EARTHQUAKE RESISTANT STRUCTURE WITH BASE ISOLATION SYSTEM

MD NOUMAN
14C71D2023, M.Tech (Civil - Structural Engineering), Ellenki College of Engineering & Technology
Email: mdnouman86@gmail.com

N. MONICA MADHURI
Assistant Professor
Ellenki College of Engineering & Technology

ABSTRACT
The main objective of this project is to protect the buildings by designing it as earthquake resistant structure. Earthquake is one of major natural disaster in which many structures damage and collapse due to improper design against seismic motion. Earthquake also affects the economy of the nation, so essential proper measures of prevention must be developed. There are many concepts of designing a building as earthquake resistant structure; the concept used in this project is base isolation. There are many types of base isolation systems but lead rubber bearing (LRB) is used as base isolation system in this project, LRB is most widely used as isolation system for buildings.

INTRODUCTION
Earthquake is natural disaster which is caused when the stress is produced on lithosphere due to collision between the plates when this stress is high the lithosphere breaks or shifts. The collision between plates may be of two types one is inter-plate and other is intra-plate. Most of the earthquakes occurred near Himalayan region are inter-plate earthquakes and earthquakes occurred near Peninsular region are intra-plate earthquakes. The most of earthquakes occurred since last century is in populated and urbanized areas which caused huge damage. There are some earthquakes which are un-noticed since they occurred deep underneath earth's crust. India lies in the northwestern end of the Indo-Australian Plate, which includes India, Australia, a major portion of the Indian Ocean and other smaller countries. This plate is colliding against the huge Eurasian Plate and going under the Eurasian Plate, this process of one tectonic plate getting underneath other is called seduction.

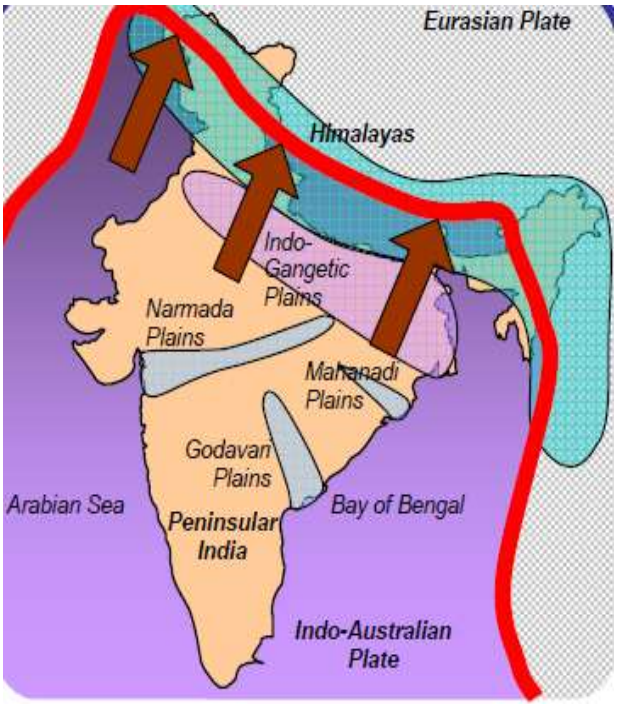


Fig: Map showing collision between different Plates

During an earthquake energy is released from fault, in the form of heat and seismic waves. These seismic waves radiate from focus (source) and shake the ground,

these seismic waves travel 100's of km from the source. The point exactly above the focus on the earth's surface is called the epicenter. The figure below shows faults, plates, focus, epicenter, seismic waves.

