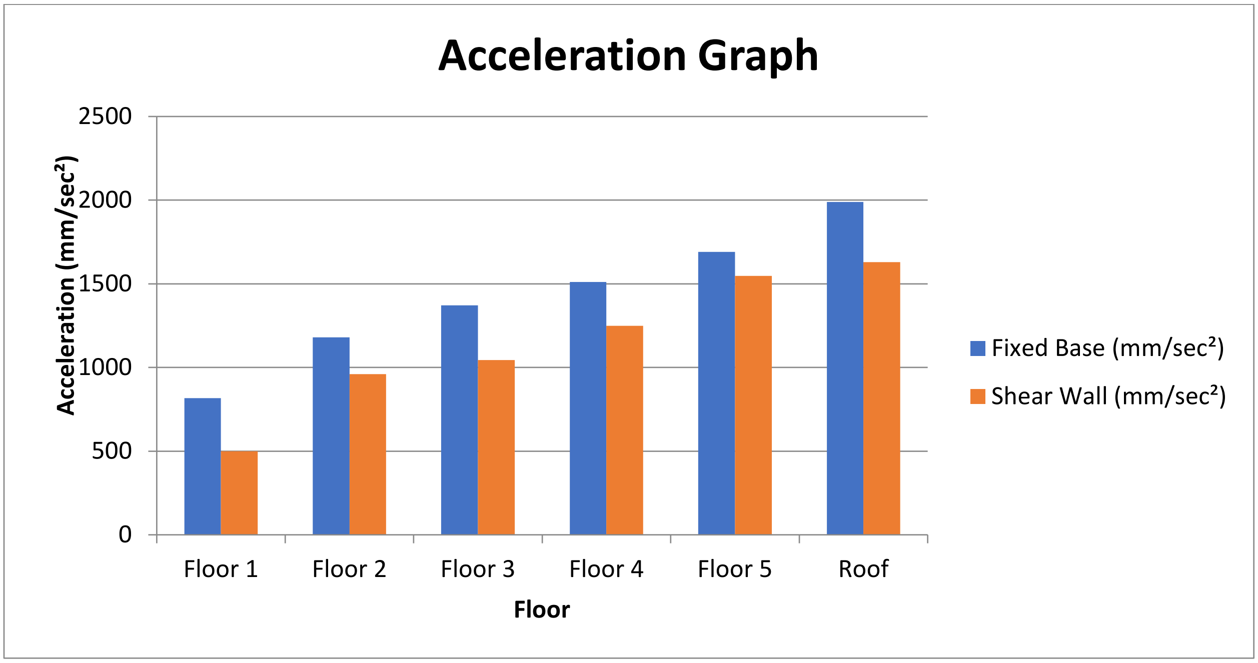



Fig 4.6 Acceleration graph (Fixed base vs Shear wall)

The acceleration on each floor is also decreasing upto a great level which is a good sign.

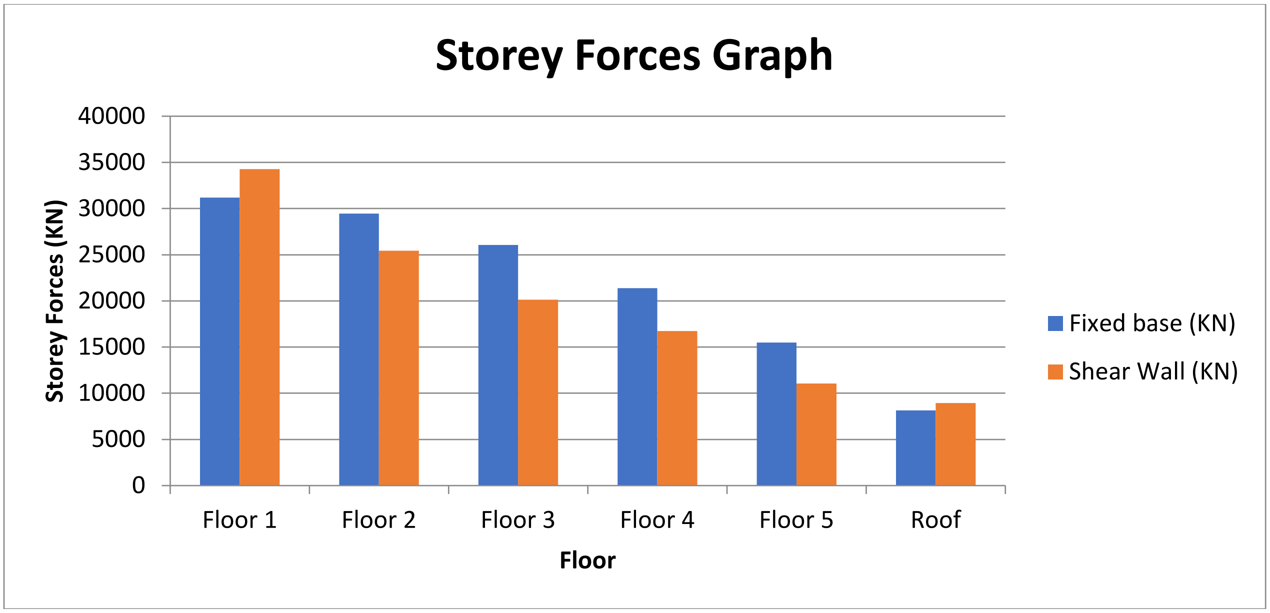



Fig 4.7 Storey forces graph ( Fixed base vs Shear wall )

Total forces on each level are decreasing by a great percentage as visible in the graph which shows a clear difference of total forces between Shear wall structure and fixed base structure.

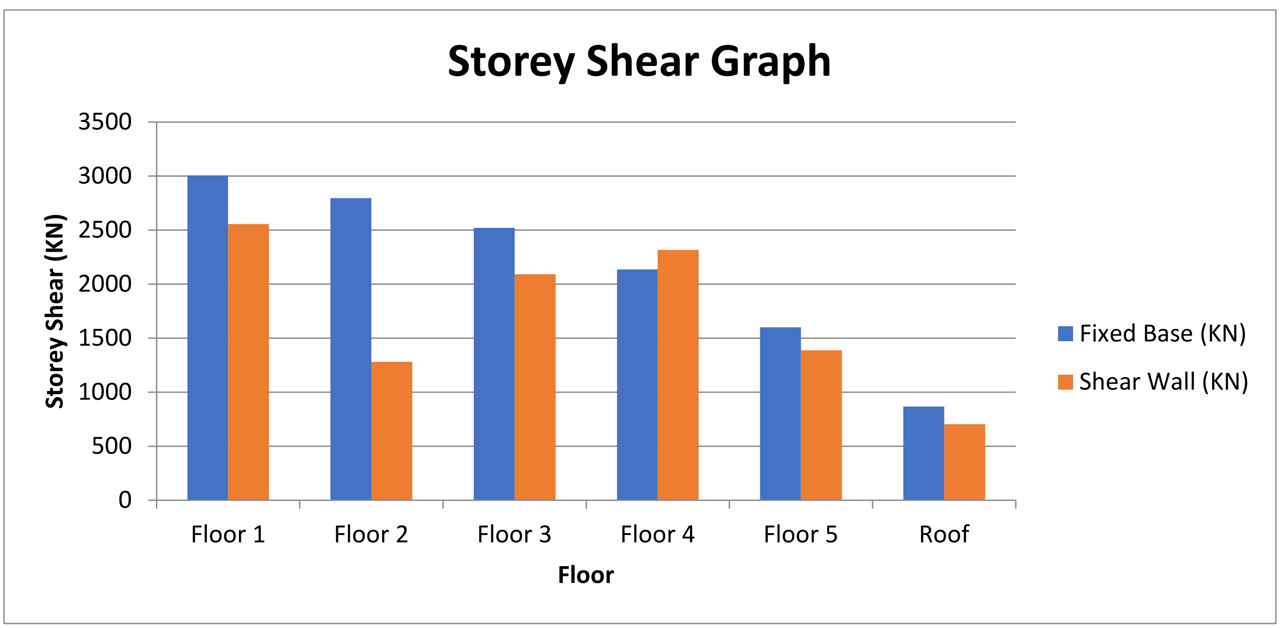



Fig 4.8 Storey shear graph ( fixed base vs Shear wall )

**Total shear on each level** - By this, you can see the total lateral load governing in a certain direction which is decreasing here in the Shear wall structure as compared to the normal fixed base.

