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SUITABILITY OF LEAD RUBBER BEARING OF HIGHRISE BUILDINGS

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Abstract: Earthquake is basically a naturally phenomenon which causes the ground to shake. The earth's interior is hot and in a molten state. As the lava comes to the surface, it cools and new land is formed. The lands so formed have to continuously keep drafting to allow new material to surface. According to the theory of plate tectonics, the entire surface of the earth can be considered to be like several plates, constantly moving. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Therefore regions close to the plate boundary are highly seismic and regions further from the boundaries exhibit less seismicity. Earthquakes may also be caused by other actions such as underground explosions.

Meanwhile, in the present study obtained from the gap analysis we came to know that, by taking 7 different models of area 400 m^2 with aspect varying from 1 to 4 and applying the properties of both fixed and LRB base. Seismic (Response spectrum analysis) analysis of all models with fixed and isolated base is carried out and results are compared. A separated model based on journal is created in ETABS and comparison is done for parameter given in journal and software model. It has been concluded that Seismic parameters are increasing with increasing number of bays. Square configuration with building aspect ratio 1 perform better as they possess lesser seismic parameters. Increase in lateral displacement is due to frictional behavior of the LRB under seismic loads. Due to increase in time period, structure experiences less amount of seismic forces. Story stiffness, base shear and over-turning moment are reduced to significant amount due to use of LRB.

Index Terms **–Earthquake, Lead Rubber Bearing, lava, Seismic Analysis.**

I. INTRODUCTION

1.1 Earthquake

Earthquake is basically a naturally phenomenon which causes the ground to shake. The earth's interior is hot and in a molten state. As the lava comes to the surface, it cools and new land is formed. The lands so formed have to continuously keep drafting to allow new material to surface. According to the theory of plate tectonics, the entire surface of the earth can be considered to be like several plates, constantly moving. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Therefore regions close to the plate boundary are highly seismic and regions further from the boundaries exhibit less seismicity. Earthquakes may also be caused by other actions such as underground explosions.

An earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves. The seismic activity of an area refers to the frequency, type and size of earthquake experienced over a period of time. At the earth's surface, earthquake occurs itself by shaking and sometimes displacement of the ground. When the epicenter of a large earthquake is located offshore, the sea bed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides and occasionally volcanic activities. An earthquake is measured by seismometers. An earthquake having magnitude of less than 5 are generally measured by Richter magnitude scale & that of magnitude up to 9 or more than 9 is measured by modified Mercalli scale. In its most general sense, the word earthquake is used to describe any seismic event, whether natural or caused by humans that generate seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activities, landslides, blasts and nuclear tests. An earthquake's pint of initial rupture is called its focus or hypocenter. The epicenter is the point at ground level directly above the hypocenter. At the time of earthquake occurrence certain waves are generated which causes destruction of human life & property. Waves generated from earthquake are of two type's body waves (P-waves & Swaves) & surface waves (Rayleigh waves, Love waves, Stoneley waves). As these waves are destructive in nature causing damages or destruction of structures, therefore it is necessary to provide effective provision to resist an earthquake.

The method of base isolation was developed in an attempt to mitigate the effects of earthquakes on buildings during earthquakes and has been practically proven to be the one of the very effective methods in the past several decades. Base isolation consists of the installation of support mechanism which decouples the structure from earthquake induced ground motions. Base isolation allows to filter the input forcing functions and to avoid acceleration seismic forces on the structure. If the structure is separated from the ground during an earthquake, the ground is moving but the structure experienced little movement.

Base isolation system: It is one of the most popular means of protecting a structure against earthquake forces. It is a collection of structural elements which should substantially decouple a superstructure from its substructure that is in turn resting on the shaking ground, thus protecting a building or non-building structure's integrity.

Lateral loads: Lateral loads are live loads that are applied parallel to the ground that is, they are horizontal forces acting on a structure. They are different to gravity loads for example which are vertical, downward forces.

Lateral load resisting system: A typical lateral load-resisting system consists of horizontal and vertical elements connected together so as to transfer lateral forces from the top of a building to the foundations.