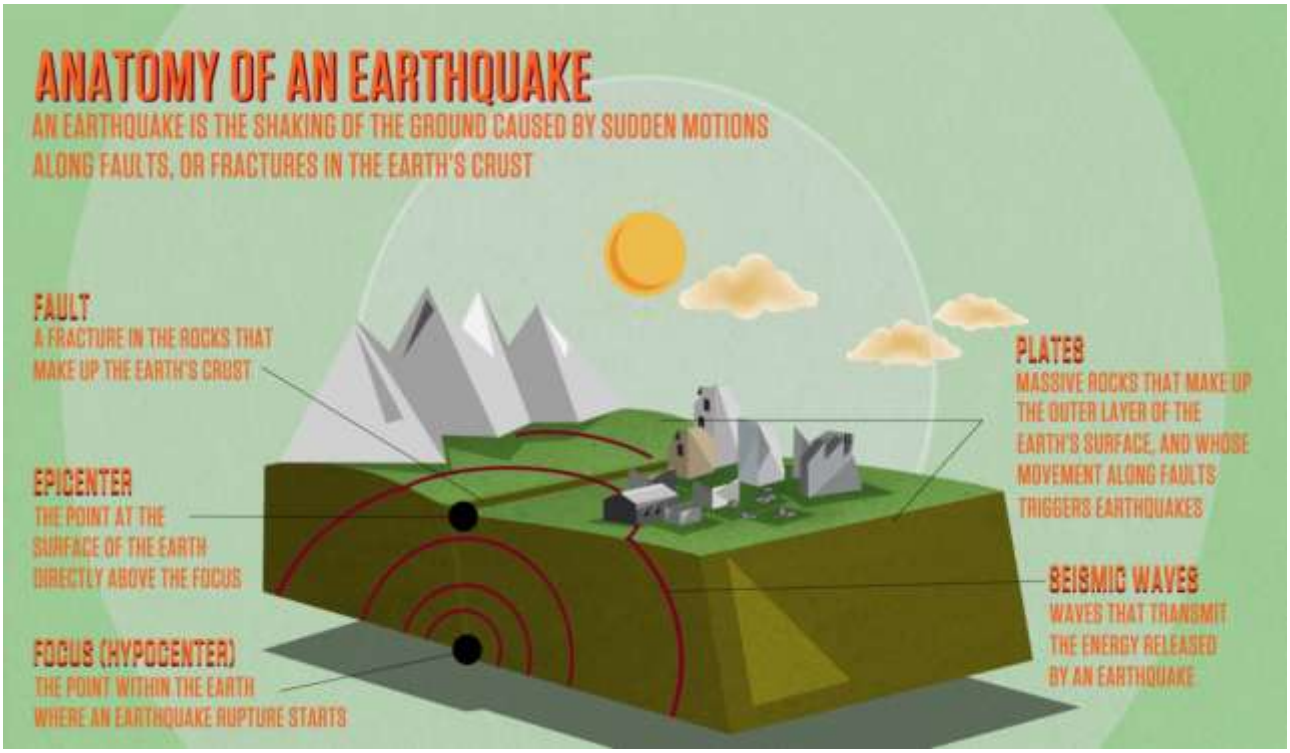


Fig: Anatomy of earthquake

To make the building earthquake resistant there are many techniques, but base isolation technique was found most widely used, this method is also found most effective in resisting earthquake.

LITERATURE REVIEW

Satish Nagarajaiah, Xiaohong Sun (2001), In this paper a case study is done on fire command and control building which survived Northridge earthquake 1994. The building is situated in Los Angeles. During earthquake seismic data was recorded and impact was observed in building. The effects of impact on base isolation are described in this paper. It is evaluated by studying the response of building with and without impact. Finally it was observed that the building's isolation system performed effectively during earthquake. But there was increase in shear and drift due to impact therefore impact must be avoided in isolated buildings.

Yozo Shinozaki, Osamu Hosozawa, Tsutomu Komuro (2004), In this paper a case study is done performance of high rise building named Sendai mt building and Thousand tower which was tallest residential base isolated structure when its construction was completed. The effectiveness of base isolation on these structures during Off-Miyagi earthquake 26 may 2003 was very helpful in protecting the structure. The conclusion from this paper is base isolation is pioneer in protecting structures during earthquake when compared

to other conventional methods, Using high strength material increases performance of building.

S. Etedali, M.R. Sohrab (2011), In this paper torsional behavior of asymmetric building with and without isolation system is studied for three and eight story steel structure to analyze the structure time history analysis is performed by using Tabas, EL Centro and Bam earthquake data. The results were observed and torsion was reduced after using isolation system. Increasing flexible edge stiffness of isolation and superstructure reduces torsional effect on the superstructure. When eccentricity is increased the effect of isolation system on torsion was very less.

