COMPARISION OF SESMIC RESPONSES OF RC FRAMED STRUCTURES HAVING DIFFERENT BASE ISOLATION CONDITIONS

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

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IN

STRUCTURAL ENGINEERING

Submitted by:

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(2K20/STE/04)

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I, ANSHUL DABAS, Roll No. 2K20/STE/04, student of M. Tech. (Structural Engineering), hereby declare that the project Dissertation titled "**COMPARISION OF SESMIC RESPONSES OF RC FRAMED STRUCTURE HAVING DIFFERENT BASE ISOLATION CONDITIONS"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degreeof Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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ABSTRACT

In day todays life many areas are prone to earthquake due to which old conventional buildings pay a heavy toll by getting damaged so countries are trying different methods to reduce the damage done by earthquakes.

Base isolation method is one of the method which is being used to protect the valuable buildings such as museums, hospitals and etc. In base isolation the super structure and the sub structure acts independently of the building which helps in saving the building as the modal period increases.

There are many type of base isolators used in practice such as Lead Rubber Bearing isolator, Friction Pendulum Bearing isolator and etc. In the present study a RC framed building was designed, G+3 with a height of 13m in which seismic analysis was done and different conditions of base isolator were studied and also of the conventional building too using the software E-tabs. The analysis was done on seven type of conditions where composition of Lead Rubber Bearing isolator and Friction Pendulum Bearing isolator were studied.

The results were compared and studied. It was found that the lead rubber bearing isolator is more effective than Friction Pendulum Bearing and way better than of conventional fixed base. The base shear, displacement, drift and the modal period were compared for the conclusion.

ACKNOWLEDGEMENT

I take this opportunity to express my deep sense of gratitude to Dr. ALOK VERMA, Professor, Department of Civil Engineering, Delhi Technological University Delhi, for his excellent guidance and perennial encouragement during the course of work in this degree course.

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Place: Delhi **ANSHUL DABAS**

Date**:** 30/05/2022 **2K20/STE/04**

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Chapter -1
INTRODUCTION

1.1. GENERAL

The best desired methods of shielding structures from earthquake pressures is base isolation. The term "base isolation" has two meanings. The first is the 'base,' which refers to a component that supports or acts as a foundation for a structure, and the second is the 'isolation,' which refers to the state of being separated. Base isolation belongs to the passive control device category. Adding some constituents to the structure affects the mass, stiffness, damping, or a combination of the two or all in the passive Control system. These components are actuated by the structure's movements and impart control forces based on their dynamic qualities. The structure does not require any external energy to operate. It is a passive control device which is placed between superstructure's base and substructure of the building.

In two ways, base isolator protects structures from earthquake forces:

1) Deflecting
2) Absorbing.

The deflection of seismic energy is making the structure's foundation flexible in lateral directions, which extends the structure's basic time period. Buildings with a longer life expectancy attracts lesser seismic forces, which the isolation system deflects. High energy ground motions at higher mode frequencies are particularly deflected. The isolator device absorbs seismic energy due to its non-linear response to earthquake activation. Under sinusoidal stimulation, the force–displacement behavior of isolators exhibits hysteretic behavior, and hence much of the input energy to the isolators is spent in the hysteresis loop. Isolators have become particularly appealing passive control devices to use in the regulation of seismic response of structures, particularly building structures, due to these two properties.

1.2 Principle of Base Isolation

A base isolation system's main premise is to adjust the structure's responsiveness such that the ground beneath it can move freely without conveying motions to the superstructure. In an ideal system for the flexible, this separation would be total. In the real world, however, there must be some connection between the superstructure and in the substructure.

A structure with perfect flexibility can last an indefinite amount of time. The structure will not accelerate when the substructure moves in a flexible form of construction, and the relative displacement between the superstructure and substructure will be equal to the ground displacement. When the ground moves, the acceleration created in the superstructure is equal to the ground acceleration, and the superstructure and substructure have no relative displacement.

The response to ground motion is somewhere in the middle because no present building is perfectly flexible or rigid. For time intervals ranging from 0 to infinity. The earthquake determines the maximum acceleration and relative ground displacements.

There will be a period of time during the majority of earthquakes when the system's acceleration exceeds the maximum ground acceleration. In most circumstances, relative displacements will not reach the infinitely long peak ground displacement. There are some major exceptions, such as soft sites and those located near the fault that caused the earthquake.

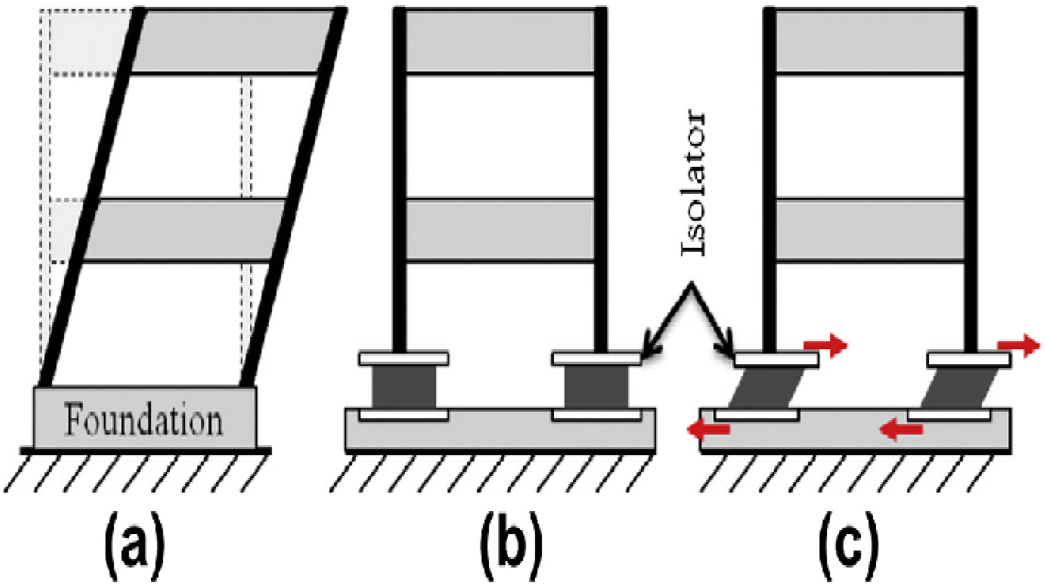


Fig 1.1 Isolator Movement

1.3 Base Isolation System

A passive control device is base isolation. Elastomeric bearing base isolation systems and sliding bearing base isolation systems are the two most common forms of base isolation systems. In elastomeric bearing base isolation systems, lead rubber bearing, laminated rubber bearing (LRB), and New Zealand (NZ) rubber bearing are commonly utilised. In sliding bearing base isolation systems, elastic sliding bearing and friction pendulum system (FPS) all commonly utilised.

Seismic is a factor that causes lateral forces to be applied to a structure's foundation, and structural engineers should address it during the design process. Seismic design aims to protect critical facilities such as hospitals, museums, and government buildings against earthquake damage. Many academics have worked on this, performing significant research to discover the best earthquake protection and survival measures.

1.3.1 Lead Rubber Bearing System

It is one of most common base isolation methods. It consists of steel plates & rubber with one or more lead plugs. Bilinear response and initial stiffness for mild earthquakes and severe winds occur from the lead core deforming in shear. Large plastic deformations are caused by steel plates in elastomeric bearings. As a result, a lead plug was used instead of an elastomeric bearing. Because they combine the functions of vertical support, stiffness at service load levels & horizontal flexibility under earthquake stress, lead-rubber bearings are an effective solution for seismic isolation concerns. An LRB system has a great damping capacity with horizontal flexibility, and also the vertical stiffness in general.

1.3.2 Friction Pendulum Bearing System

The friction pendulum base isolator mechanism has a unique force-displacement loop. The horizontal component of the dish's reaction to gravity's vertical force forces it to centre. With time, this horizontal component grows larger. An energy dissipation device exists due to friction between the spherical surface & the articulated slider. Depending on lubrication feature, this coefficient of friction could range from.03 to 0.09. The lower the coefficient of friction, the better the friction pendulum system's centering effect. Higher friction coefficients, on the other hand, are preferred because they encourage energy dissipation, which reduces dynamic displacement during earthquakes.
More friction, on the other hand, increases the potential to activate higher modes in the isolated structure due to the quick change in loading as the velocity changes direction. Any friction pendulum base isolation system must strike a compromise between low friction to reduce residual offset and larger mode excitation and high friction to reduce dynamic displacement.

1.4 OBJECTIVE OF STUDY

The first goal of this study is to look into the non-linear analysis for fixed and base isolated 4-story buildings designed to the Indian Standard Code like IS 456 (2000), IS 1893 Part 1 of Practice for Design of "Concrete Structures to different isolation systems (friction pendulum isolator and lead rubber bearing system) and the effects of foundation compliance during earthquakes. On both having fixed base and as well as base isolated multistory building, non-linear time history analysis is used.

There are two studies: one compares the response of fixed base & base isolation (FPS & LRB) conditions, other compares the performance of two distinct isolators when used together in different percentage which are 100%FPB, 80%FPB-20%LRB, 60%FPB-40%LRB, 40%FPB-60%LRB, 20%FPB- 80%LRB, 100%LRB. Finally, base shear,drift, displacement & modal period i.e. evaluated with time histories analysis to conclude the results of the analysis. All the conditions and stiffness values kept the same for the parametric study too to find the optimum condition for the isolation.

Chapter – 2

LITERATURE REVIEW

2.1 Overview of Past Study

Peng-Hsiang, Charng

The scholar's recommended to conduct a study to comprehensively examine the seismic responses of flexible & stiff 12-story multi-story buildings against the various base isolation systems, and further note the impact of substructure compliance on each and every response when being subject to various earthquakes. Simultaneously, the seismic reaction of the freshly proposed segmental buildings is being investigated. We can see segmental building concept as a further extended part of traditional base isolation technique however, it is more flexible all through the superstructure. We can also further divide the superstructure of a number of buildings into many segments which are coupled by extra isolation systems placed in the upper stories and not only the traditional isolation system which is situated at the base.

General view is that any rise in the additional viscous damping in the structure might lessen the acceleration responses and dynamic displacement of the structure in question. The study is aimed to further analysis the impact that the additional damping has on the seismic response when it is compared with the structures without additional damping for various ground motions. Furthermore, to help the designer better grasp the design at the preliminary stage, a deep analysis and design considerations for base isolated and various structures are proposed.