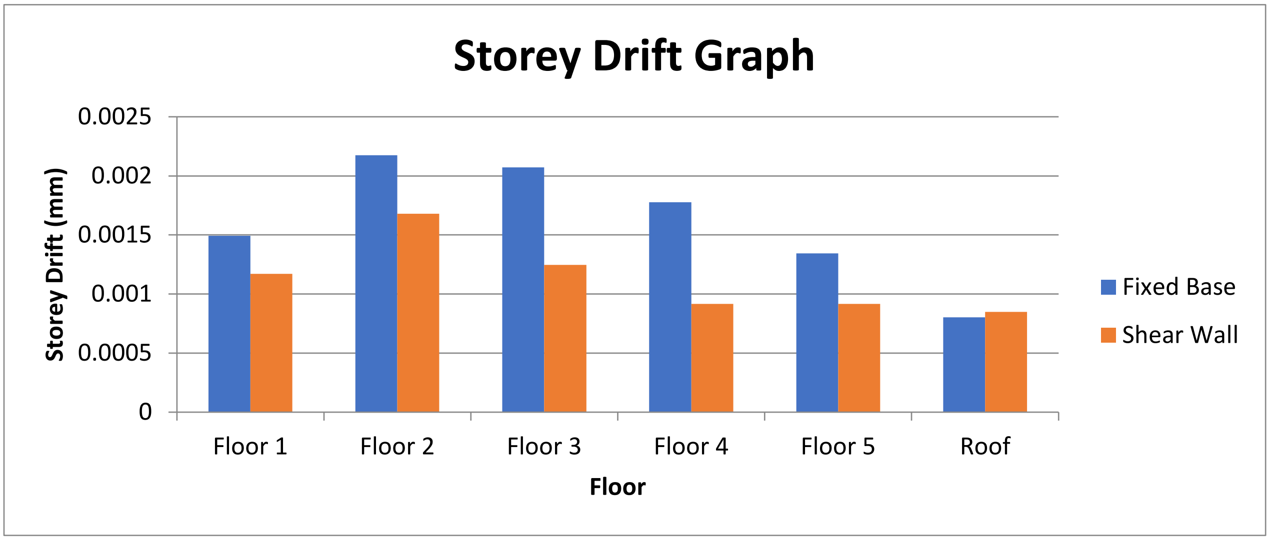



Fig 4.9 Storey drift graph (Fixed graph vs Shear wall)

It is the relative displacement of one level with respect to another level (level above or below), More the storey displacement more will be the damage done to the structure.

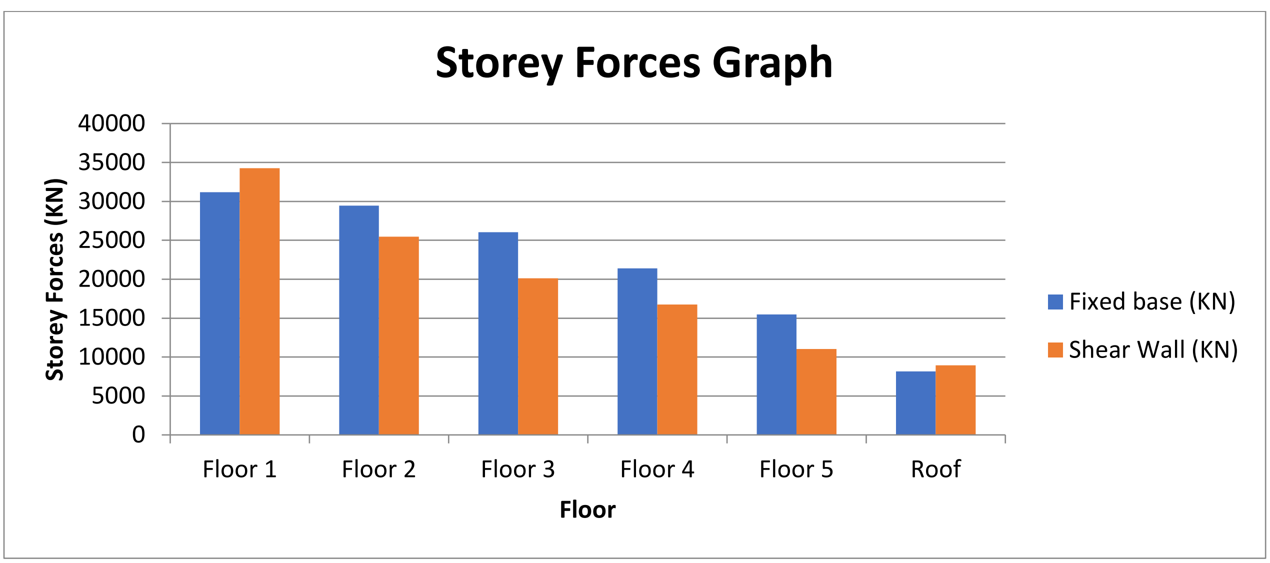



Fig 4.10 Storey force graph ( Fixed base vs Shear wall )

These are the total forces on each level Forces on each storey are reducing greatly after the Shear wall is applied to the structure . That means the structure is experiencing less force that with increases the strength of the structure to withstand an earthquake or any other calamity.

These are the first four mode shapes of the structure after applying Shear wall in the building