Md. Arman Chowdhury, Wahid Hassan (2013), In this paper 20 story irregular building is modeled and analyzed using SAP2000 v15. Dynamic analysis of a irregular structure with and without isolator is performed. Both response spectrum analysis and time history analysis are performed. The structure was designed for Bangladesh earthquake zone. For time history analysis CHI-CHI, EL Centro and Northridge seismic data were used. The results of displacement for different stories in X and Y direction for all methods of analysis were compared and it is observed displacement was significant in first five stories of base isolated structure and difference was decreasing between displacement with increasing story height and relative inter-story displacement of base isolated structure was less then fixed base structure. This indicates that axial load on column was reduced after using isolator which also reduces reinforcement of the column. Finally base isolation is required to reduce design loads and safety of structure against earthquake

Hossein Monfared, Ayoub Shirvani, Sunny Nwaubani (2013), In This paper a far reaching history of the seismic base-isolation endeavors from the authentic confirmations until the latest Base isolation systems are studied. The two noteworthy frameworks for base-isolation purposes have been quickly clarified and a benchmark structure has been explored as a delegate of a 5-story building. The accompanying conclusions can be drawn from analysis results:

1. The principal time of the structure is expanded when utilizing an appropriate base isolation framework in contrast with the altered base structure.
2. The isolation effectiveness increments as the seismic power increases.

The adequacy of a base-isolated framework relies upon the attributes of the information available and additionally the properties of the isolation gadgets and superstructure. Consequently, there is a vital need to do an exhaustive introductory study to explore the effectiveness of a specific base-isolation framework for a structure concerning the seismic guide of the region and attributes of the likely earthquakes. This is remarkable on the grounds that the expense of isolation will continuously be a vital thought and one of the principal worries of any task by financial specialists. All things considered, base isolated structure costs more than a fixed one. Additional building works keeping in mind the end goal is to dissect and study point by point configuration of the structure and its isolation framework. However there

are many advantages of using base isolation systems against earthquake.

Rui C. Barros, H. Naderpour, S.M. Khatami, and A. Mortezaei (2013), the paper describes about seismic pounding. The pounding is defined as a collision of two buildings during earthquake. To overcome pounding a new concept of providing impact model was developed. Impact model consist a dashpot and three springs. For analysis one 2 story building and one five story building are placed side by side to study the effect of impact. By analysis it came to know that the developed new model of impact was effective in reducing pounding effect on building. For earthquake data required to analyze structure kobe 1995 and loma prieta 1989 data were used and time history analysis was performed.

Chauhan Kalpesh M, Dr.B.J.Shah (2013), In this paper a methodology of designing lead plug rubber bearing is given. Here the LRB is designed for bridges and was designed as per AASHTO recommendations. To decide the size of bearing number of trials must be carried out in design by using different techniques.

MODELLING AND ANALYSIS OF BUILDING USING ETABS

ETABS is an advanced, yet simple to utilize, unique reason investigation and configuration program grew particularly to build frameworks. ETABS Version 9.7.1 elements a natural and effective graphical interface combined with unmatched displaying, investigative and outline methodology, all coordinated utilizing a typical database. Although fast and simple for basic structures, ETABS can likewise handle the biggest and most complex building models, including an extensive variety of nonlinear practices, settling on it the apparatus of decision for basic designers in the building business.

ASSIGNING PROPERTIES OF LRB IN ETABS

- Insert a story at 0.5m above base
- Click on define
- Click on link properties
- Click on add new property
- Name it as LRB
- click on LRB
- assign properties
- Isolator type is Isolator 1
- Assign direction properties
- In direction U_1, Effective stiffness is K_V, it is linear
- In direction U_2, Linear Effective stiffness is $K_{eff(R)}$, Non-linear Effective stiffness is K_H
- In direction U_3, Linear Effective stiffness is $K_{eff(R)}$, Non-linear Effective stiffness is K_H
- Damping is 5% and post yield stiffness ratio is 0.1
- Yield strength is Q_R
- This completes defining LRB properties
- Next step is to select all the nodes at LRB story
- Click on assign>Joint or point>Link properties>Select LRB
- This completes assigning link properties