Base Shear: Base shear can be defined as the maximum lateral force that will occur due to seismic ground motion at the base of a structure. When earthquakes load acts, the structure starts to vibrate, loading been transferred from soil to base of the structure.

Story Drift: Story drift can be defined as "It is the displacement of one story with respect to the other story.

Story Displacement: Story displacement can be defined as "It is the displacement of a story with respect to the base of a structure.

Over-turning moment: The overturning moment of an object is the moment of energy capable of upsetting the object; that is, the point where it has been subjected to enough disturbance that it ceases to be stable, it overturns, capsizes, collapses, topples or otherwise incurs an unwanted change in its circumstances, possibly resulting in damage and certainly resulting in inconvenience.

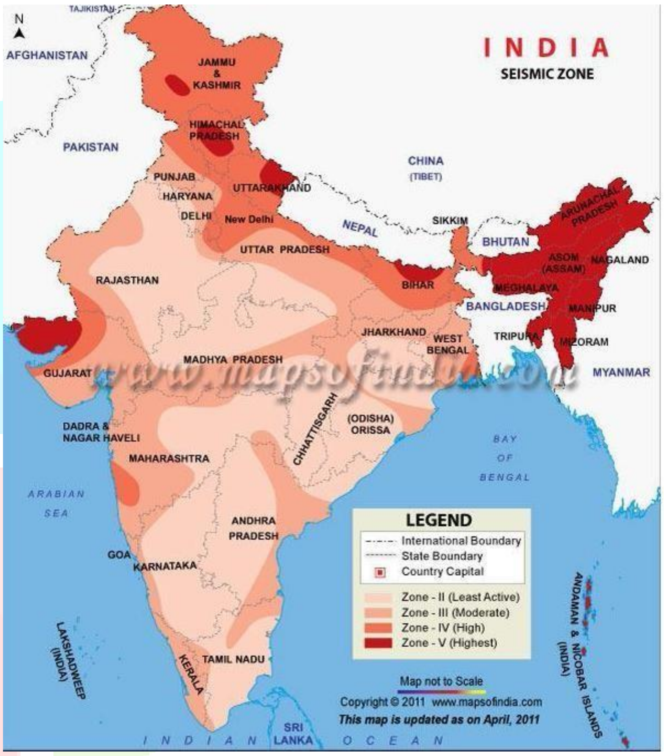

Figure 1.1: Earthquake zones in India

1.2 Earthquake Effects

There are several types of induced damages due to earthquake like: ground shaking, ground failure. Tsunamis Etc. but the main cause of damage is the ground shaking.
Others are secondary disasters.

1.2.1 Ground Shaking

The principal cause of earthquake-induced damage is ground shaking. As the earth vibrates, all the buildings on the ground surface responds to that vibration in varying degrees. Earthquake induced accelerations, velocities and displacements can damage or destroy a building unless it has been designed and constructed or strengthened to be earthquake resistant. Therefore, the effect of ground shaking on building is a principal area of consideration in the design of earthquake resistant buildings. Seismic design loads are extremely difficult to determine due to the random nature of earthquake motions. However, experiences from past strong earthquakes have shown that reasonable and prudent practices can keep a building safe during an earthquake.

1.2.2 Ground Failure

Earthquake-induced ground failure has been observed in the form of ground rupture along the fault zone, landslides, settlement and soil liquefaction. Ground rupture along a fault zone may be very limited or may extend over hundreds of kilometers. Ground displacements along the faults may be horizontal, vertical or both and can be measured in centimeters or even meters. Obviously, a building directly astride such a rupture will be severally damaged or collapsed. While a landslide can destroy a building, settlement may only damage it. Soil liquefaction can occur in low density saturated sands of relatively uniform grain size. The phenomenon of liquefaction is particularly important for dams, bridges, underground pipelines, and buildings standing on such ground.