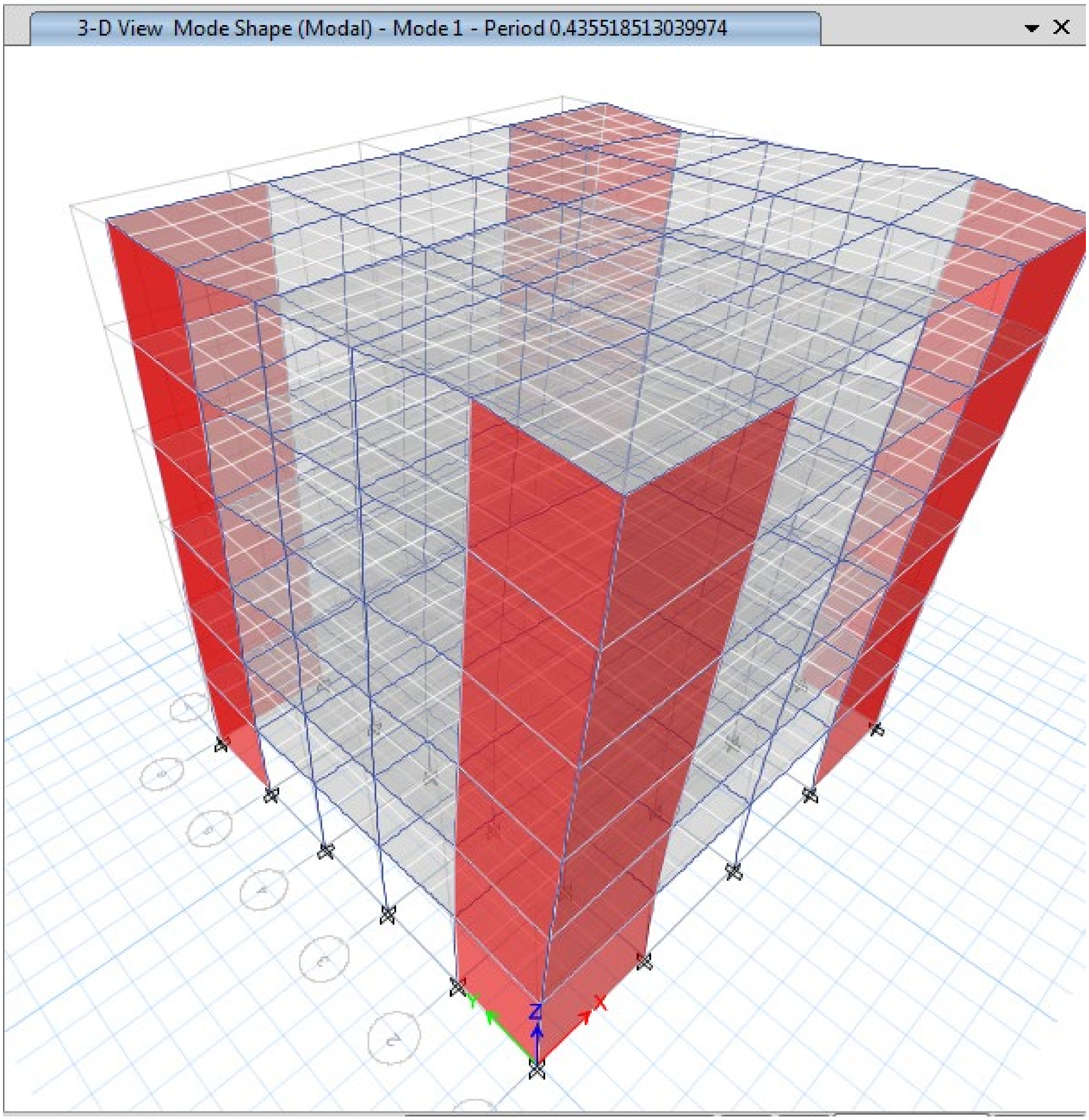



Fig 4.11 Mode shape 1

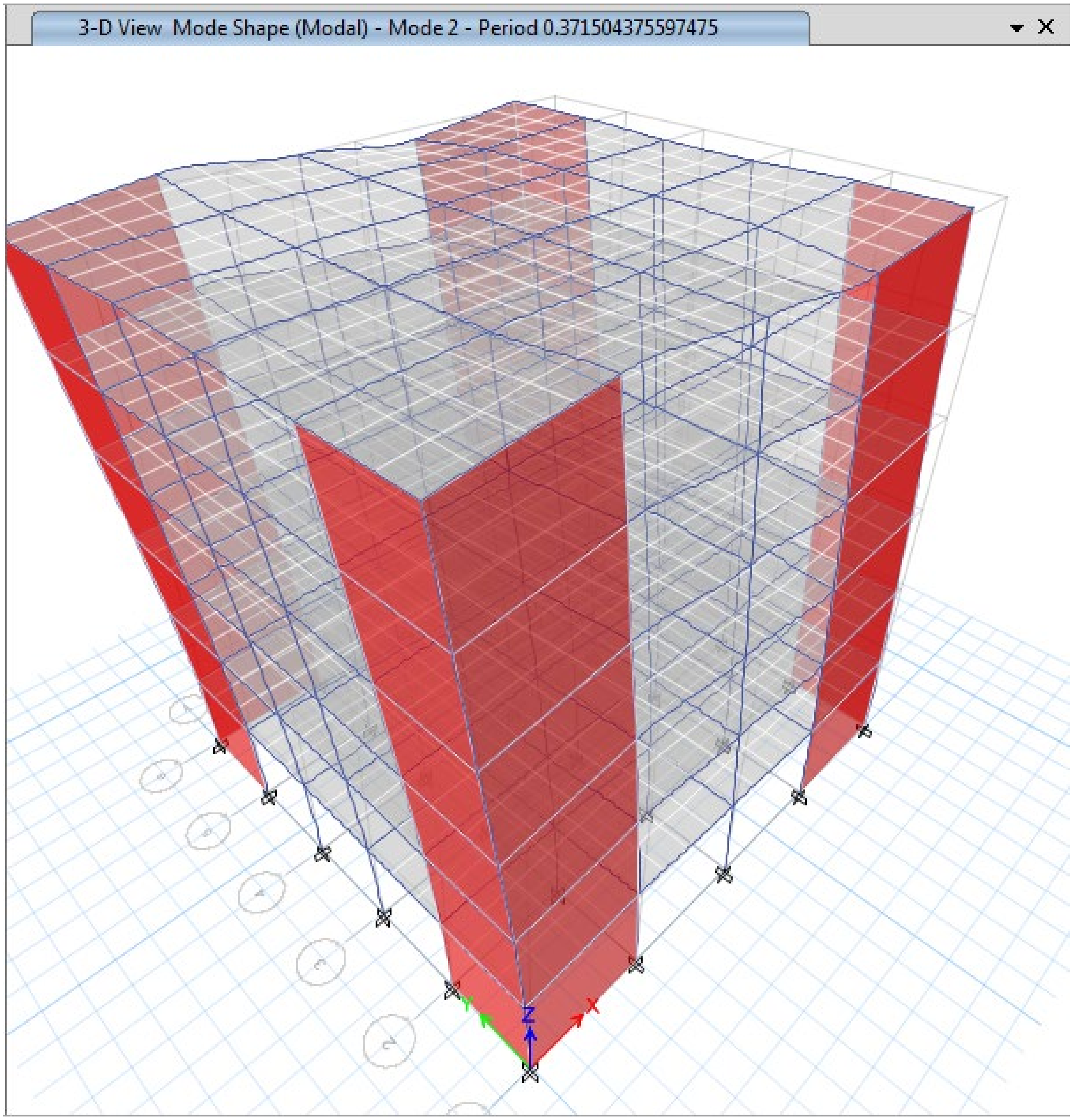



Fig 4.12 Mode shape 2

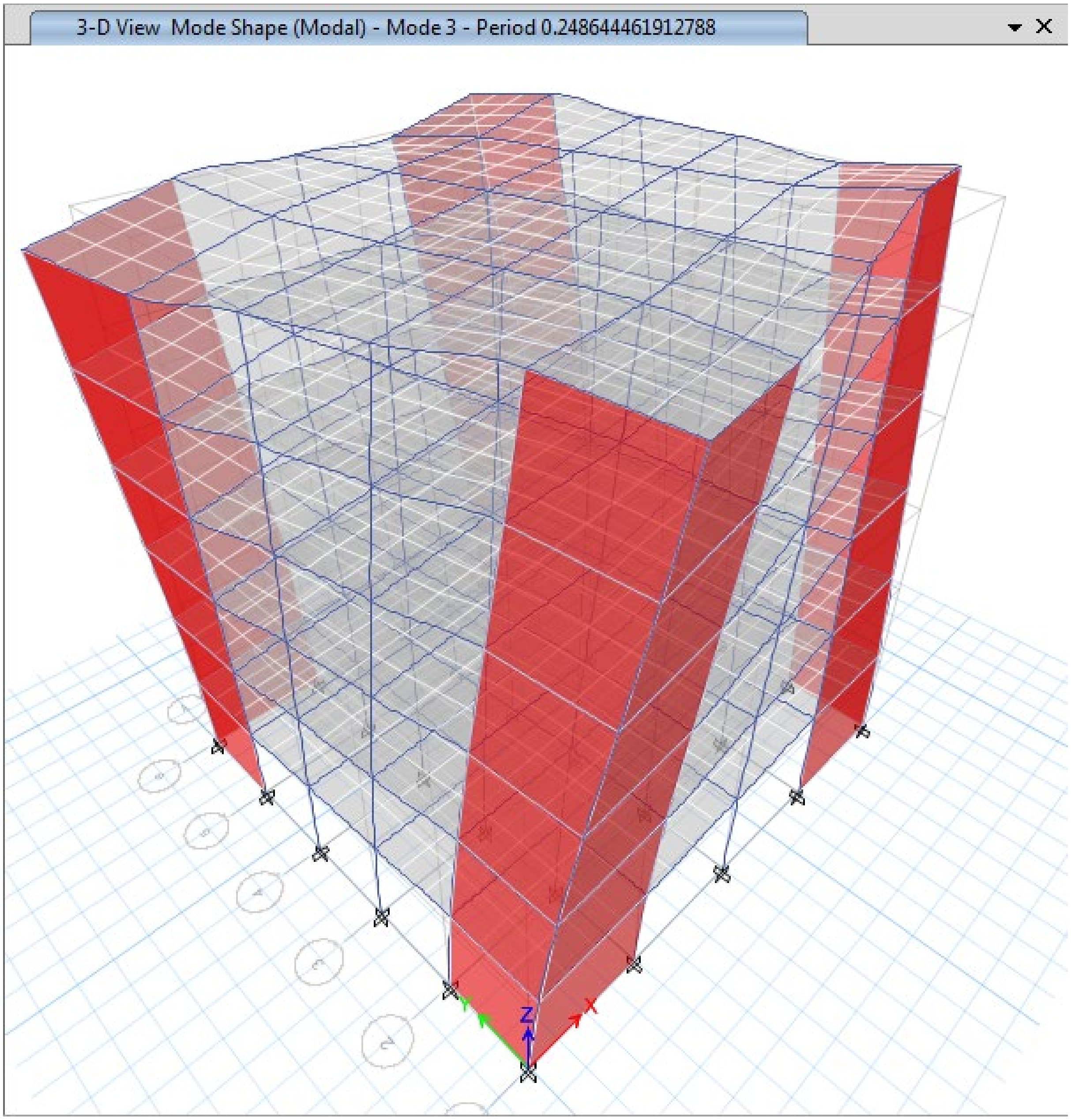



Fig 4.13 Mode shape 3

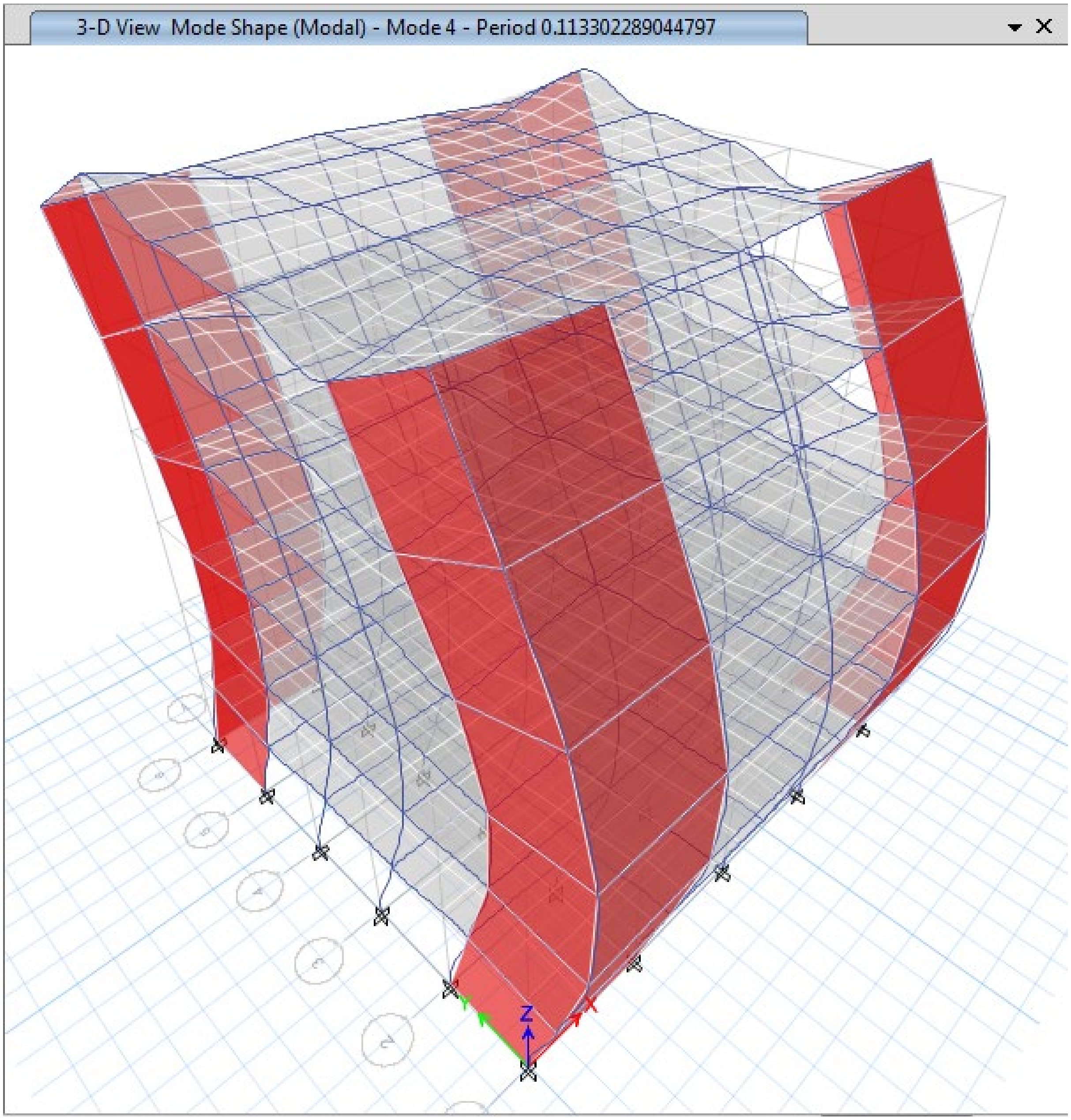



Fig 4.14 Mode shape 4

After Analysis Different types of graph of the story are –