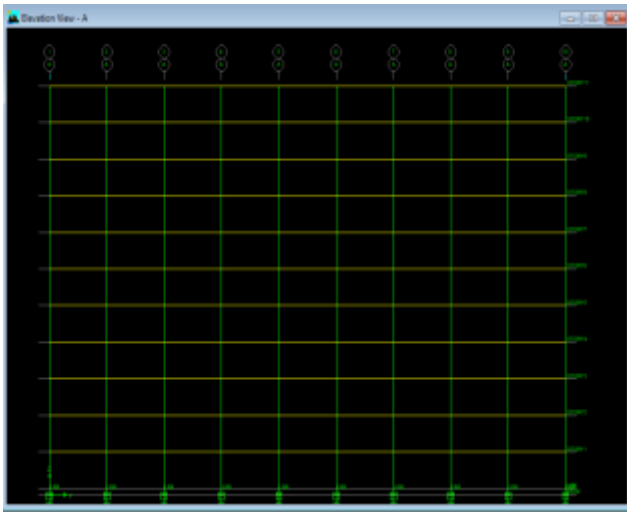
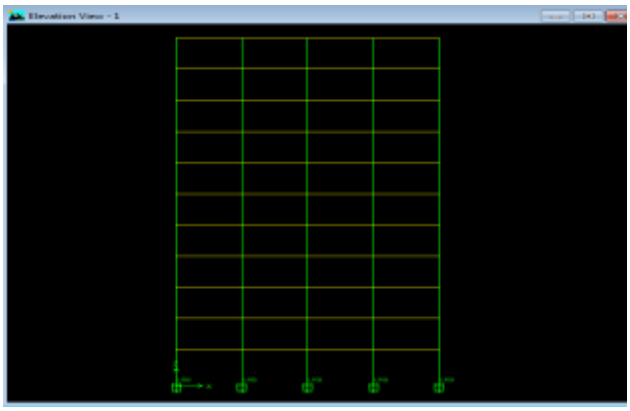


Figure showing LRB above base in elevation view along YZ plane



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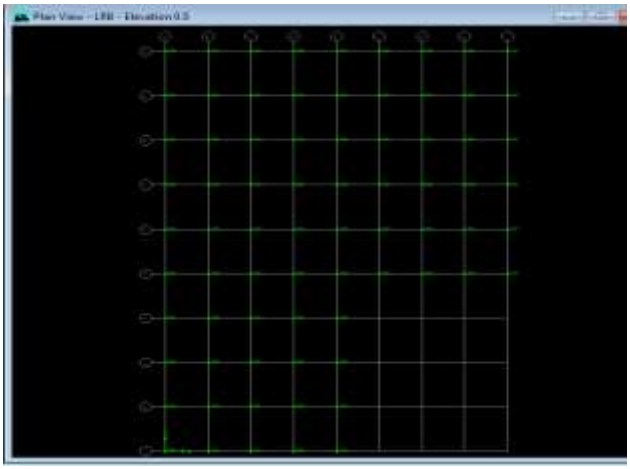
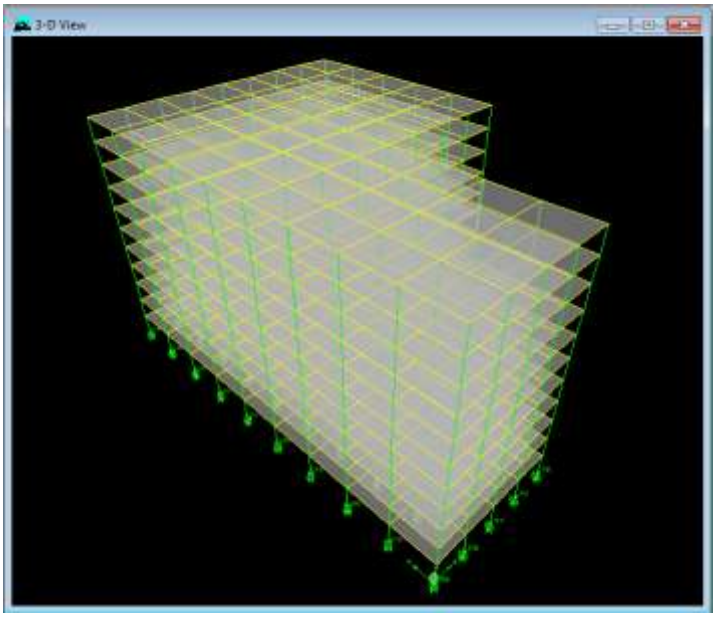