II. Related Work

1. Fabio Mazza et al. (2012) the main objective of this work is to compare different baseisolation techniques, in order to evaluate their effects on the structural response and applicability limits under near-fault earthquakes. In particular, high-dampinglaminated-rubber bearings are considered, in case acting in parallel with supplemental viscous dampers, or acting either in parallel or in series with steel-PTFE sliding bearings. Numerical investigation is carried out assuming as reference test structure a base-isolated five-storey reinforced concrete (RC) framed building designed according to Eurocode 8 (EC8) provisions. A bilinear model idealizes the behaviour of the RC frame members, while the response of the elastomeric bearings is simulated by using a viscoelastic linear model; a viscous-linear law and a rigid-plastic one are assumed to simulate the seismic behaviour of a supplemental damper and a sliding bearing, respectively. The seismic analysis of the test structures, subjected to strong ground motions recorded near faults, is carried out by using a step-by-step procedure.
2. N. Torunbalci and G. Ozpalanlar (2008) the main objective of this work is to make a comparison between the seismic isolation and fixed based building, rather than comparing seismic isolation alternatives with in themselves. In the analysis total base shear forces, storey shear forces, maximum absolute acceleration and relative soft storey drifts are compared and results are discussed. Seismic isolation and energy dissipating system are some of the design strategies applied to increase the earthquake resistance of the structures. Base isolators have less time period value as compared to rubber and friction pendulum systems. The natural period of the structure in the fixed base situation is increased in the system containing base isolators.
3. Manoj U. Deosarkar and S. Gowardhan (2015) in this research, 6-storey RCC structures are designed as isolated and fixed base. We will examine the response of the building isolated using combined isolation system consisting of high-damping rubber bearing, lead rubber bearing and friction pendulum system at the base column are used. Nonlinear time history analysis is considered in modelling. At the end of analysis time period, storey shear and storey displacement are compared for isolated and fixed base structure. It is observed that combined isolation system helps to increase time period and storey displacement and to decrease storey shear, storey drift and storey acceleration. It is observed that fixed base building have zero displacement at base of building whereas, all base isolated buildings models shows increase in amount of lateral displacement at base.
4. Ganga Warrier A. et al. (2015) the principle of base isolation is vibration isolation. It decouples the building from damaging action of the earthquakes. The isolator partially reflects and partially absorbs input seismic energy before it get transmitted to the structure. Laminated Rubber bearing isolators are placed between the superstructure and foundation which reduces the horizontal stiffness of the system. The superstructure acts like rigid body, thus inter storey drift is reduced. Building situated on soft need isolators with bigger diameter than situated on rocky soils. Both thickness and diameter increases as greater earthquake prone area is chosen. The diameter of isolators decrease as the desired value of time period increases, provided the soil condition and rubber used are the same. For the same soil condition and time period thickness of the isolators decreases with increase in damping percentage. Building situated on soft soil condition require thicker isolator than those situated on hard soil conditions, required the time period and damping are the same.
5. Md. Mohiuddin Ahmed et al. (2019) the seismic performance of both regular shape and irregular shape building depends on height of the building along with other important structural parameters. Increasing the building height increases base shear and base moment at the base of the building. During earthquake slender building are more vulnerable than any other building. The outputs of this present study will help other engineers and researchers to understand to understand the influence of vertical aspect ratio on building parameters. Base shear increases gradually with increase in building heights. The base shear is obtained lower for 5 storey building and higher for 20 storey buildings. Storey over turning moment increases gradually with increase in building height. Lowest value is obtained in case of 5 storey building where as highest in case of 20 storeys building.
6. Peng Pan et al. (2008) this paper deals with recent design and construction of base- isolated building structures in japan, including statistical data with respect to the common usage as well as the number of new projects. It is notable that the size, height and fundamental natural period of new base-isolated building increases steadily with time, indicating that base isolation in japan is reaching maturity. Base isolators and dampers commonly adopted in Japan are also introduced; with emphasis on recent design efforts to enlarge the natural period of base isolated structures and reduces the lateral forces induced in the superstructure .The floor area, height and natural period of base isolated building structures keep increasing and the maximum shear exerted into the superstructure remaining low, which is clear indication of the confidence and maturity of seismic isolation design in japan. Slide bearing are increasingly applied to reduce shear force. Basic design procedure that are becoming standardised after 20 years of experiences are outlined. These involves the determination of design earthquake forces, modelling of the base isolation layer, modelling of the superstructure selection of the ground motions, time-history analysis and performance criteria.