Norio Hori, Shuang Zou, Masahiro Ikenaga, Kohju Ikago & Norio Inoue

The scholar opined that in Japan there is a rise in the number of application of the base isolation system in detached houses. The substantial base dynamic displacement of a detached base house, on the other hand, exceeds the design limit. It was seen on 11 March

2011 when the Great East Japan earthquake occurred .To ignore this overall damage because of much more excessive displacement device for controlling seismic displacement of base isolated structures by the introduction of friction damper with coupling mechanism.

In modern day earthquake scenarios the friction damper is not activated. When the ideal length is reached with respect to deformation of the isolated story then only the damper gets activated along with the coupling mechanism to lessen the displacement.

The scholars have indicated that the results of the experiments shows that the proposed friction damper is very much successful in reducing the maximum response displacement of the every isolated stories, along with a small rise in the response acceleration on superstructure. However, a rise was also noted in the higher mode vibration after coupling of the friction damper. The reason behind studying of ideal stiffness of plastic and friction force is that the vibrations are directly attributed to the shock and rise in the stiffness as a consequence of friction damper.

Vasant A. Matasagar and R.S. Jangid

Vasant A. Matasagar and R.S. Jangid have focused on the seismic response of multistory base isolated building by comparing different types of isolator system which are connected by the use of viscous dampers to adjoining to base isolation or fixed base structure which are not similar. The focus of this study will be on the model of multistoried buildings as a shear type building with lateral degree of freedom at separate floors which are interconnected to various floor levels using the viscous dampers.

The conclusion of the study was that to control the large bearing displacement in the base-isolated structures, connection of the two adjacent base isolated buildings with viscous damper is very useful. Furthermore, the conclusions of the study also stated that the effectiveness of connection of viscous damper to the structures was because of the following factors:

1. When we connect the adjacent base- isolated and fixed- base buildings

2. Using dissimilar isolation systems for both the adjacent buildings.

3. Effectively separating the time period of adjacent structures.

4. Keeping the flexibility of the superstructure higher.

Saif Hussain, David Lee & Eloy Retamal

The main idea of Saif Hussain, David Lee & Eloy Retamal was that elastomeric pads, sliding plates or inverted pendulums could be used for Seismic Base Isolation. Energy dissipation means can be used in every method however keeping it only to the hysteretic damping. There were some limitation of Hysteretic dampingwhen we talk about energy absorption and it may lead to excite higher modes in fewer cases. Viscous dampers could be ideal solution to tackle such problems. Viscous damping makes an addition of energy dissipation by loads which are 90o out of phase with bending and shear loads such that even if the damping levels have a high value upto 40 percent, the impact remains minimum.

Nitish Takalkar & D. K. Paul

According to studies taken by Nitish Takalkar & D. K. Paul, flexibility should be introduced between substructure and superstructure in seismic base isolation system, it will decouple the superstructure from earthquake ground motion. They found out that friction pendulum isolator system is a good alternative in the base isolation system for studies of multi-storey building when we talk about earthquake ground motion. The force-deformation characteristics of the isolation system was considered as bi- linear. For the medium risen RC buildings, the suitability of friction pendulum isolator was checked.

The study showed that the friction pendulum isolator was economical and ideal for multi-story buildings that are medium risen. The impact that the isolation damping has in response of structure parameters was analyzed while varying effective damping of FPS from 5% to 35%for five spectrums compatible time histories. The study did the roof acceleration and variation of bearing displacement of isolated building was been studied with varying percents of damping of the isolation system. The conclusion was that roof acceleration reduces to isolation damping level and after that it starts increasing due to involvementy of higher modes. The design of Friction pendulum system was to increase time period of structure that helps to reduce the response in the building subjected to strong ground motion.

Shashi K. Thakkar and Sarvesh K. Jain

The observation of the study conducted by them was that the isolation damping was effective in decreasing the dynamic displacement at level of isolation. The rise of damping to a certain level reduces top accelerations and story shears after which any increase in the participation of higher modes leads to rise in the response. There subsists an optimum value of damping which giver a lower value of displacements without any increase in the involvement of higher modes. The ideal value of damping is based on the characteristics of ground motion and have low the value for earthquake motions with high frequency contents. It was noted that usually only upto 15% damping is been required in the base isolation system.

S.D.Darshale and N.L.Shelke

The isolated base structure's response was studied. There are several options available. Base isolation is one type of energy dissipation mechanism. It's an energy management system that's completely passive. Isolator is a device that partially reflects and partially absorbs radiation to isolate the superstructure and base. As a result of the insertion of the lead rubber isolator, the horizontal movement of the building rises, i.e. the fundamental natural time period increases and the horizontal stiffness of the building decreases. The inner tale drift decreased to some extent when the isolator was installed. The G+14 regular RCC building is used to compare the rigid base and base isolated buildings. The fundamental natural time period of the structure is approximately 1.7 seconds, but it is 4.3 seconds for isolated structures. As the natural time period lengthens, energy dissipation increases and responsiveness declines. Because of the isolating inner narrative drift, base shear acceleration is reduced.

Athanasios A.Makore

His study on a hybrid base isolation system under seismic excitation was presented. The controlling parameter, characteristics, or physical attribute of the hybrid base isolation system were investigated in two buildings. The building was isolated at Salamono, Sicily, and optimization techniques were employed to construct the isolator property. For the two bearings, two types of systems were created: high damping rubber bearings and high damping rubber bearings.Two independent mathematical models were created for the bilinear and trilinear base systems, as well as a particular columb model for the hybrid base isolation system for friction slides bearing. Multiple analytical models were explored for various earthquake forces and acceleration over time using nonlinear dynamic analysis. The findings revealed that the performance of hybrid bearing systems varies depending on seismic vulnerability, location, and type.

M.K. Shrimali1, S.D. Bharti2

In this paper it is showed that Control devices for seismic vulnerability are being used more frequently these days. The research focuses on the potentially dangerous effects of surrounding buildings' hammering. Controlled devices have become essential for mitigating this damage. The research was based on a comparison of damper and isolated systems. According to the research, the hybrid system of seismic hazard control outperforms semi-active control and more attention has been given to determine the varying parameters of control devices.

Y. LI AND J. LI

The paper discusses the base isolator with different stiffness and damping, as well as the modelling design and experimental testing of the innovative isolator. An earthquake's effect can be so powerful that the rubber's passive nature cannot withstand the energy released by seismic activity. Smart base isolation with adaptive and controlled features was developed by altering the stiffness and damping properties of the isolator. Smart rubber design, experimental testing, and dynamic modelling are all demonstrated in this study

A. N. Lin, H. W. Shenton

The seismic findings of rigid base and base isolated concentrically braced steel frames with exceptional moment resistance were given. The base isolation and fixed base frames were designed using various codes. The base isolated building was designed for 100%, 50%, and 25% of the SEAOC recommended lateral forces, while the fixed base frames were developed according to 1990 structural Engineering Association of California (SEAOC) recommended design base shear. For this study, 54 distinct ground motion record records were employed. With these yielding frames, yielded elements, and overall relative roof displacement, on-linear time history analysis was performed for various results such as roof displacement, collapsed frames, and so on. The results obtained for various conditions revealed that using 50% of the SEAOC suggested lateral force provides compatibility with higher performance over other combinations. A comparative analysis of fixed and isolated moment braced steel frames was conducted for peak achieved response.

Lin Su, Goodarz Ahmadi, and Iradj G. Tadjbakhsh

The attributes of the electricity de France (EDF) base isolator and the resilient base isolator (R-FB1) device were combined to create a new combination of base isolator. As a result, a new isolator known as the sliding robust base isolation system was created (SR-F). A curve is constructed for this isolator response spectra and compared to that acquired by the EDF and R-FB1 isolator systems. The acquired results were also compared to a fixed base system. For varied settings and earthquake data, base shear, spectral acceleration, and spectral displacement have been discovered. The results from these various earthquake data were then compared to the SR-F new suggested isolator. All seismic peak responses for EDF and R-FB1 were recorded, and the findings were compared to the SRF system. As a result, maximum responses were lowered without causing significant base displacement. This isolator's peak response was likewise not very severe in terms of frequency and amplitude content.

Chapter – 3

DESIGN OF STRUCTURES

3.1 GENERAL

A total of three structures are designed for the analysis where one structure is having fixed base, second structure is having LRB isolator and the third structure is having FPB isolator. The results of the structures are compared with each other on the bases of modal period, displacement, drift and the shear too. The design calculation of the LRB and FPB are provided in appendix-II.

3.2 FIXED BASE STRUCTURE

The fixed base building are normal conventional buildings constructed on the ground and when an earthquake motion occurs it pay a heavy toll or can say sustain extensive damage. The building is having fixed base which means the translation in X direction, translation in Y direction & translation in Z direction are not allowed with the rotation about X, rotation about Y & rotation about Z are also not allowed too as the name explains itself the base is fixed from all directions.

3.2.1 DESIGN MODEL OF FIXED BASE

For the analysis time history earthquake analysis is used but for base shear static analysis is also done by the help of E-tabs 18 software. The time period and the mode shapes of the building are obtained for all the building such as with base fixed and with isolator too. From the time history analysis, the time dependent responses of building for the whole duration of earthquake are find out like the displacement, shear and the drift. This is how the analysis of multistory building will be done. For the time history analysis the "Imperial Valley-02" earthquake is used which is a magnitude of 6.95 and the detail of earthquake is given in appendix-II.