Figure showing that LRB is provided on each footing in plan view



Isometric view showing LRB at base

RESULTS AND DISCUSSION

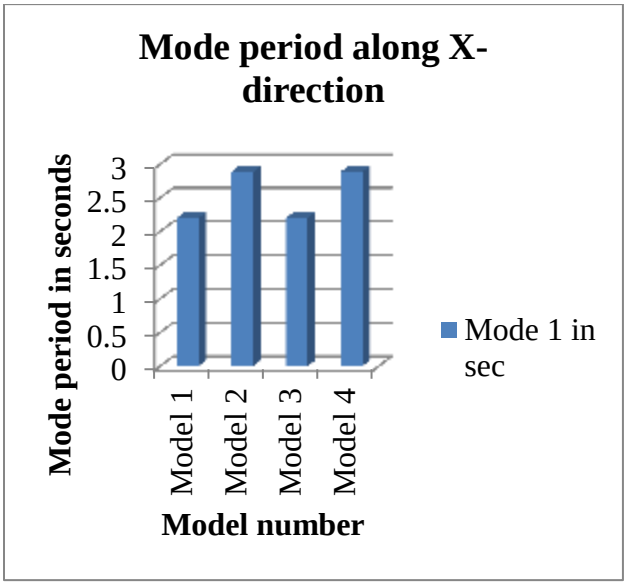
The results are compared for fixed base and base isolated structure by dynamic analysis. Two methods of dynamic analysis were carried out they are Response spectrum analysis and Time history analysis. The results were compared for Story drifts, Base shear, Story shear, Point displacements and Mode shapes.

The mode period of all four models are tabulated in table below we can observe that model 2 and model 4 which are base isolated by providing lead rubber bearing at base have increase in mode period in all three modes when compared to model 1 and model 3 which are fixed base. Graphs are plotted for all three modes to compare all the models. Graphs are plotted with model number in x-axis and mode period in y-axis. Mode 1 increased by 24%, Mode 2 increased by 29% and Mode 3 increased by 30% in model 2 and model 4 (base isolated)

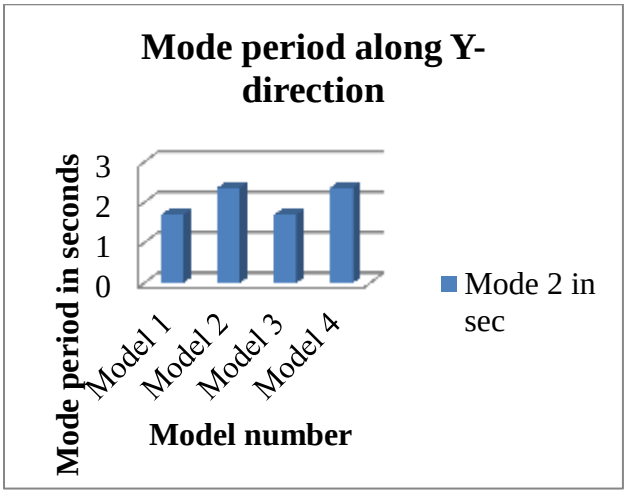
when compared to model 1 and model 3 (fixed base).

Mode Number	Mode direction	Type of model			
		Model 1	Model 2	Model 3	Model 4
Mode 1 in sec	Y direction	2.2002	2.886	2.2002	2.8862
Mode 2 in sec	X direction	1.6911	2.3703	1.6911	2.3708
Mode 3 in sec	Torsion	1.5942	2.2508	1.5942	2.2511