2.1 Summary of Literature Review

Base isolation increases the flexibility at the base level of building. Time period of the structure increases by the use of lead rubber bearing which helps in less transfer of lateral forces at time of earthquake. Due to base isolators, base shear is reduces in each direction (x and y) as compared to fixed base building. Increase in flexibility of the system, time period of the structure is also increases. Combining the desirable features of various systems, a new design for a friction base isolator is also developed and its performance is studied. It is shown that, under design conditions, all base isolators can significantly reduce the acceleration transmitted to the superstructure. Different possibilities are explored to increase the feasibility of base isolation for such type of buildings. Strategies proposed in this study are increasing superstructure stiffness, increasing superstructure damping and increasing flexibility of isolation system. Building situated on soft soil need isolators with bigger diameter than situated on hard rocky soils. Both thickness and diameter increases as greater earthquake prone area is chosen. The diameter of isolators decreases as the desired value of time period increases provided the soil condition and rubber used are the same.

2.2 Gap Analysis

Isolators perform three function:-horizontal flexibility, energy dissipation and rigidity against normal lateral loads. Lead Rubber bearing isolators performs these function efficiently by reducing the horizontal stiffness of the system, it increases the time period of structure and decreases the spectral acceleration of the structure. The super structure acts like a rigid body, thus inter storey drift is reduced. Base isolators have less time period value as compared to rubber and friction pendulum systems. Building situated on soft soil condition require thicker isolator than those situated on hard soil conditions, required the time period and damping are the same. As the aspect ratio increases the building become more critical. Effect of wind and earthquake force increase for the higher aspect ratio. The tall building should have small aspect ratio i.e. sides of the building should be nearby equal in size which will make it less critical. In comparison of square (aspect ratio 1) and rectangular configuration (aspect ratio 4, 6 and 8), the square configuration perform better as they possess lesser values of all these seismic parameters. Therefore, the configuration which have elongated /long diaphragms should not be preferred. Meanwhile, in the present study models from aspect ratio 1 to 4 is considered for seismic analysis of fixed base and lead rubber bearing base.

III. ANALYSIS OF PROBLEM

To analyse (RSA) multi story building with fixed base and lead rubber bearing base techniques and compare the results of fixed base and lead rubber bearing base of different model based on analysis to get optimum results.

1. Buildings with different length to width ratios is considered and modelling is done, after modelling response spectrum analysis is carried out for fixed base structures.
2. Design of lead rubber bearing based on the results obtained from analysis of fixed base structures.
3. Assigning the properties of Lead rubber bearing to structures and response spectrum analysis is carried for buildings with lead rubber bearing base.
4. The results will be compared in between lead rubber bearing base models and fixed base models. Thus, effects of lead rubber bearing base systems on these buildings will be studied.

IV. PERPOSED WORK

In present work, response spectrum analysis is carried out on 3D RC 9 storied buildings of 7 different dimension according to aspect ratio differ by 0.5 is taken which has area of 400 m^2 to evaluate and achieve the objectives of the present study.