3.2.1.1 MATERIAL AND STRUCTURAL PROPERTIES

Properties of concrete and structure

Ground floor height	4m
Floor to floor height	3m
No. of grid in X direction	3
No. of grid in Y direction	5
Spacing in X and Y grid	5m
Grade of steel	Fe415
Grade of concrete	M30
Slab thickness	150mm
Columns	230X350 mm
Beams	230X230 mm
Live load on all floors	$3KN/m^2$
Seismic Zone factor	0.36
Response Reduction Factor (R)	5
Importance Factor (I)	1
Site Type	II
ECC. Ratio	0.05
Maximum vertical load	2179.52 KN
Design Time Period	2.67 sec

Table 3.1 Properties of concrete and structure

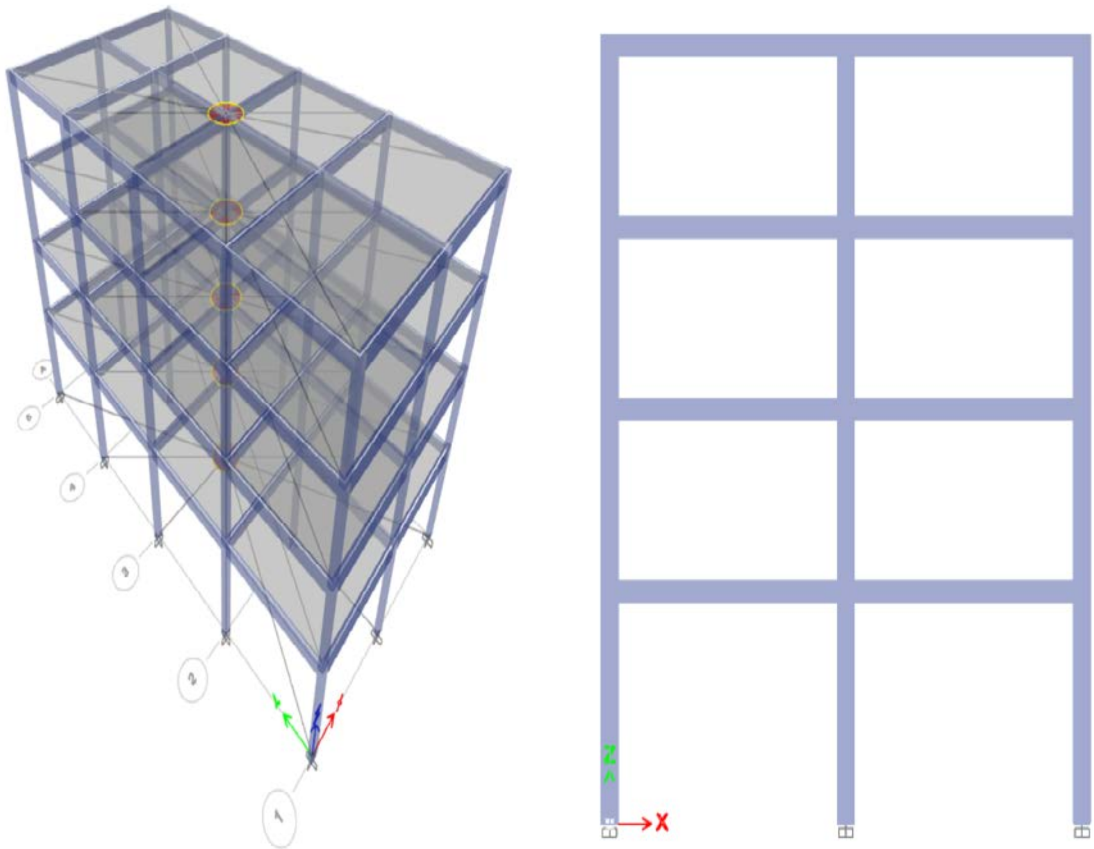


Fig 3.1 Design model of fixed base

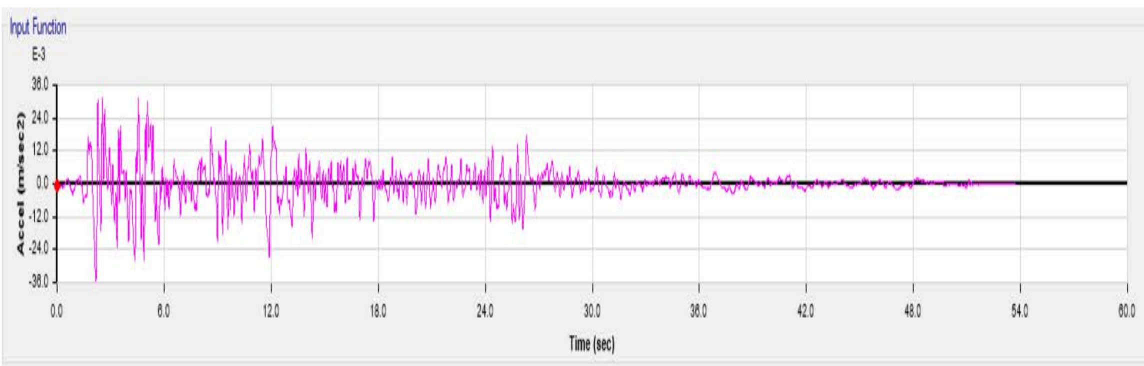


Fig 3.2 Acceleration v/s Time for fixed base in X-axis

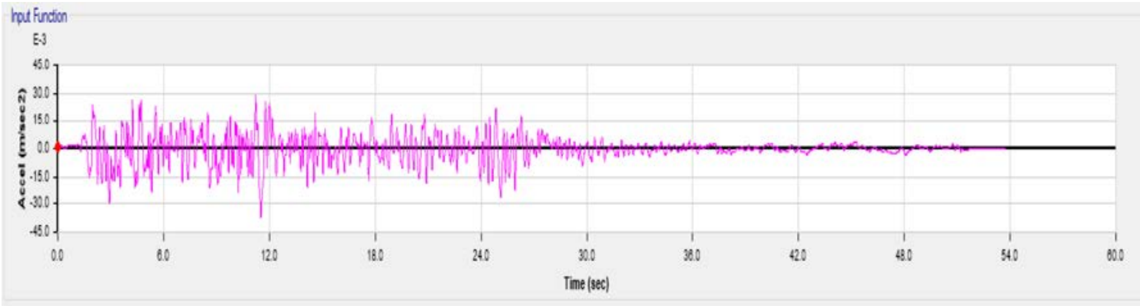


Fig 3.3 Acceleration v/s Time for fixed base in Y-axis

3.3 Friction Pendulum Bearing

In this work, a friction pendulum isolator (FPB) system was designed with two stainless steel plates, the top plate being flat and the bottom plate being concave, and an articulated slider moving during the earthquake. Between the articulated slider and the bottom plate, lubricant is necessary. Teflon is a lubricating substance with a fast friction coefficient of 0.05 and a slow friction coefficient of 0.03. The coefficient of friction influences the behavior of a friction pendulum isolator system.

Friction pendulum isolator consist of:-

1. Top and bottom plate
3. Articulated slider
4. Enclosing cylinder for lateral displacement restraint

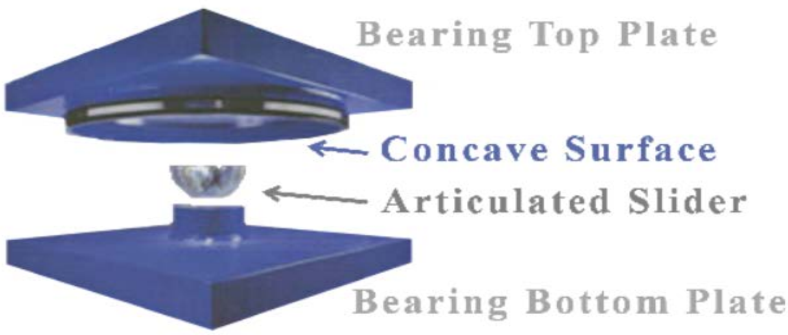


Fig 3.4 Friction pendulum isolator

Source:- https://www.semanticscholar.org/paper/EFFECT-OF-VERTICAL-COMPONENT-OF-EARTHQUAKE-ON-THE-A-Amaral/7b502cb7eebc92dd1fd5f28c45a1a6f831d6312b

3.3.1 DESIGN MODEL OF FRICTION PENDULUM BEARING

The time history earthquake analysis is done with E-tabs. Time history technique is used to evaluate the building's natural and modal shapes. The displacement, shears, base shear, moments, and axial loads of the elements at various quantities of earthquake ground motions have been estimated by using time history analysis of the building's time dependent reactions throughout the entire period of the earthquake excitation. Analysis approaches such as have been used to analysis the seismic behavior of multistory buildings via isolators. Imperial valley-02,(5-19-1940) is chosen for Time History study with NPTS of 5372 and DT of 0.01sec to fully understand the seismic performance of the multistory building.