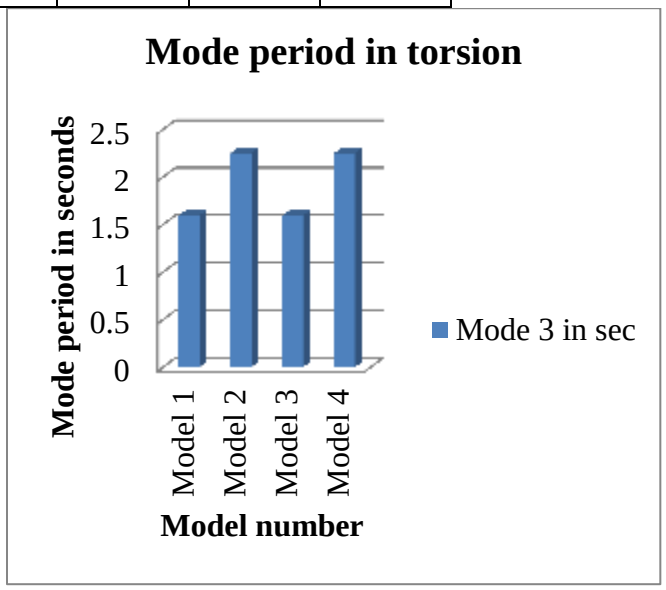
Table 4.5.1: Mode period results of all models



Graph showing comparison between mode 1 results of all models



Graph showing comparison between mode 2 results of all models



Graph showing comparison between mode 3 results of all models

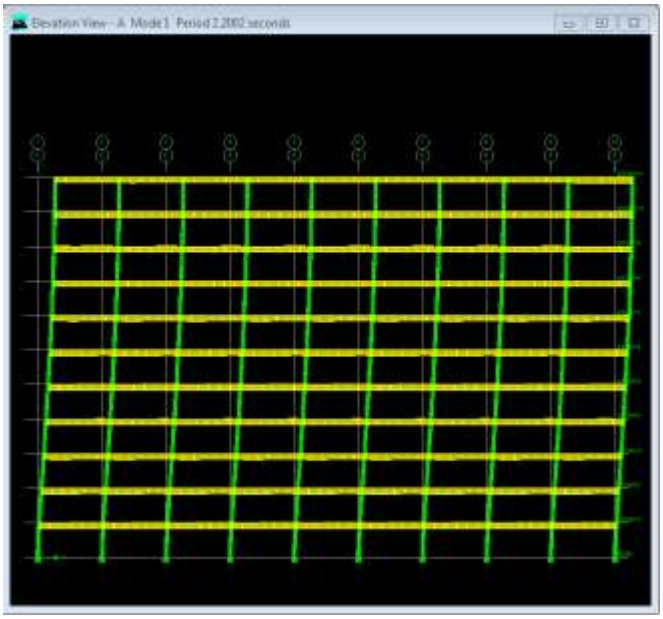


Figure showing the mode 1 (y-direction)

which is 2.2002sec of model 3 which is fixed base

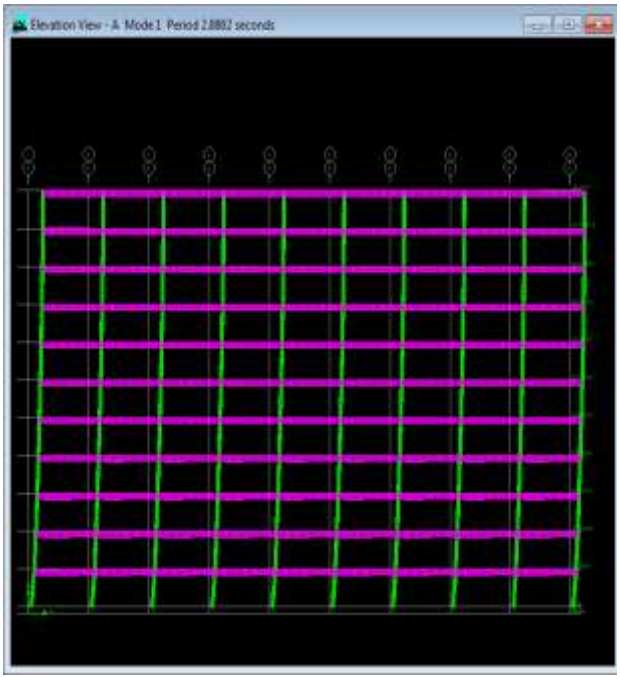


Figure showing the mode 1 (y-direction) which is 2.88622sec of model 4 which is base isolated