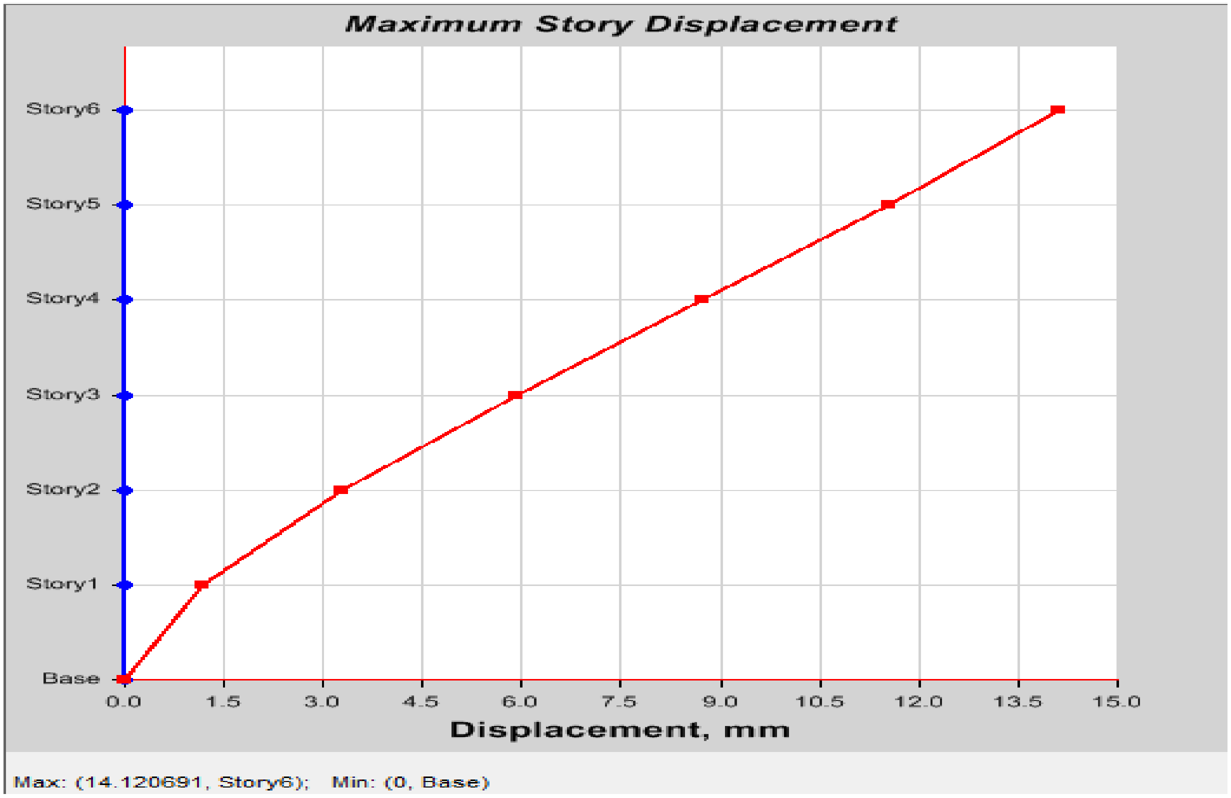



Fig 4.15 Maximum Story Displacement

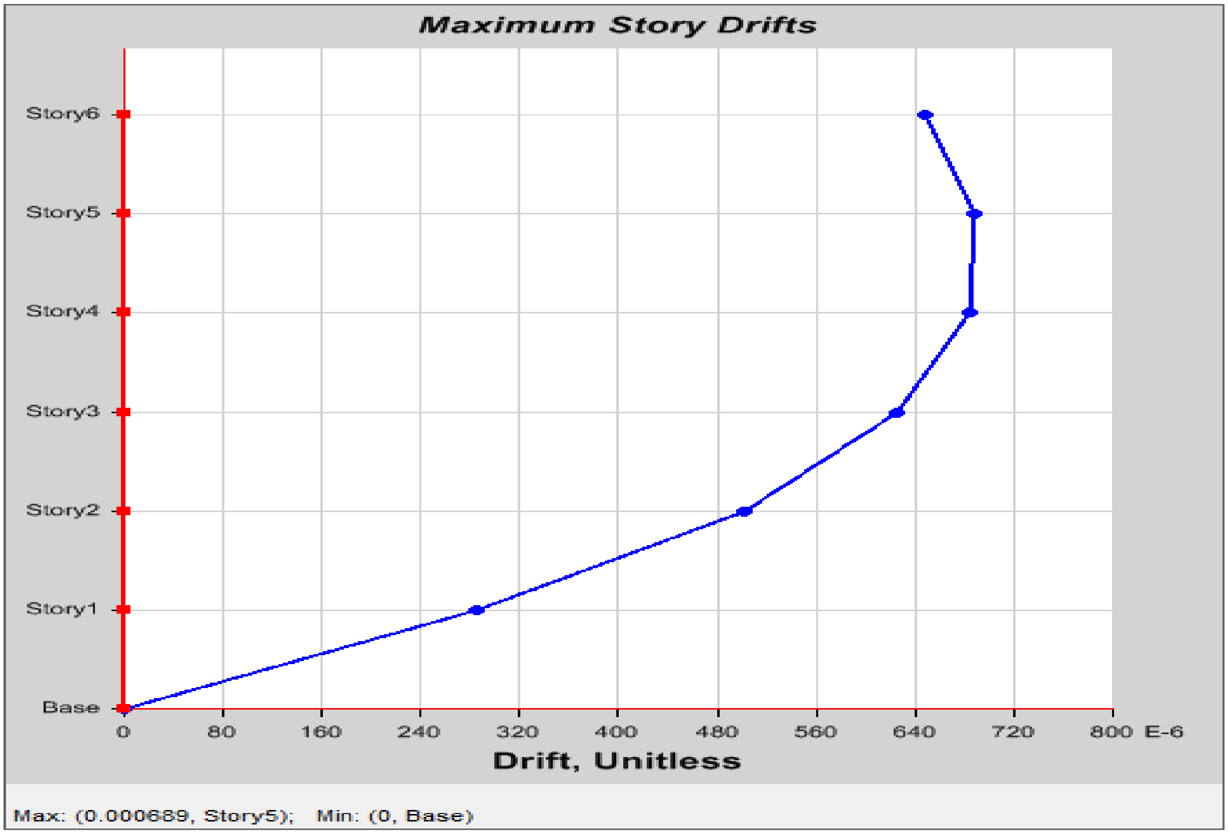



Fig 4.17 Maximum Story Drifts

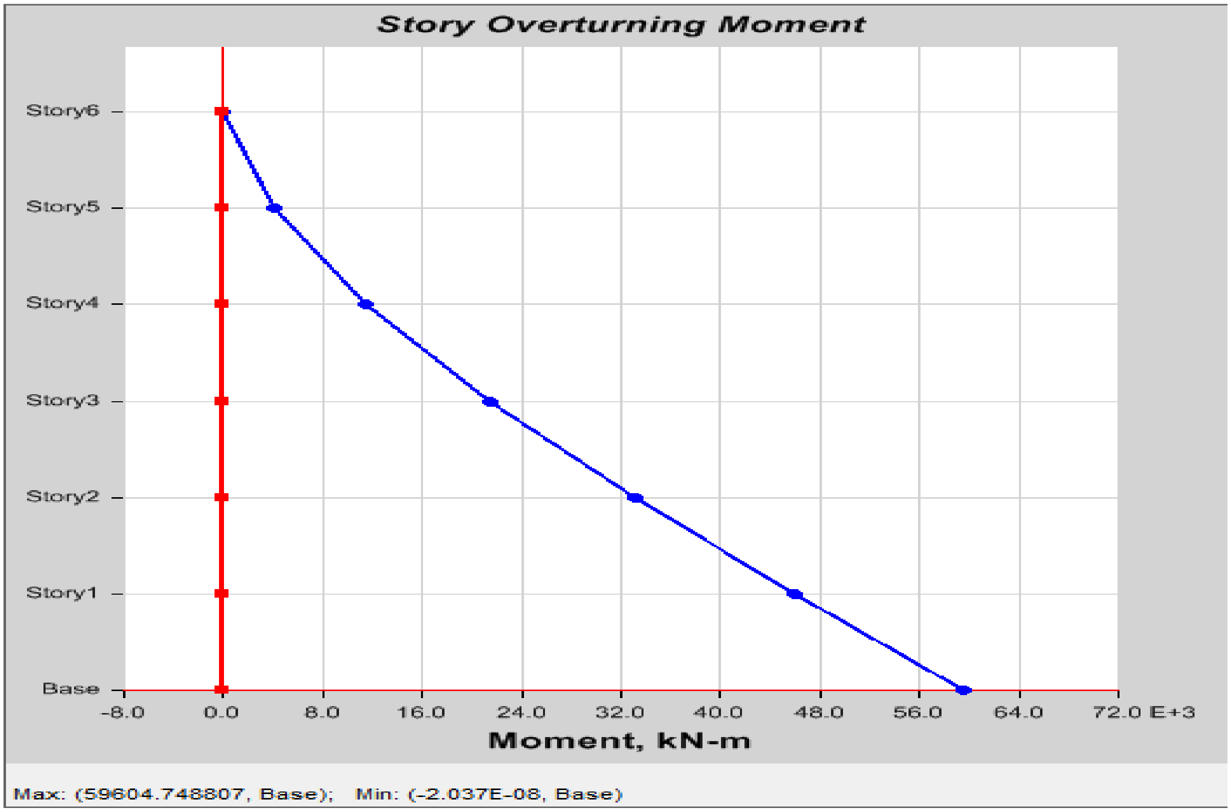



Fig 4.18 Maximum Story Moment

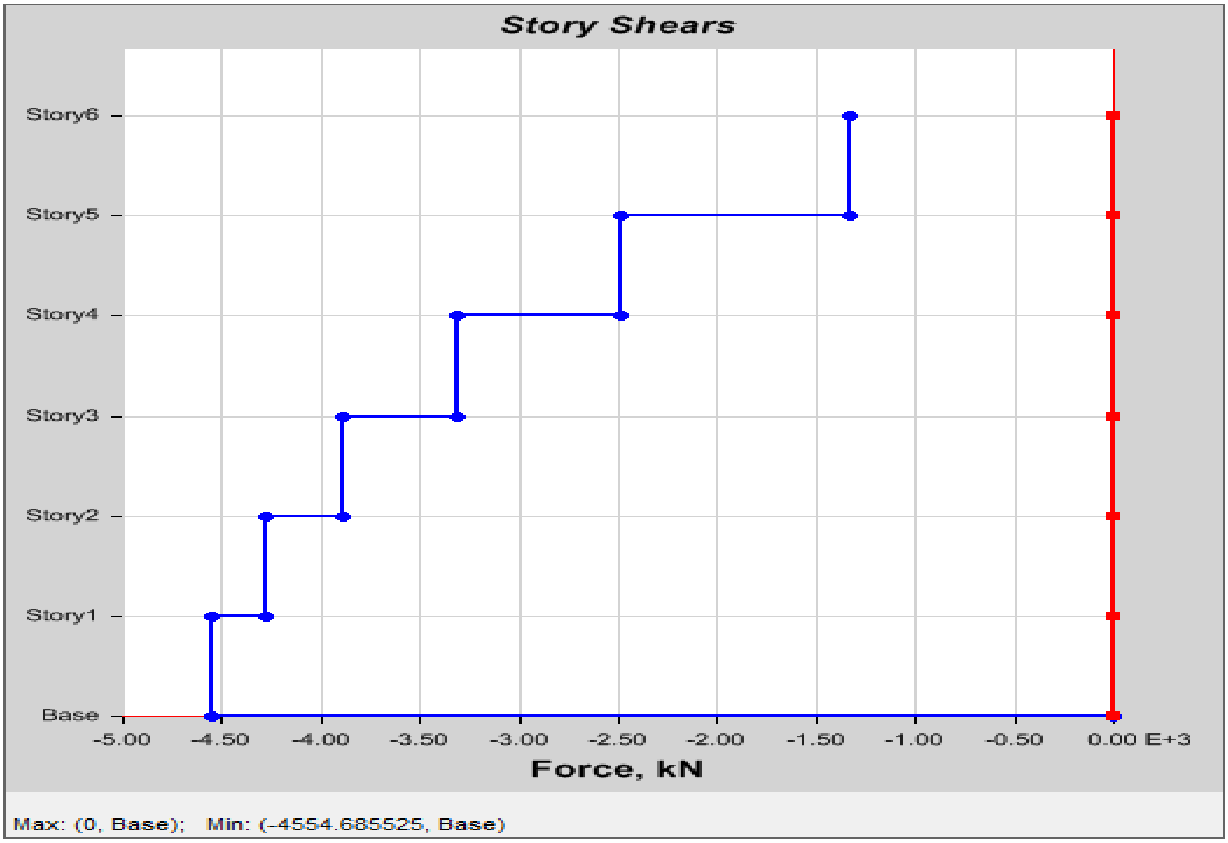



Fig 4.19 Maximum Story Shear

## Results-

We will see the difference between Model-1 with a Fixed base & Model-3 with a Shear wall. From the results, we will find less variation in Story Shear, Story Drift, Base Shear in the 3rd Model. 3rd Model will show more stiffness for the building But, the variation in the maximum displacement of stories in the model is very low while compared with the Fixed base model.