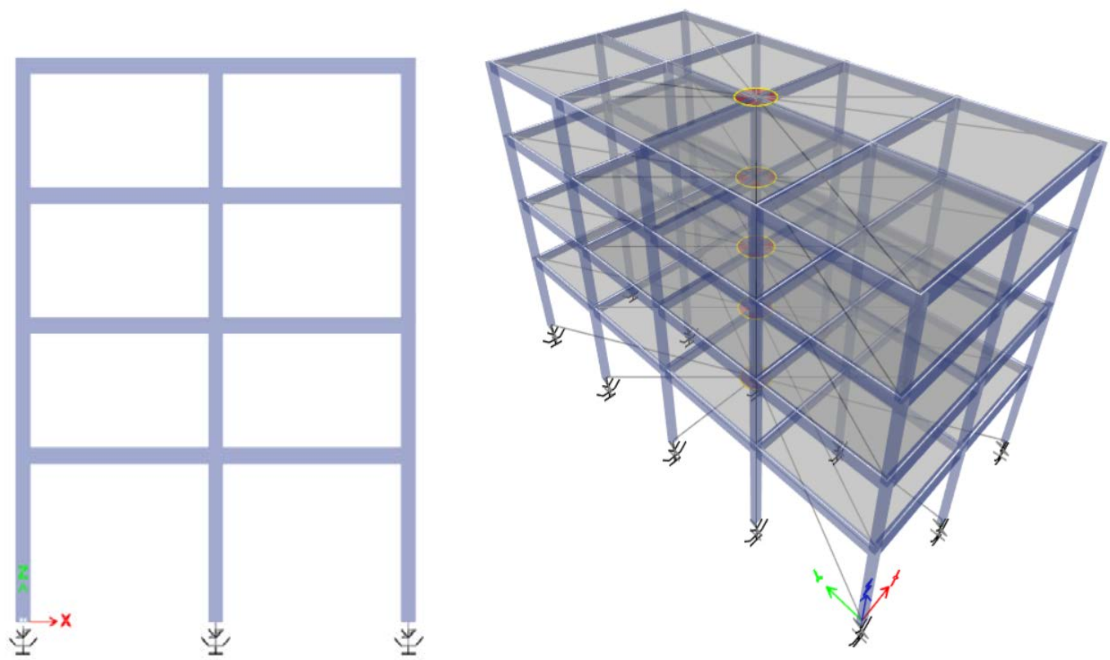


Fig3.5 Design model of FPB

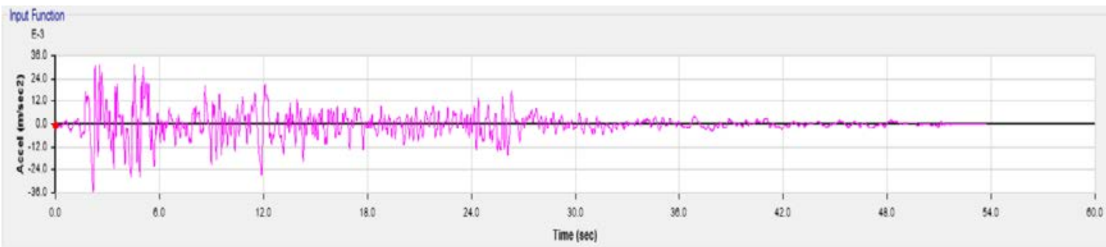


Fig 3.6 fps x axis time graph

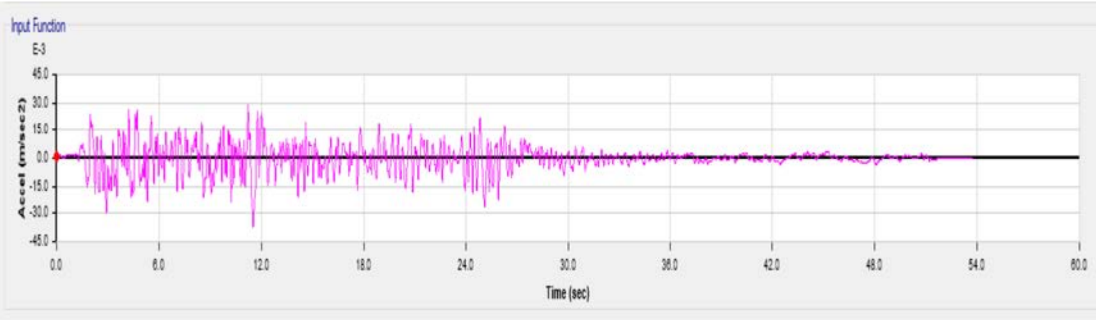


Fig 3.7 fps y axis time graph

3.4 LEAD RUBBER BEARING

In this work, a Lead Rubber Bearing (LRB) system was designed with two steel plates, the top and bottom sealing plate being flat continued by top and bottom loading plates. Lead core is cylindrical in shape wrapped with rubber cover and is also connected both the loading plates. It is a type of elastomeric bearing thus have laminated elastomeric pad.

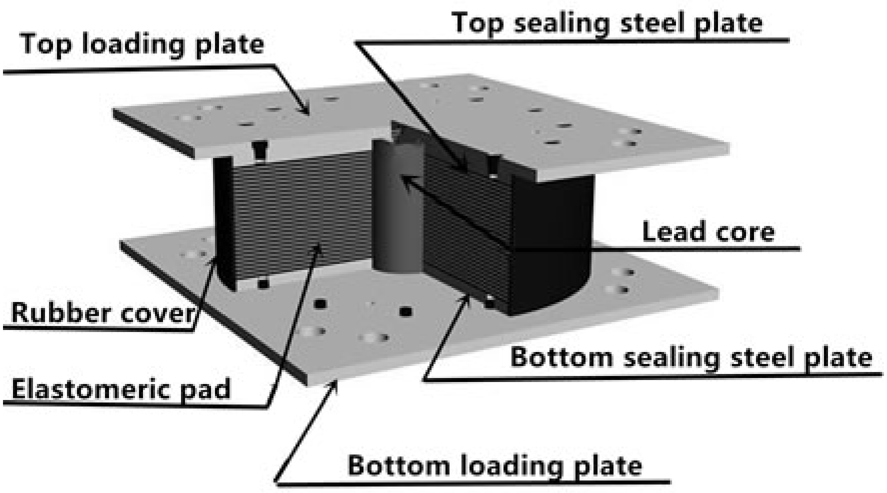


Fig 3.8 Component of LRB

Source-
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.bridgebearing.org%2Fbridgebearing%2Flead-rubber-bearing.html&psig=AOvVaw3dsM1-sVpWh9AKZdnwL9sJ&ust=1652773139161000&source=images&cd=vfe&ved=0CAwQjRxqFwoTCNiqrpbC4_cCFQAAAAAdAAAAABAD

3.4.1 Design of LRB

U_1 Effective Stiffness	1226933.82 KN-m
U_2 & U_3 Effective Stiffness	1226.93 KN-m
U_2 & U_3 Effective Damping	0.05
U_2 & U_3 Stiffness	11306.44 KN/m
Post-elastic tangent stiffness	1130.64 KN/m
U_2 & U_3 Yield Strength	37.43 KN
Stiffness ratio	0.1

Table 3.2

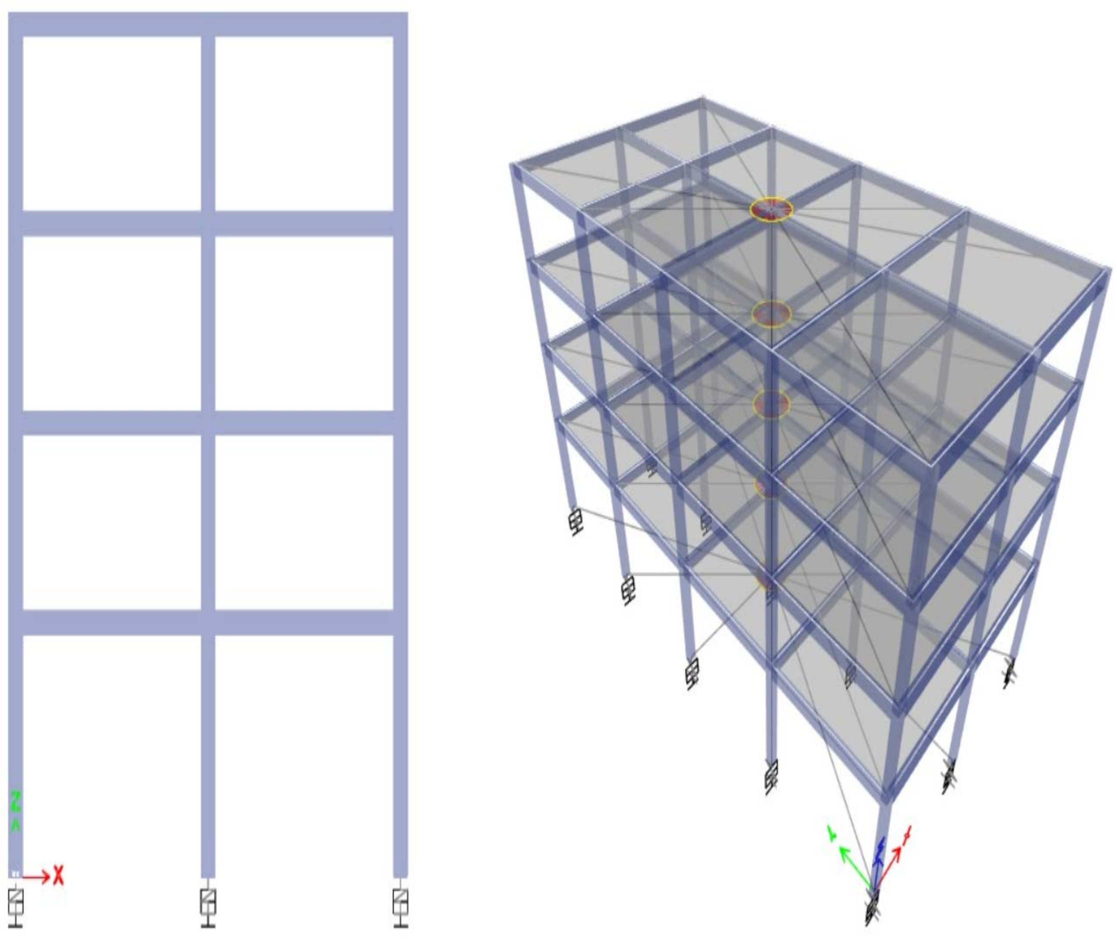
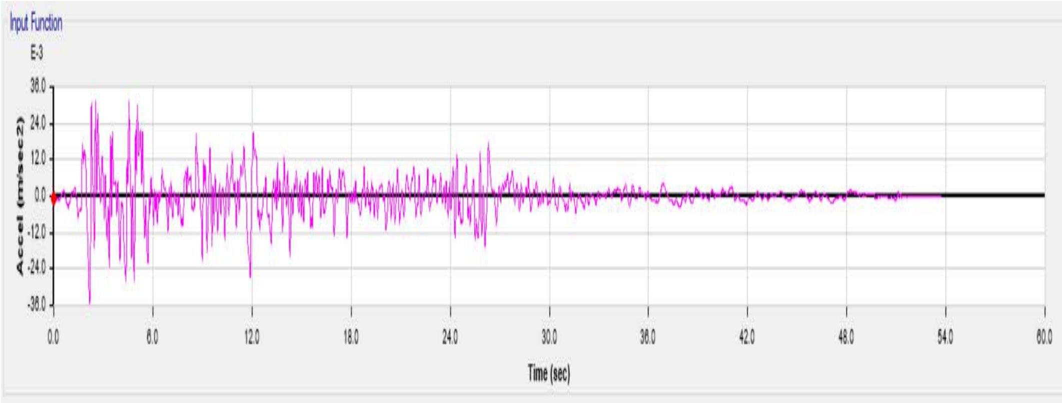
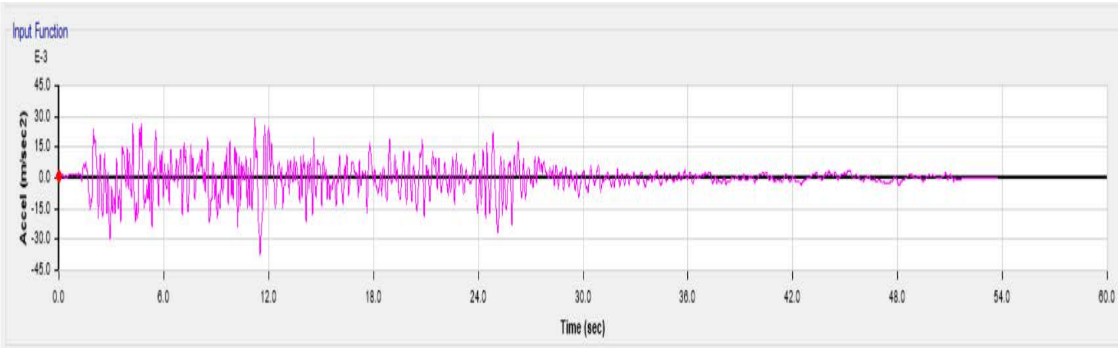


Fig 3.9 Design model of LRB



3.10 LRB X axis time graph



3.11 LRB Y axis time graph

Time histories given above is used in our study as an earthquake forces applied on our model. Imperial Valley acceleration time history data for 60 sec, 5372 points at 0.01 sec interval.