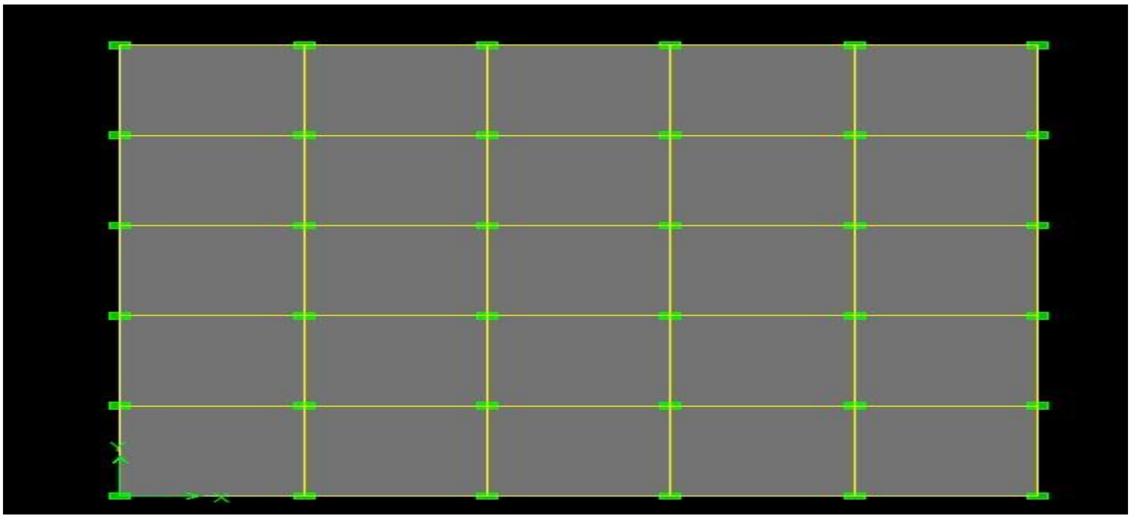

Figure 4.1: Plan of Model

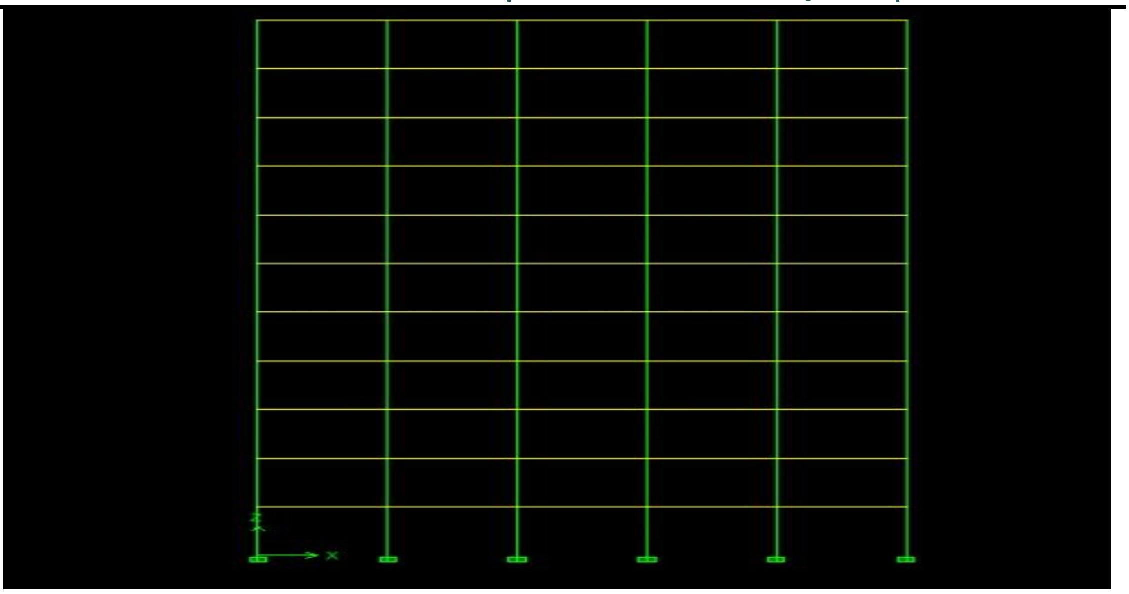

Figure 4.2: Elevation of Model with fixed base

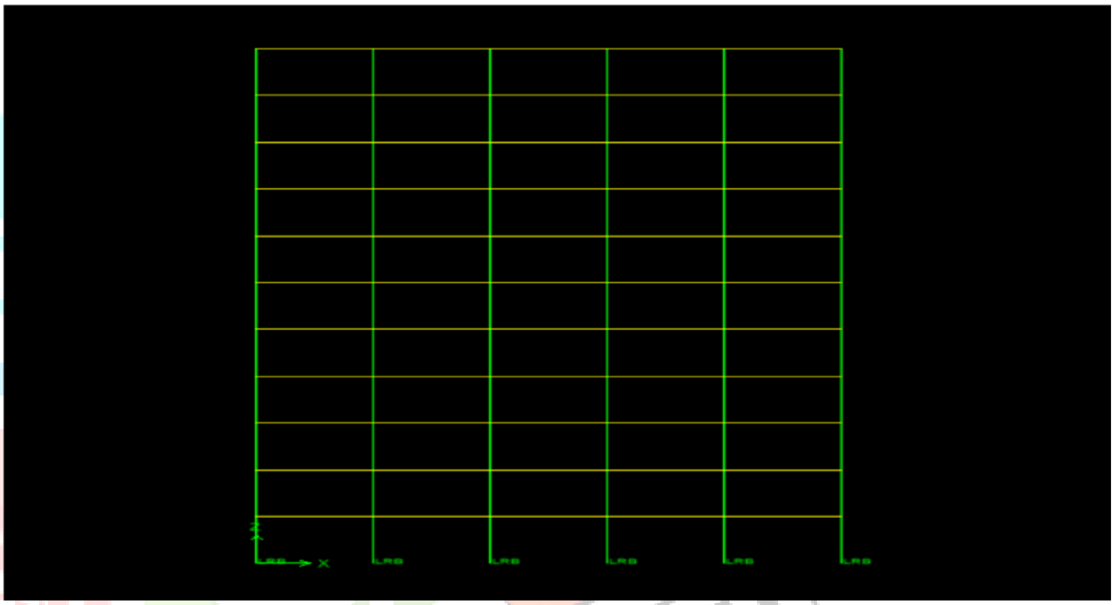

Figure 4.3: Elevation of Model with isolated base

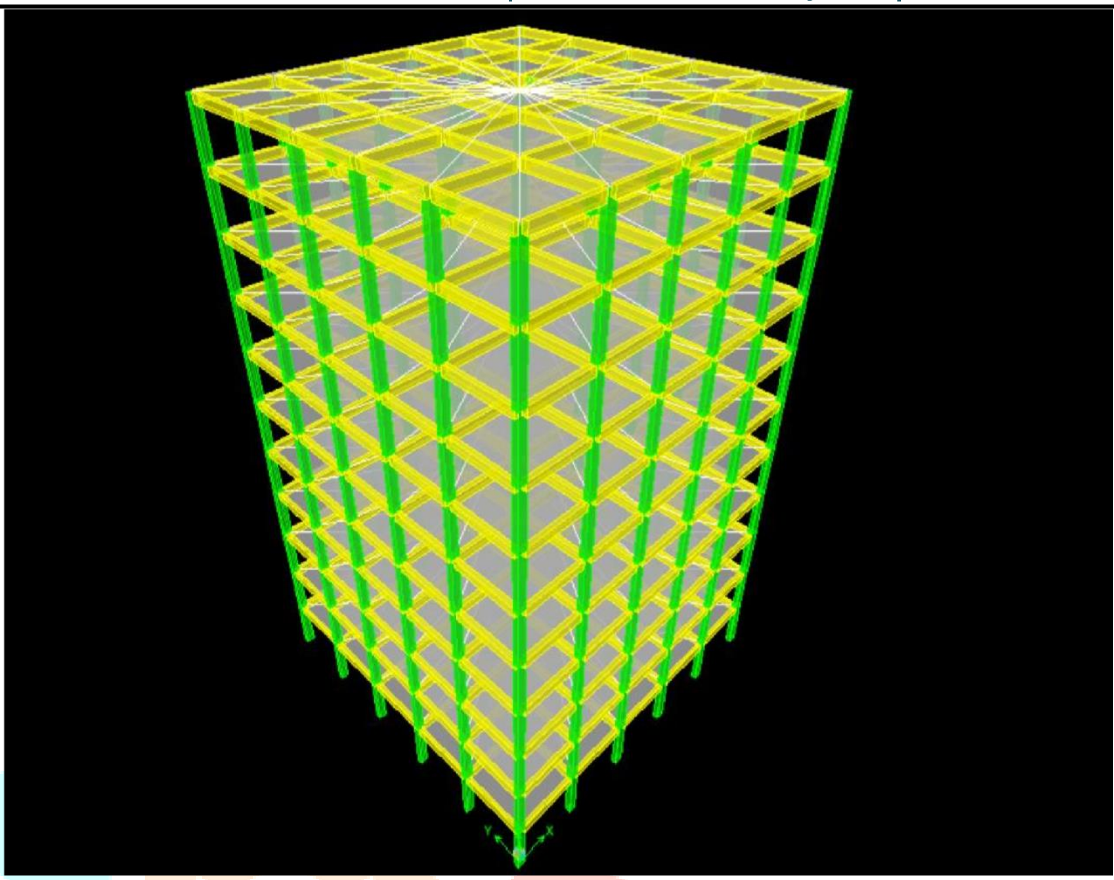

Figure: 4.4 3D rendered view of Model

4.1 Loads Acting on Buildings:

Loads acting on buildings are mainly of gravity loads and lateral loads.

4.1.1 Gravity Loads

Gravity loads include self-weight of building, floor finish which is taken as 1.5 kN/m^2 and live load which is taken as 2 kN/m^2 as per IS 875 (part-II) for a residential building that would be acting on the structure in its working period. We have also considered wall load as imposed load on internal beams as 7.5 kN/m^2 and on external beams 13 kN/m^2.

4.1.2 Lateral Loads

In contrast to the vertical load, the lateral load effects on buildings are quite variable and increases rapidly with increase in height. Most lateral loads are live loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load, an Earthquake load, and an earth pressure against a beachfront retaining wall. Most lateral loads vary in intensity depending on the buildings, geographic location, structural material, height and shape.

4.2 Equivalent Static Analysis

The total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure.