# 5 INFERENCES

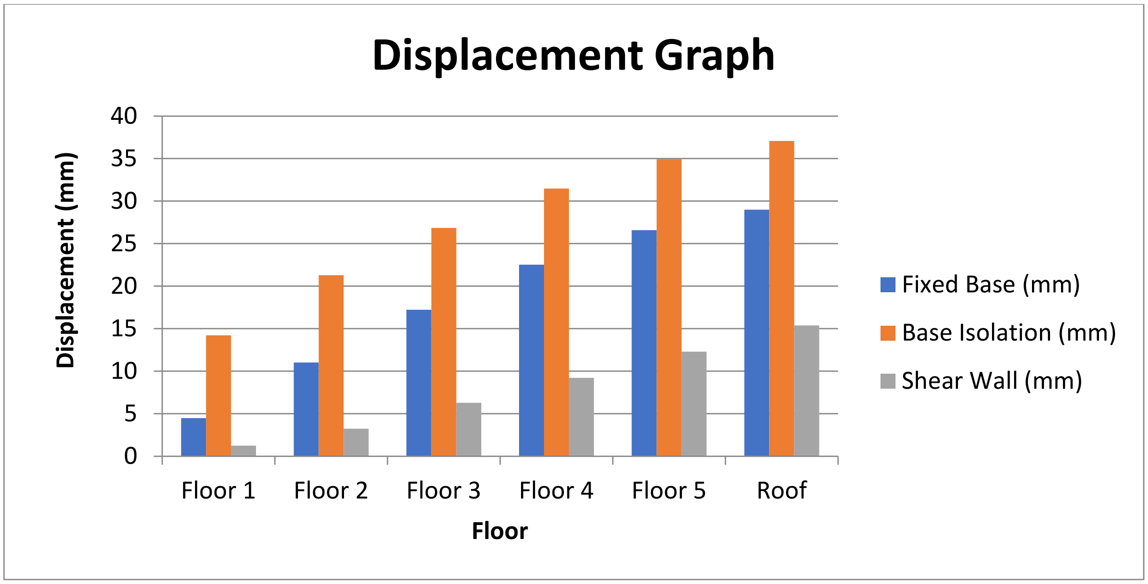



Fig 5.1 Displacement Graph

From the above graph, we can say that by using the shear wall in our building design we can minimize the displacement response of each storey during the seismic period.

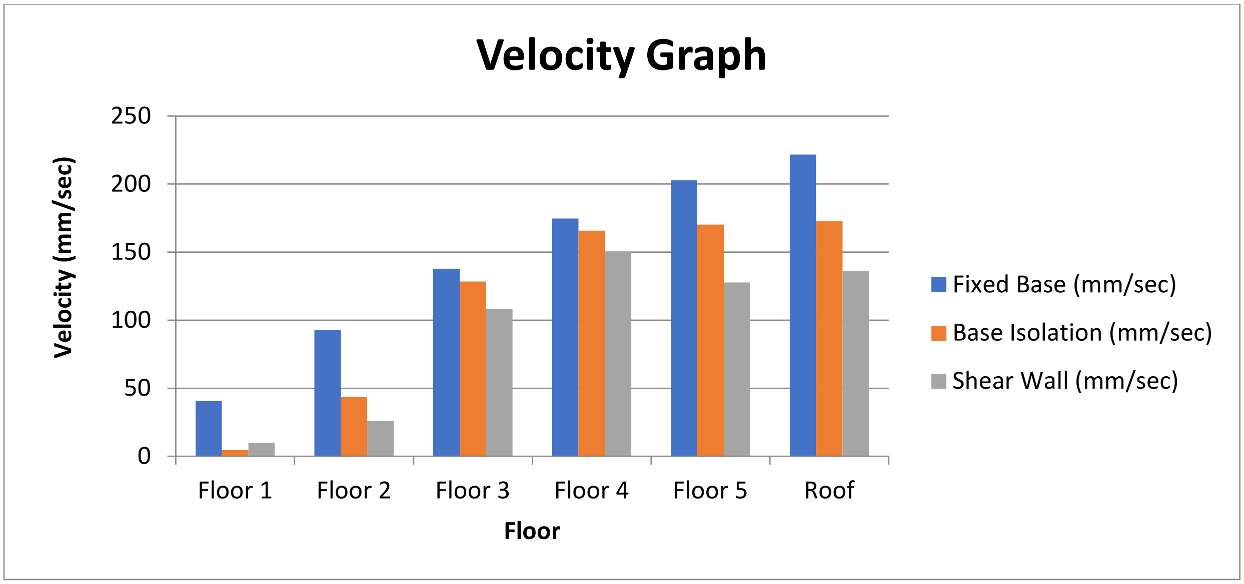



Fig 5.2 Velocity Graph

Shear wall gives the minimum value of velocity response of the structure as compared to fixed base and base isolation during the seismic period

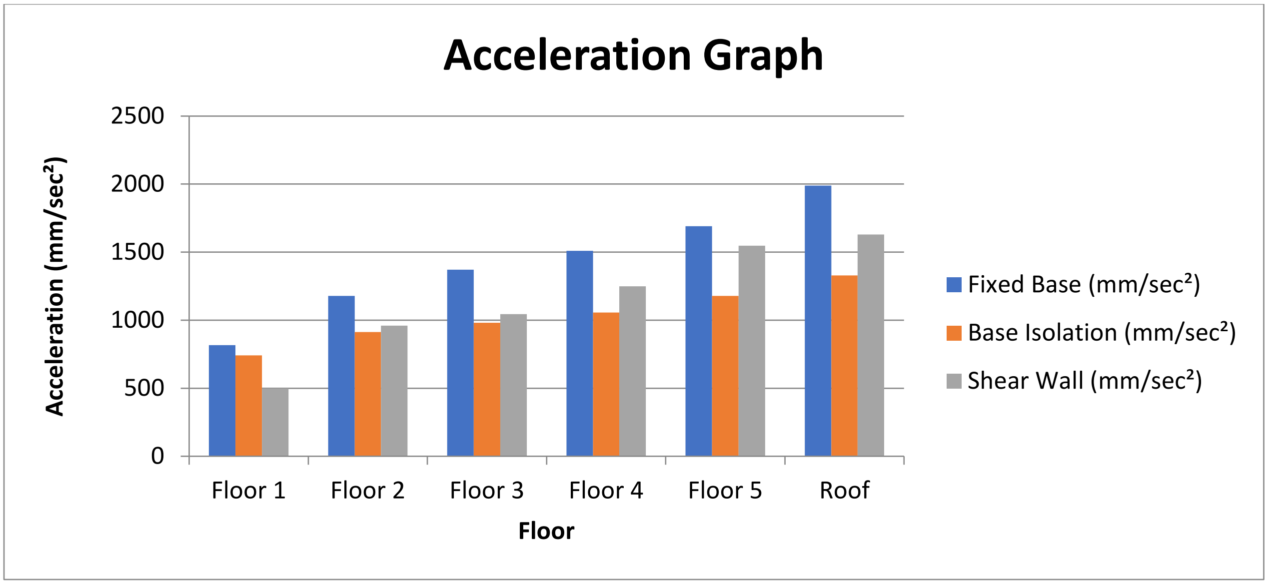



Fig 5.3 Acceleration Graph

From the graph, we can say that after using the shear wall in our building design we get the maximum value of acceleration response during the seismic period as compare to base isolation.