Chapter-4
COMPARATIVE STUDY OF FIXED AND BASE ISOLATED

4.1 TIME PERIOD FOR DIFFERENT MODES

	LRB	FPB	FIXED
MODE 1	4.9632	4.453	2.6719
MODE 2	4.1183	3.496	2.1746
MODE 3	3.9161	3.32	2.093
MODE 4	0.9912	0.975	0.8427
MODE 5	0.8448	0.807	0.6706
MODE 6	0.8075	0.771	0.6514
MODE 7	0.5068	0.498	0.4779
MODE 8	0.4155	0.382	0.3579
MODE 9	0.407	0.375	0.3538
MODE10	0.3833	0.346	0.3426
MODE11	0.3428	0.289	0.2383
MODE12	0.329	0.278	0.2371

Table 4.1 Time period of different mode shapes in seconds

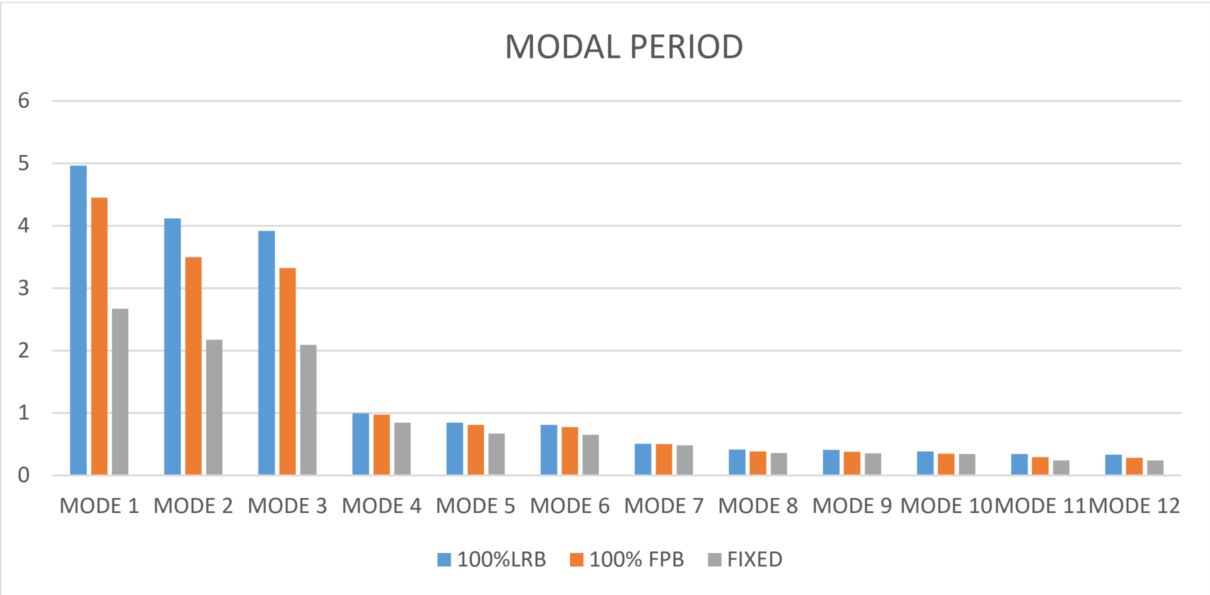


Fig 4.1 Modal period for fixed and isolated (LRB & FPB) in seconds

As we can clearly see that the time period is increased in isolation system as compared to fixed base. The time period in LRB is higher than the FPB in isolation system. So this means when we provide flexibility to the structure the time period of the structure will also be increased. We also know that time period is directly proportional to displacement also therefore providing flexibility by using base isolator LRB AND FPB to the structure will result in increase of time period and displacement

4.2 Floor Displacement

From story drift analysis, we can see that in comparison to base isolated buildings, drift is reduced in fixed base buildings which occurs as a result of building isolation, as time periods to extend, and displacement to grow as a response of the lengthening of time periods.

Displacement at different story

In x-axis

	LRB	FPB	FIXED
BASE	2.585	0	0
STORY 1	6.384	4.234	2.491
STORY 2	7.409	5.301	3.7
STORY 3	8.326	5.86	4.83
STORY 4	8.9	6.435	5.99

Table 4.2 Displacement at each story in X direction in mm

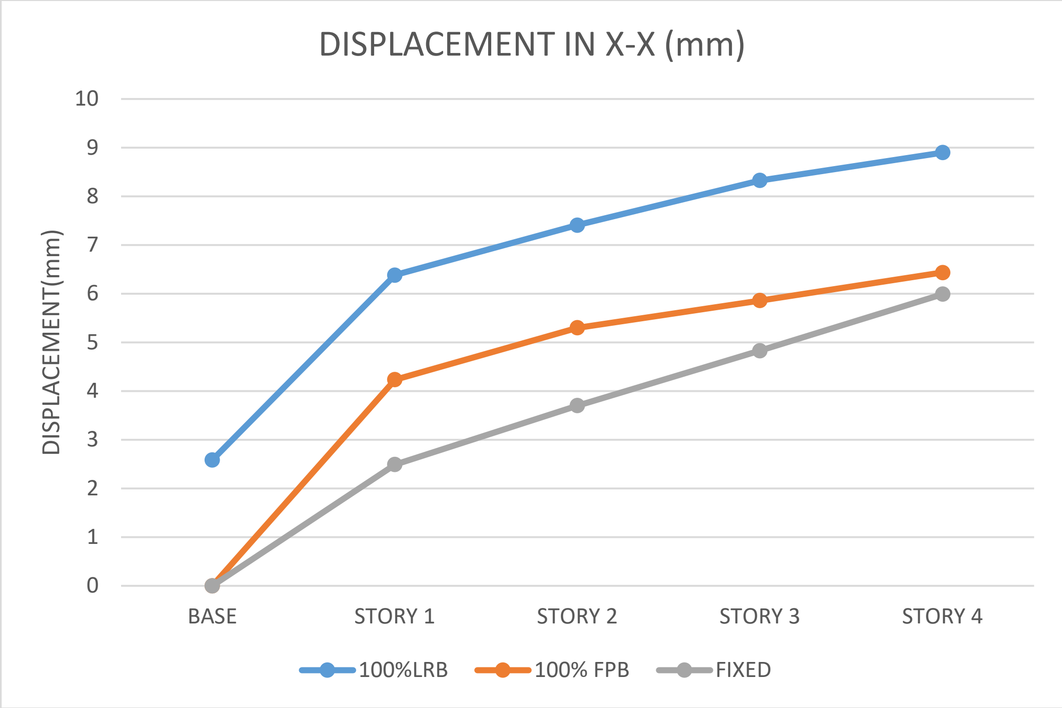


Fig 4.2 Displacement at each story in X direction in mm

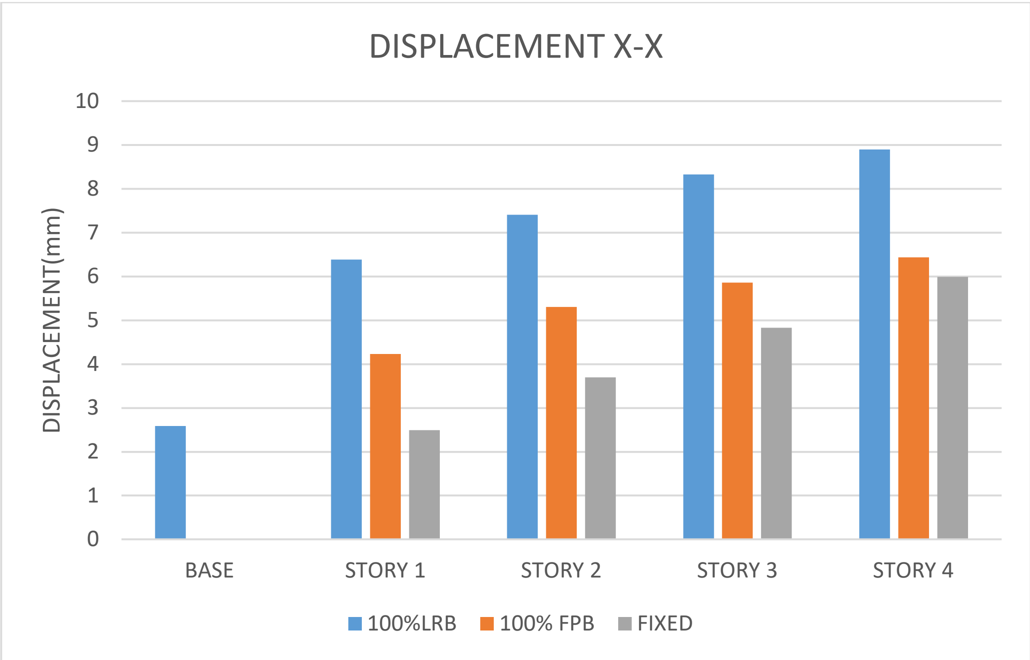


Fig 4.3 Displacement at each story in X direction in mm

In Y-axis

	LRB	FPB	FIXED
BASE	3.06	0	0
STORY 1	12.06	12.785	3.543
STORY 2	13.3	14.862	5.117
STORY 3	14.02	15.97	5.992
STORY 4	14.4	16.49	6.909