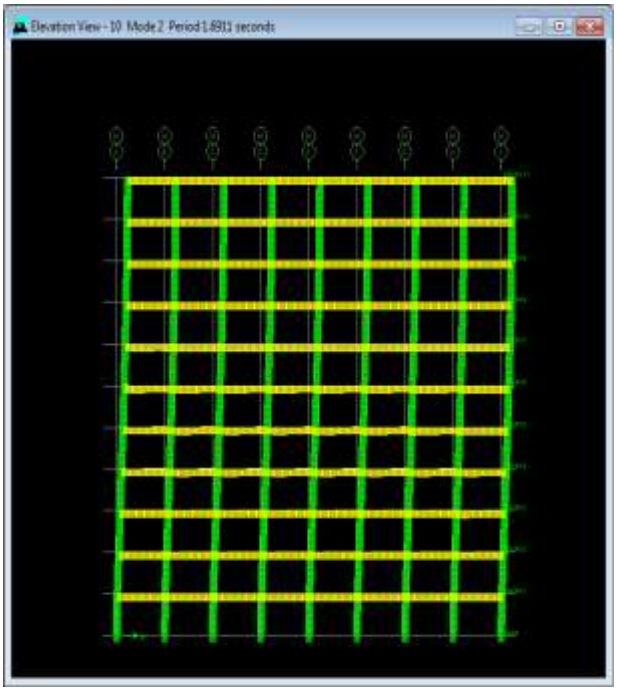


Figure showing the mode 2 (x-direction) which is 1.6911sec of model 3 which is fixed base

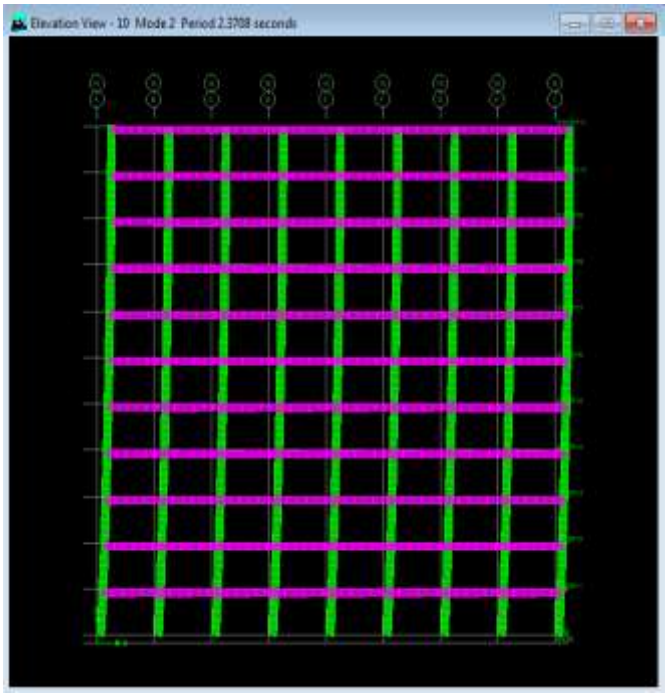


Figure showing the mode 2 (x-direction) which is 2.3708sec of model 4 which is base isolated

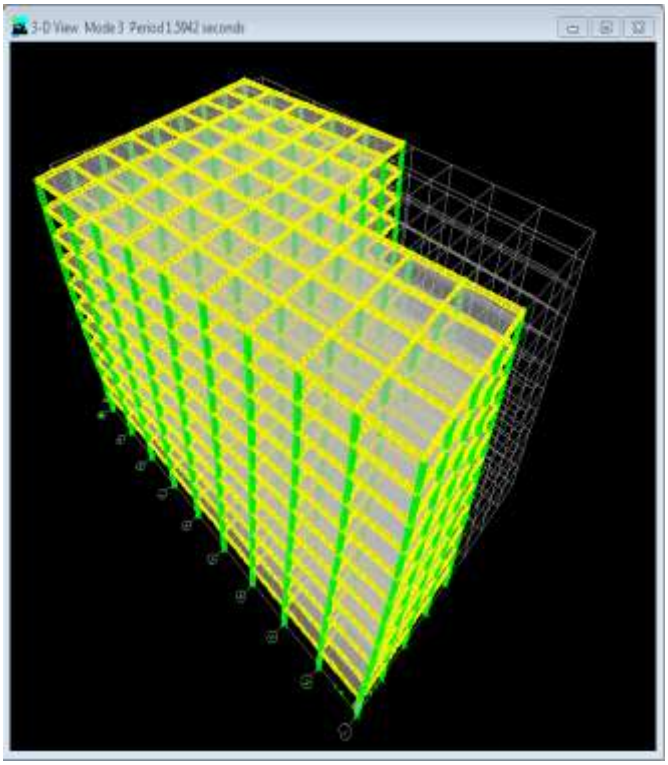


Figure showing the mode 3 (torsion) which is 1.5942sec of model 3 which is fixed base