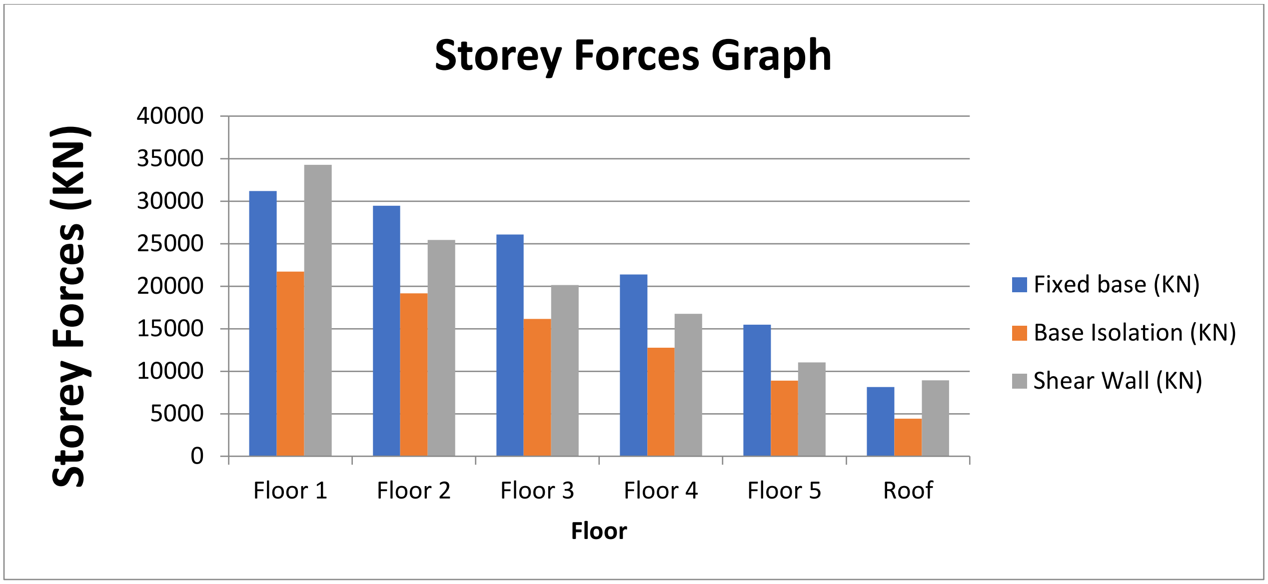



Fig 5.4 Storey Forces Graph

From the above graph, we can say that by using base isolation in our building design we can minimize the storey forces on each storey of the structure during the earthquake period.

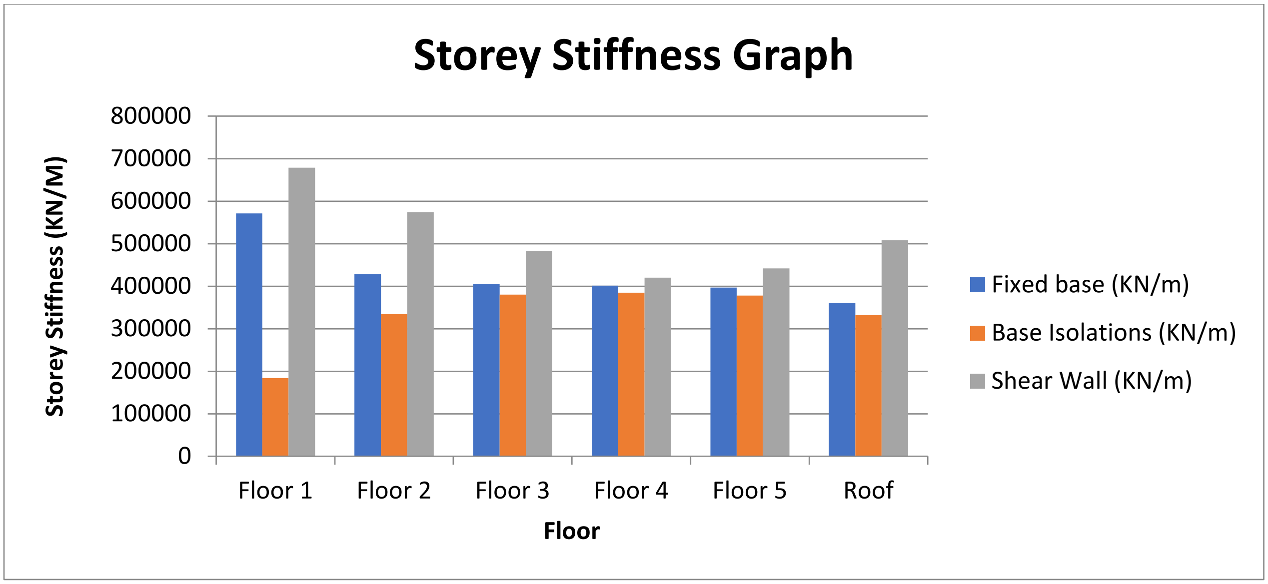



Fig 5.5 Storey Stiffness Graph

By using a shear wall in our building design the overall stiffness of the structure is increased to resist the lateral forces, uplift force, storey shear, etc during the seismic period which makes our structure more strengthening and also increases its durability.

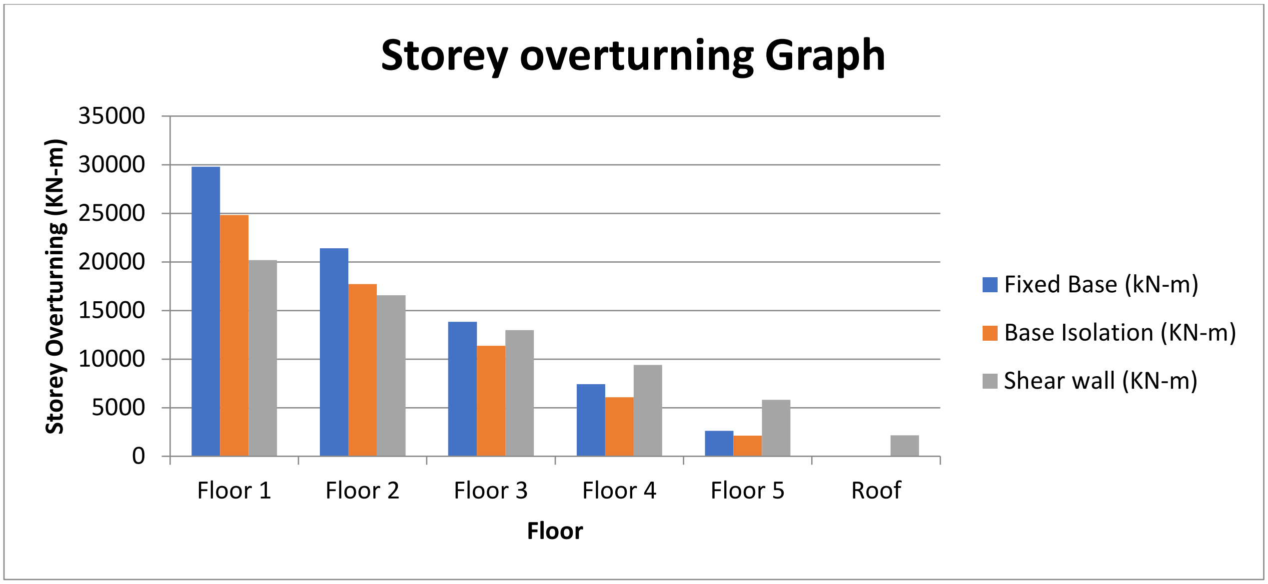



Fig 5.6 Storey Overturning Graph

By using base isolation in our structure we get minimum storey overturning response of the structure during the seismic period. Due to that, the chance of the collapse of the building gets reduced.