Table 4.3 Displacement at each story in Y direction in mm

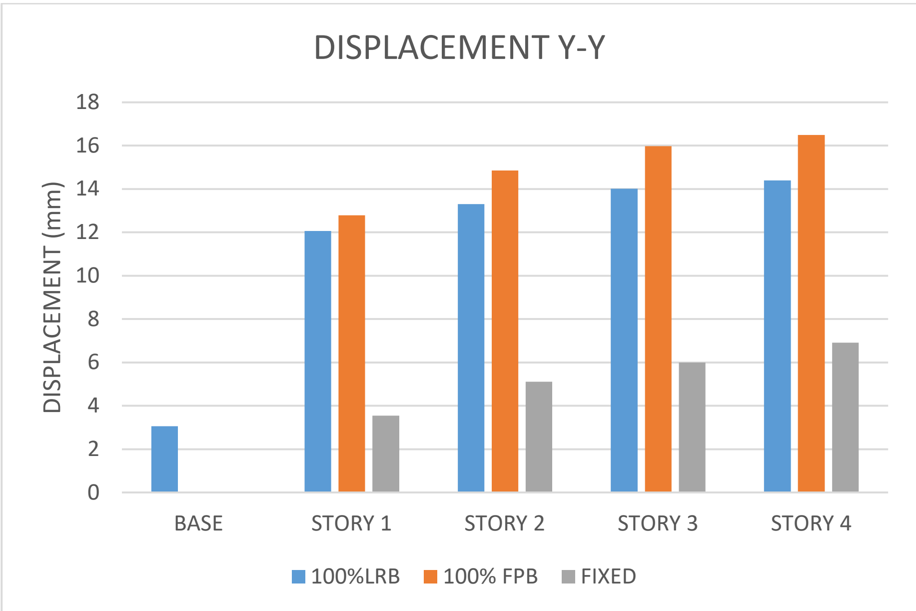


Fig 4.4 Displacement at each story in Y direction in mm

4.3Drift at each story

In x-axis

	LRB	FPB	FIXED
STORY 1	0.00137	0.001102	0.000623
STORY 2	0.000484	0.000406	0.000561
STORY 3	0.000324	0.000272	0.000647
STORY 4	0.000262	0.000192	0.000535

Table 4.4 Drift at each story in X direction in meter

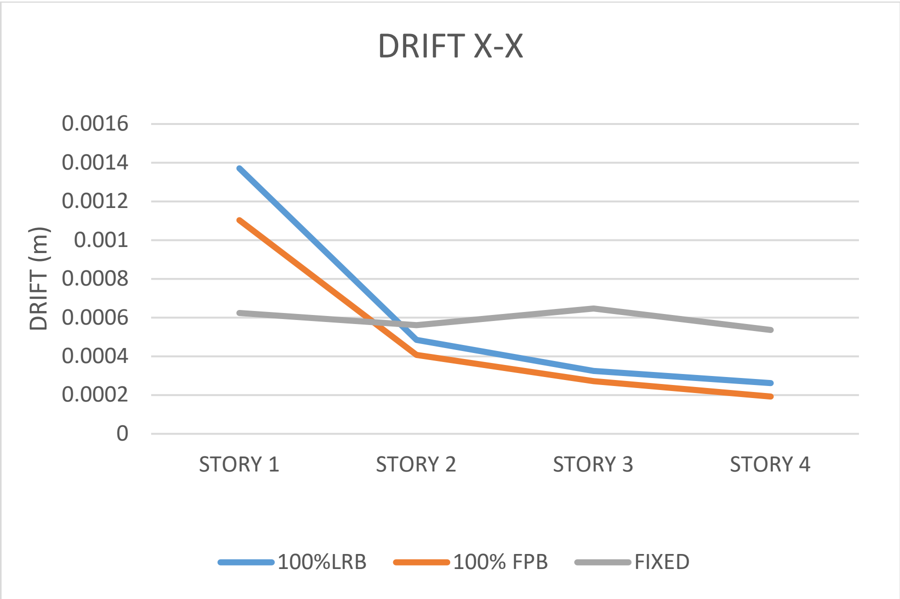


Fig 4.5 Drift at each story in X direction in meter

In Y-axis

	LRB	FPB	FIXED
STORY 1	0.00239	0.003184	0.000903
STORY 2	0.000563	0.00073	0.000663
STORY 3	0.000336	0.000463	0.00053
STORY 4	0.000249	0.000267	0.000378

Table 4.5 Drift at each story in Y direction in meter

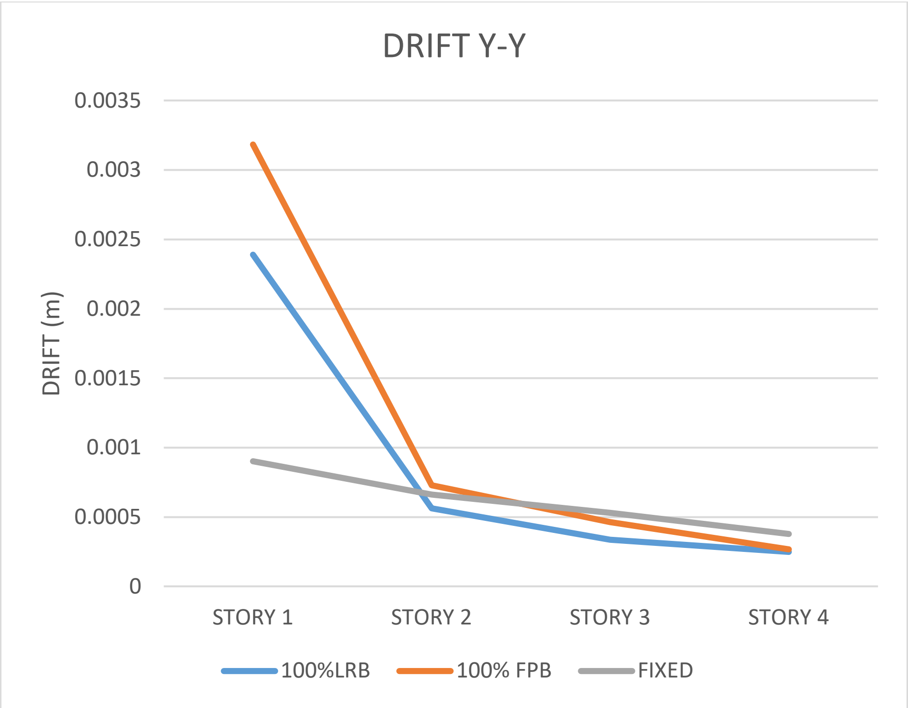


Fig 4.6 Drift at each story in Y direction in meter

4.4 Base shear

In X-axis

	LRB	FPB	FIXED
STORY 1	45.57	45.09	104.76
STORY 2	56.62	42.39	67.32
STORY 3	41.88	31.3	94.11
STORY 4	38.48	22.95	74.17

Table 4.6 Story shear in X direction in KN

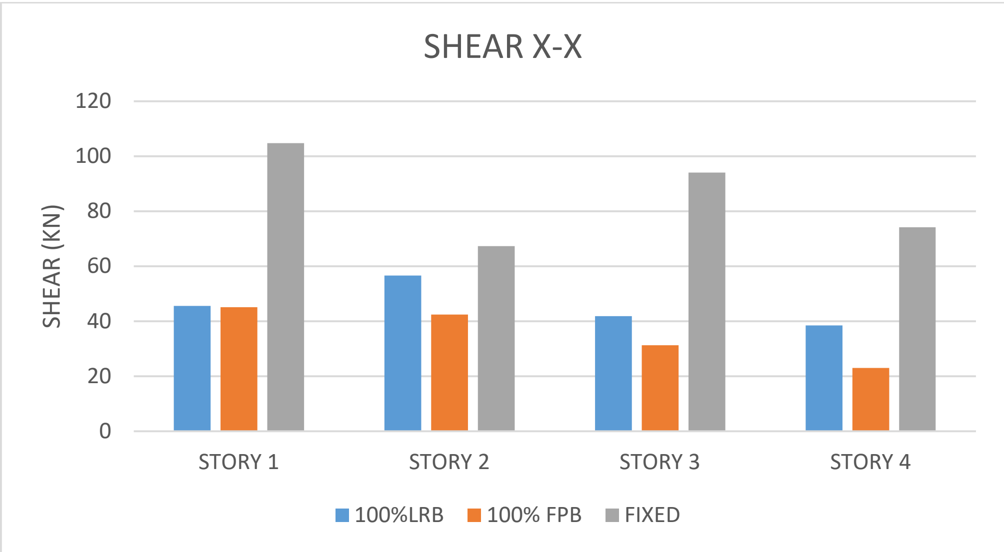


Fig 4.7 story shear in X direction

In Y-axis

	LRB	FPB	FIXED
STORY 1	52.05	67.23	77.5
STORY 2	48.08	56.69	66.04
STORY 3	32.74	44.7	53.32
STORY 4	25.54	25.35	37.38

Table 4.7 Story shear in Y direction in KN

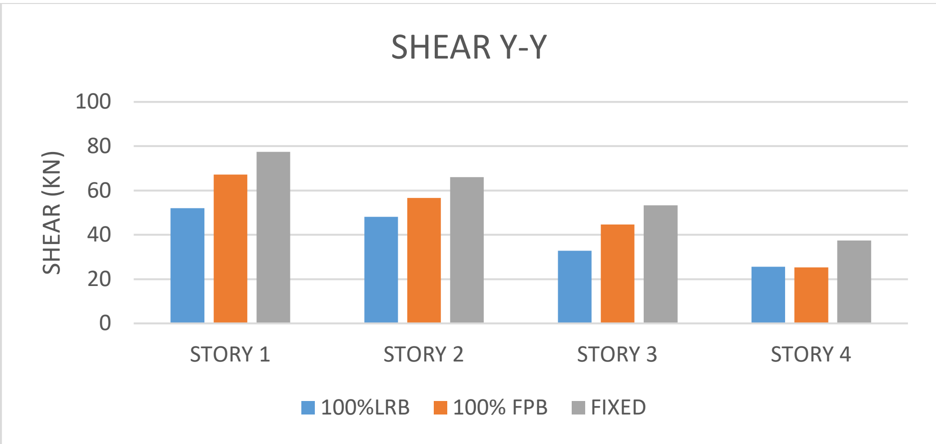


Fig 4.8 Story shear in Y direction in KN

Chapter-5
PARAMETRIC STUDY OF FRICTION AND LEAD ISOLATOR

5.1 GENERAL

As we seen earlier that isolator are very useful for the structure as the time period and displacement increases, base shear decreases by using the base isolator (lead rubber bearing and friction pendulum bearing) as compared to fixed base. So, we did a parametric study by changing the percentage of isolator in the structure due to which we have cases like

- 20%LRB, 80%FPB;
- 40%LRB, 60%FPB;
- 60%LRB, 40%FPB;
- 80%LRB, 20%FPB;
- 100% LRB
- 100% FPB

All other details of the structure and concrete are kept the same as before whereas the stiffness of the isolators (Lead rubber bearing and friction pendulum bearing) are also kept the same. The time history earthquake analysis is done again for these case for the displacement, drift, shear and the time period too just like before to find the optimum case if their exist one.