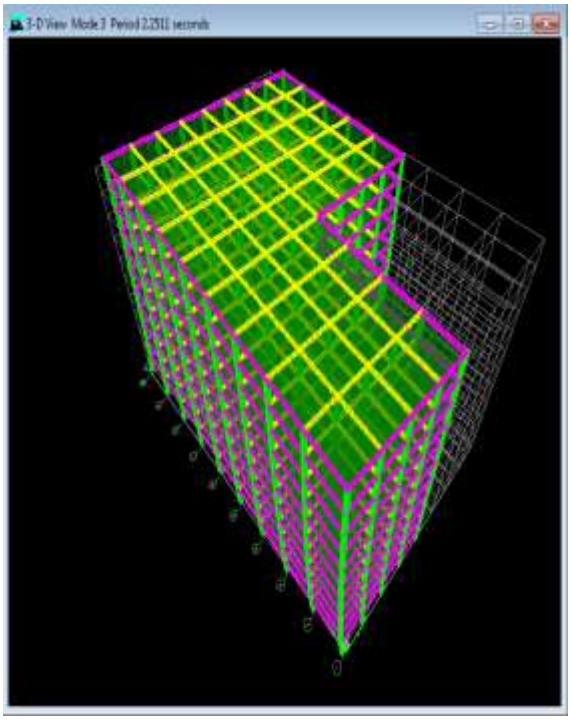


Figure showing the mode 3 (torsion) which is 2.2511sec of model 4 which is base isolated

CONCLUSION

In this project the following conclusions can be drawn,

Response Spectrum Analysis

Model 1 which is fixed base and Model 2 which is base isolated by providing lead rubber bearing these two models were analyzed by response spectrum analysis from these building models following conclusions can be made.

- Story shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building as shown in Fig.
- Base shear is also reduced after providing LRB which makes structure stable during earthquake as shown in Fig.
- Story drift are reduced in higher stories which makes structure safe against earthquake as shown in Fig.
- Point displacements are increased in every story after providing LRB which is important to make a structure flexible during earthquake as shown in Fig.
- Mode periods are increased which increases reaction time of a structure during earthquake as shown in Fig.
- Finally it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.

Time History Analysis

Model 3 which is fixed base and Model 4 which is base isolated by providing lead rubber bearing these two models were analyzed by Nonlinear-time history analysis from these building models following conclusions can be made

- Story shear reduced after the lead rubber bearing (LRB) is provided as base isolation system which reduces the seismic effect on building as shown in Fig 4.1.3 and Fig 4.1.4
- Base shear is also reduced after providing LRB which makes structure stable during earthquake as shown in Fig.
- Story drift are reduced in higher stories which makes structure safe against earthquake as shown in Fig.
- Point displacements are increased in first three stories after providing LRB which is important to make a structure flexible during earthquake and relative point displacement between stories were significantly reduced after LRB is provided which reduces axial load on column hence

reduced reinforcement in column as shown in Fig.

- Mode periods are increased which increases reaction time of a structure during earthquake as shown in fig.
- Finally it is concluded that after LRB is provided as base isolation system it increases the structures stability against earthquake and reduces reinforcement hence make structure economical.

When both the methods of analysis are compared it is observed that response spectrum is code based analysis were UBC 1997 spectra is used and time history analysis is based on previous earthquake disasters in which Bhuj earthquake data is used. The time history analysis was found much efficient in providing results when compared to response spectrum analysis.

FUTURE SCOPE

- In this study, plan irregular structure is used and further study can be carried out for regular structure
- In this study base isolators were provided at base further study can be carried out providing isolators at different levels of a building
- Studies can be carried out by providing different type of isolators like resilient sliding systems, natural rubber bearing etc...
- Further, studies can be carried out by using different types of moment resisting frame and dual systems
- Studies can be carried out for providing both dampers and isolators in a structure