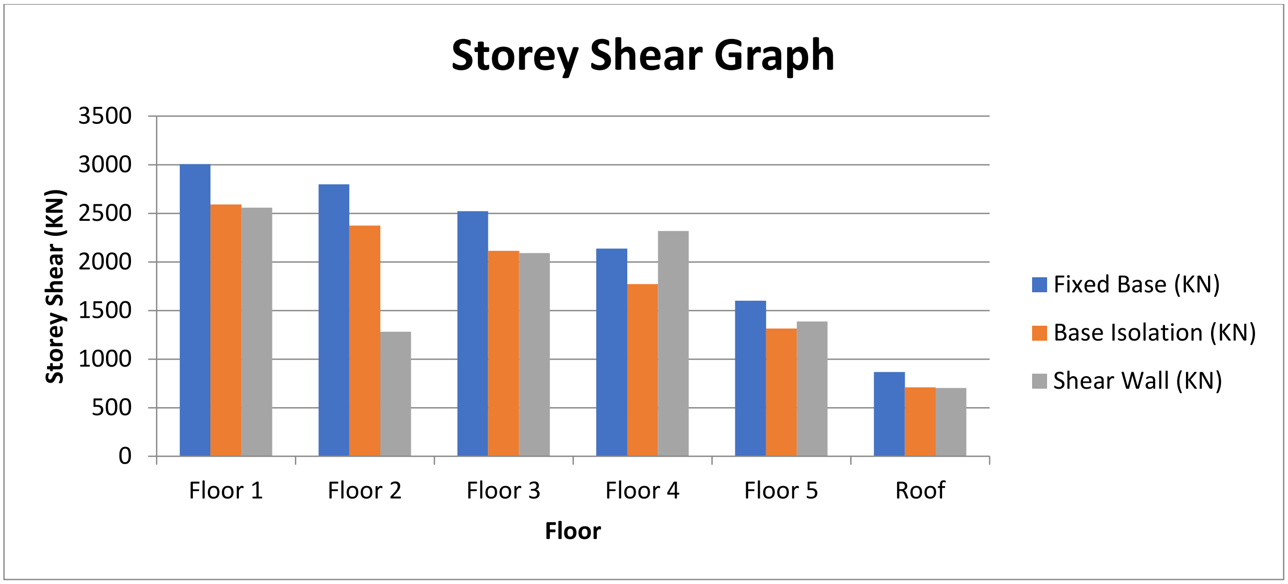



Fig 5.7 Storey Shear Graph

From the above graph, we can say that by using both base isolation and shear wall we can get the minimum value of storey shear during the earthquake time.

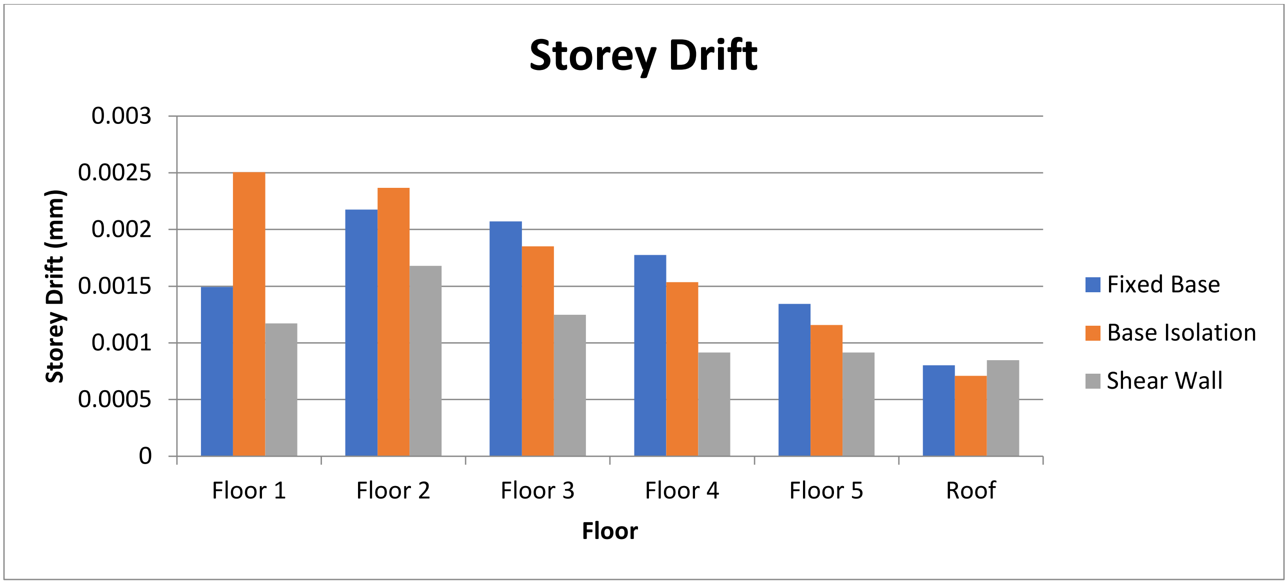



Fig 5.8 Storey Drift Graph

By using Shear wall in our building design we get the minimum value of storey drift during the seismic period as compare to fixed base and base isolation.

# 6 CONCLUSION

- Shear walls are especially important in high-rise buildings, whereas base isolation can be used for both tall and small buildings.
- By designing shear walls in our structure we get minimum values of displacement, velocity, storey drift, etc during the seismic period.
- By using base isolation in our building designing we get the minimum value of acceleration, storey forces, storey overturning moments as compare to a shear wall.
- The ateral sway of a building gets reduced by increased stiffness provided by the shear wall thus making the structure more strengthening and makes it more durable during the seismic period.
- Lead Rubber Bearing (LRB) helps reducing the storey shear thus increasing resistance to the seismic impact. Storey drift in higher storey is minimized, rendering the system protected from earthquakes.
- Base isolator increases the resilience of the structures against earthquakes after LRB is given as a base isolation mechanism and decreases strengthening, thereby making the structure economical.

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Figure Sources:

*Figure 31 Different layers constituting earth's structure:*
*https://www.sciencenewsforstudents.org/article/explainer-earth-layer-layer*

*Figure 32 Theory of plate tectonics; Figure 33 Flow of convection currents; Figure 34 Elastic Rebound Theory: Earthquake Tip Documents, IIT Kanpur*

*Figure 35 Earthquake resistant structure: http://en.bbarta24.net/national/2016/05/05/1559*

*Figure 6 Seismic design methodology:*
*https://www.onlinecivilforum.com/site/basic-aspects-of-seismic-design/*

*Figure 7 Design Acceleration Coefficient (Sa/G) (Corresponding To 5 Percent Damping) : IS 1893 (2016) part 1*

*Figure 8 Diaphragms:* https://www.structuremag.org/?p=577

*Figure 9 Shear Wall : https://theconstructor.org/structural-engg/shear-walls-structural-forms-positioning/6235/*

*Figure 36 Cross-Bracing*
*https://theconstructor.org/structural-engg/shear-walls-structural-forms-positioning/6235/*

*Figure 11 Roof Truss:*
https://www.thebalancesmb.com/roof-trusses-used-in-house-construction-844841

Figure 12 Moment Resisting Frames:
https://ascelibrary.org/doi/10.1061/%28ASCE%29ST.1943-541X.0000359)

Figure 13 *Tomb of Cyrus, Iran (the oldest base-isolated structure in the world)*
*https://happho.com/base-isolation-techniques-applications-advantages-disadvantages/*

Figure 14 Concept of Base Isolation; Figure 15 Results of survey on sense of fear; figure 16 technique: IIBA Masanori, Department of Structural Engineering, Building Research Institute, Japan.

Figure 17 features of base isolation:
https://www.kenken.go.jp/english/contents/topics/japan-journal/pdf/jj2011aug_34-37.pdf

Figure 37 Elastomeric Rubber Bearing : https://www.bridgebearings.org/product/lead-rubber-bearing.html

Figure 38: Tuned mass Damper: https://www.bridgebearings.org/product/lead-rubber-bearing.html

Figure 39: Enormous pendulum (TMD) helps keep Taiwan's tallest building, Taipei from swaying

https://www.atlasobscura.com/places/tuned-mass-damper-of-taipei-101

Figure 21 Simple Roller Bearing; Figure 22 elastomeric bearing:
https://www.bridgebearing.org/bridgebearing/lead-rubber-bearing.html

Figure 23 Roller and Ball Bearing:
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Figure 24 springs : https://kineticsnoise.com/hvac/spring_isolators.html

Figure 40 Spherical Sliding Bearing

http://www.eq-ins.com/default.cfm?pageID=advanced_earthquake_resistant.html

Figure 26, 27, 28: Laminated Elastomeric bearing pad

https://www.bridgebearing.org/bridgebearing/laminated-elastomeric-bearing-pad.html

Figure 41: Load distribution and movement resistance source:

https://www.bridgebearing.org/bridgebearing/laminated-elastomeric-bearing-pad.html

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