5.2 STRUCTURE DESIGN CASES

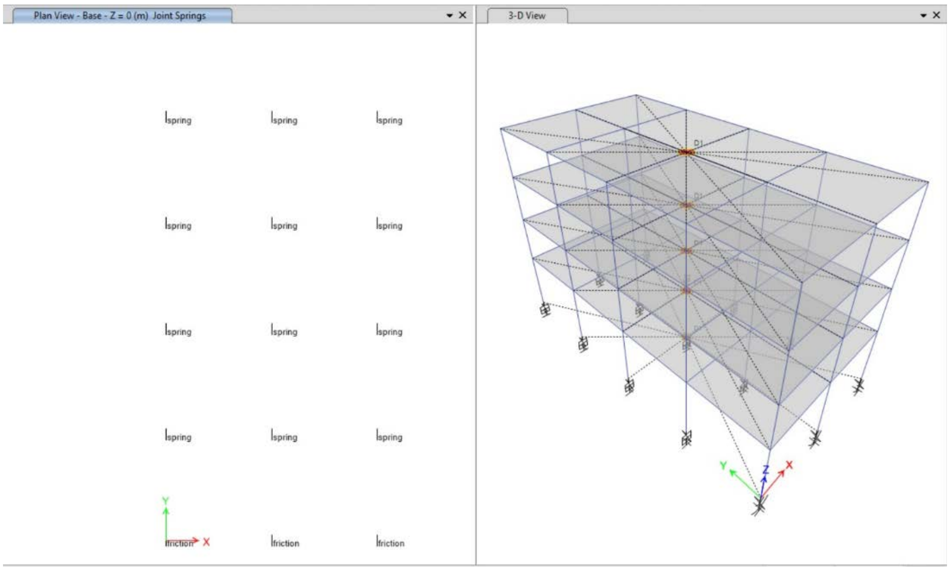


Fig 5.1 20%FPB, 80%LRB

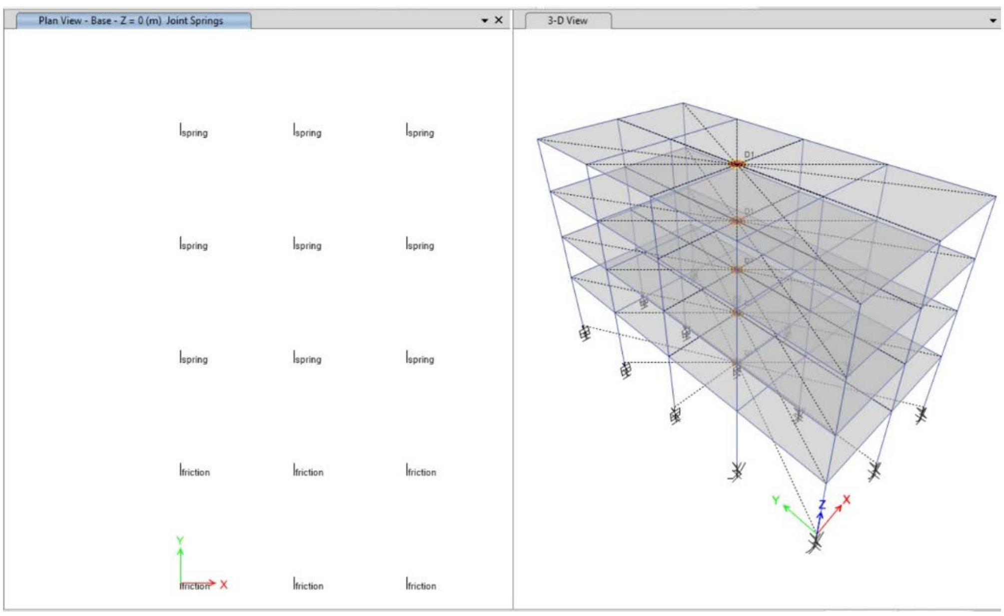


Fig 5.2 40%FPB, 60%LRB

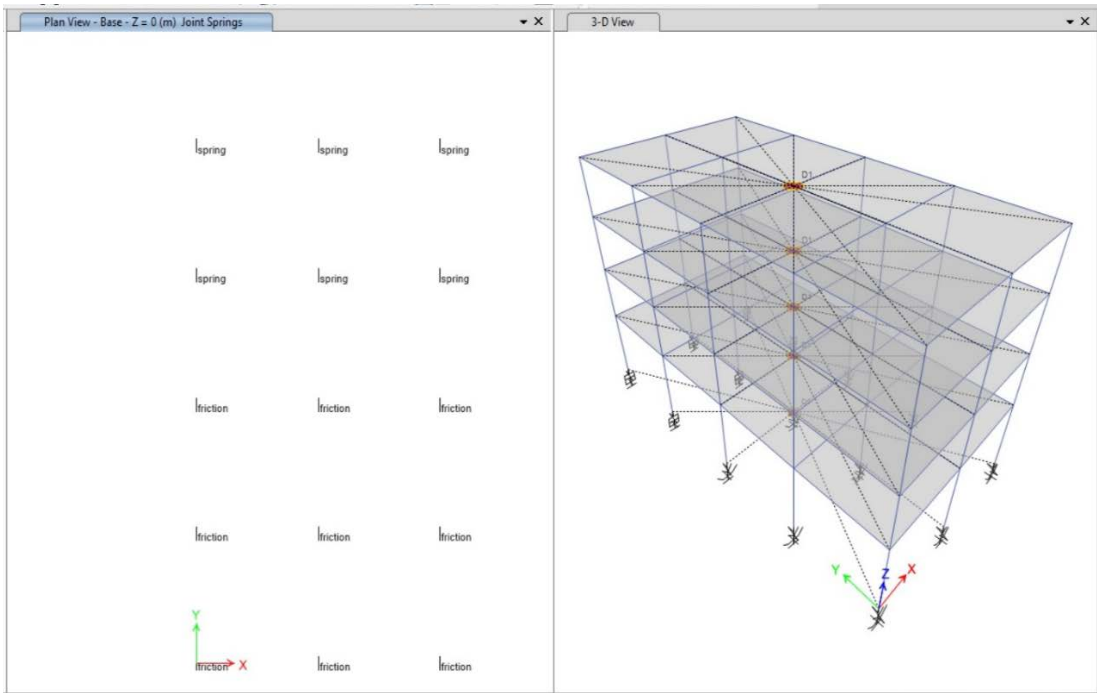


Fig 5.3 60%FPB, 40%LRB

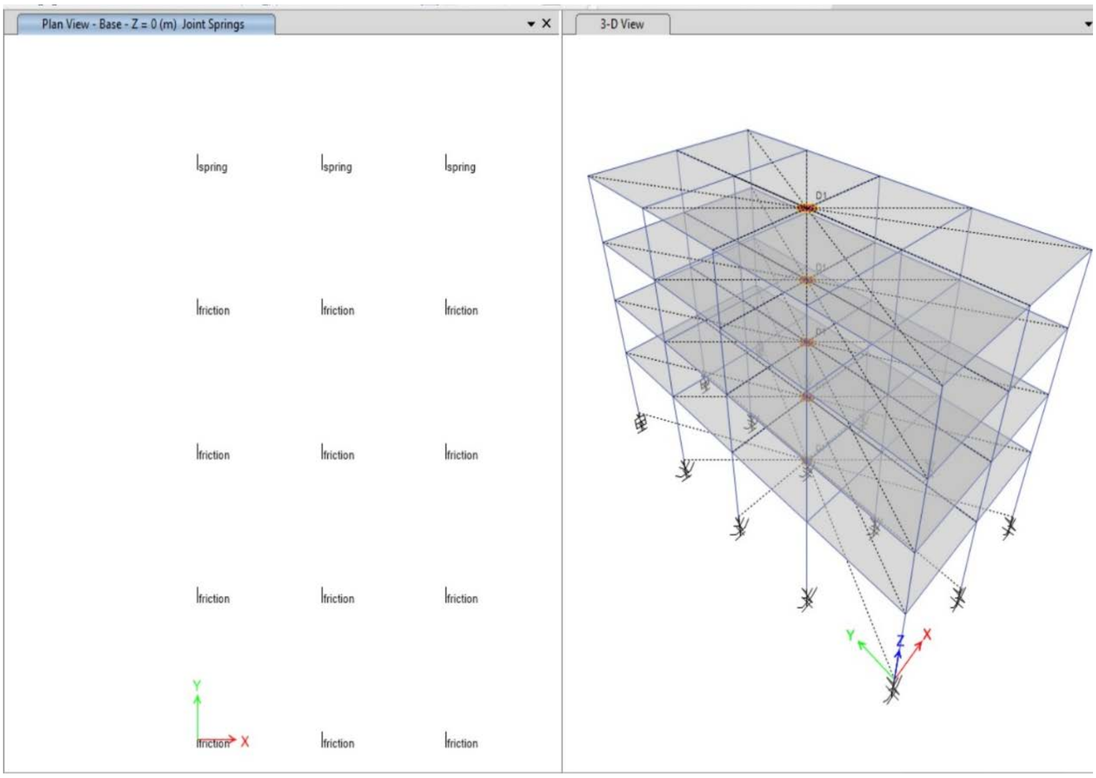


Fig 5.4 80%FPB, 20%LRB

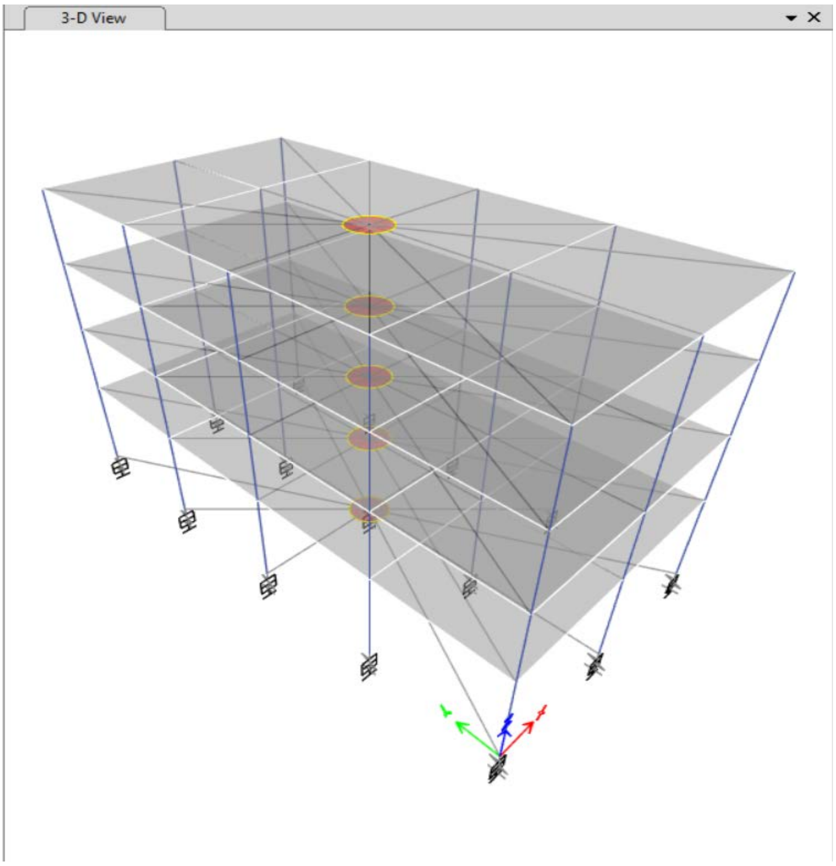


Fig 5.5 100% LRB, FPB 0%

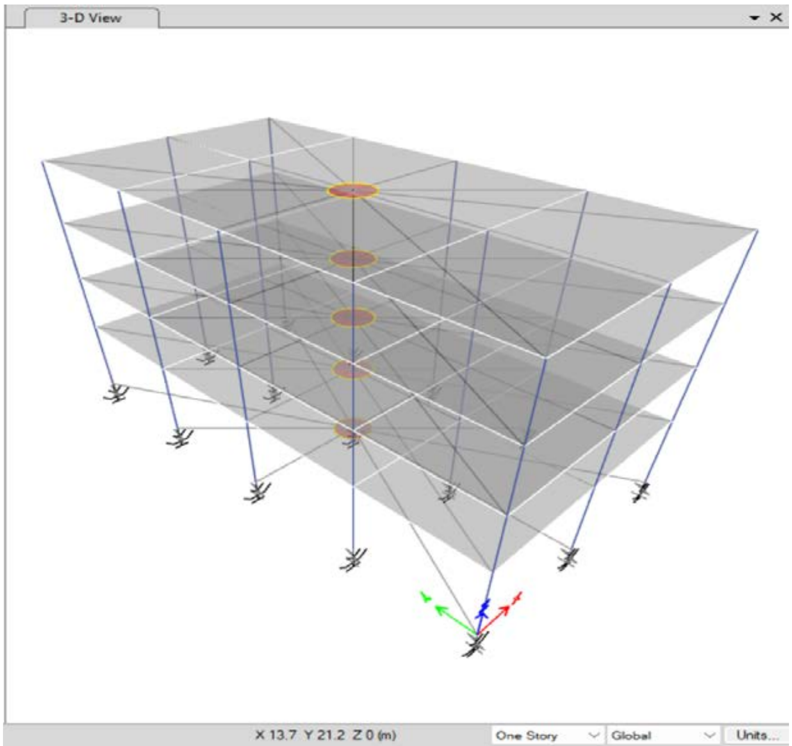


Fig 5.6 100% FPB, LRB 0%

DISPLACEMENT

In X-axis

	100% FPB	80% FPB-20%LRB	60% FPB-40%LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
BASE	0	0.05	0.185	0.524	1.265	2.585
STORY 1	4.234	4.12	4.456	5.303	5.625	6.384
STORY 2	5.301	5.267	5.442	6.554	6.773	7.409
STORY 3	5.86	5.87	6.11	7.262	7.408	8.326
STORY 4	6.435	6.359	6.613	7.677	7.974	8.9

Table 5.1 Displacement at each story in X axis at different cases of isolator in mm

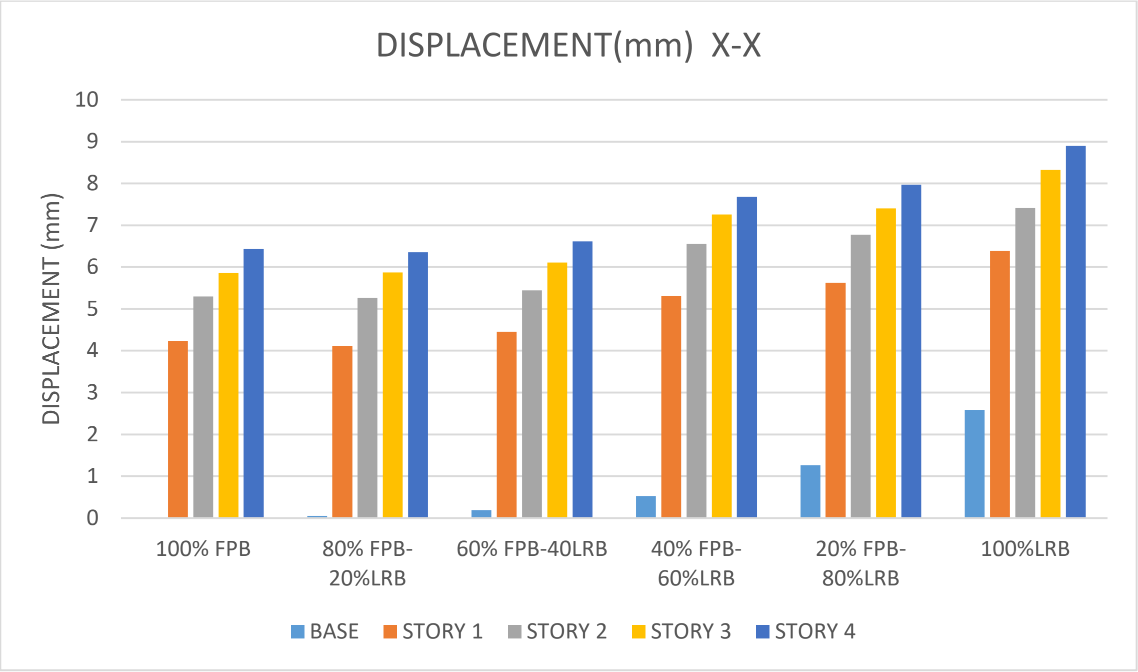


Fig 5.7 Displacement at each story in X axis at different cases of isolator in mm