Following procedure is generally used for the equivalent static analysis: i) Calculation of lumped weight.

ii) Calculation of fundamental natural period.

The fundamental natural period of vibration (Ta) in seconds of a moment resisting frame building,

$T_a = 0.75h^{0.75}$ (Without brick infill panels) .... (1)

$$T_a = \frac{0.09h}{\sqrt{d}}$$ (With brick infill panels) ...... (2)

Where, iii) Determination of base shear (VB) of the building.

Where,

$$A_h = \frac{Z\, I\, S_a}{2\, R\, g} \quad \text{......... (3)}$$

Is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficient (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

iv) Lateral distribution of design base shear

The design base shear V_B thus obtained is then distributed along the height of the building using a parabolic distribution expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \quad \text{.............. (4)}$$

Where, Qi is the design lateral force, Wi is the seismic weight, hi is the height of the i^{th} floor measured from base and n is the number of stories in the building.

4.3 Dynamic Analysis of Buildings

Dynamic analysis shall be performed to obtain design seismic forces, and its distribution to different levels along the height of the building and to the various lateral load resisting elements under any of the following conditions.

1. For regular buildings, if the height is greater than 40m in zones IV and V or greater than 90m in zone II and III
2. For irregular buildings, if the height is more than 12m in zone IV and V and more than 40m in zone II and III.

Dynamic analysis can be performed either by Time history method or Response spectrum method.

V.CONCLUSION

1. It has been concluded that with minimum stiffness for model 2 and 3 with aspect ratio 1.5 and 2, LRB with less area and diameter is considered to be efficient and effective for cost economic projects. So building with longer span in y direction should not preferred for LRB to be cost effective.
2. It has been concluded that increase in lateral displacement is due to frictional behavior of the LRB under seismic loads**.** Due to increase in time period, structure experiences less amount of seismic forces. Story stiffness, base shear and over-turning moment are reduced to significant amount due to use of LRB.
3. It has been concluded that seismic parameters increases with increasing number of bays. The higher number of bays, the seismic parameters increases excessively. Square configuration with building aspect ratio 1 perform better as they possess lesser seismic parameters. So building with elongated shape/long narrow diaphragms should not be preferred. So overall study proves that model with aspect ratio 1, 1.5 and 2 are best suitable for the application of LRB.

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