In Y-axis

	100 % FPB	80% FPB-20%LRB	60% FPB-40LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
BASE	0	0	0.113	0.219	0.484	3.06
STORY 1	12.785	12.81	12.8	12.83	12.46	12.06
STORY 2	14.862	14.92	14.91	14.92	14.4	13.3
STORY 3	15.97	16.09	16.08	16.09	15.73	14.02
STORY 4	16.49	16.65	16.65	16.63	16.51	14.4

Table 5.2 Displacement at each story in Y axis at different cases of isolator in mm

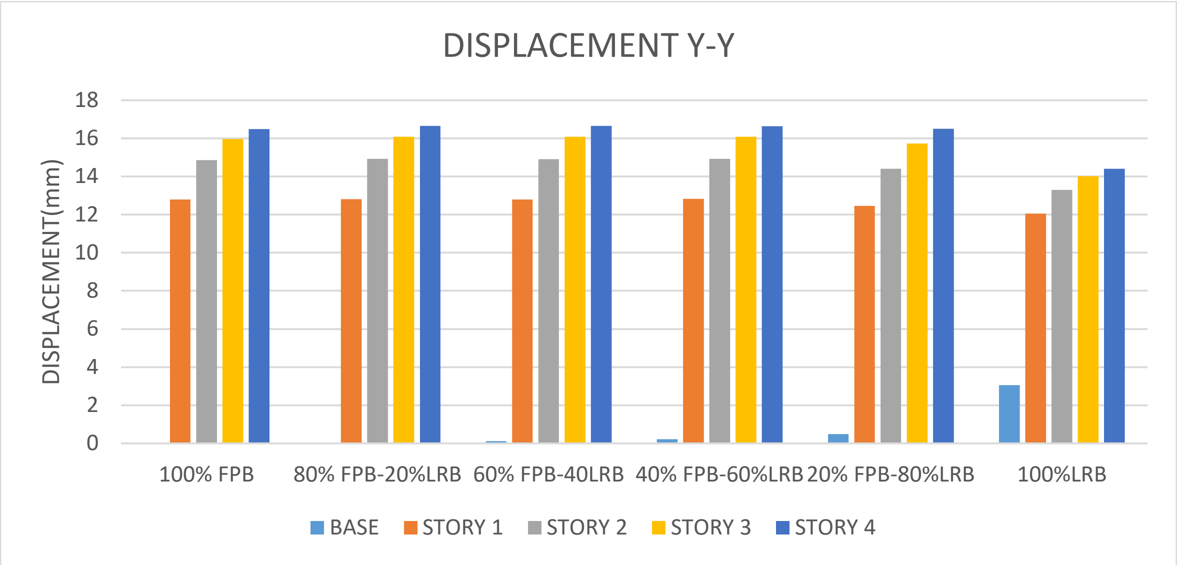


Fig 5.8 Displacement at each story in Y axis at different cases of isolator in mm

Story Drift

In X axis

	100% FPB	80% FPB-20%LRB	60% FPB-40%LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
STORY 1	0.001102	0.001102	0.001118	0.001256	0.001372	0.00137
STORY 2	0.000406	0.000414	0.000406	0.000479	0.000476	0.000484
STORY 3	0.000272	0.000265	0.00026	0.000297	0.000361	0.000324
STORY 4	0.000192	0.000179	0.000179	0.000191	0.000239	0.000262

Table 5.3 Drift at each story in X axis at different cases of isolator in meter

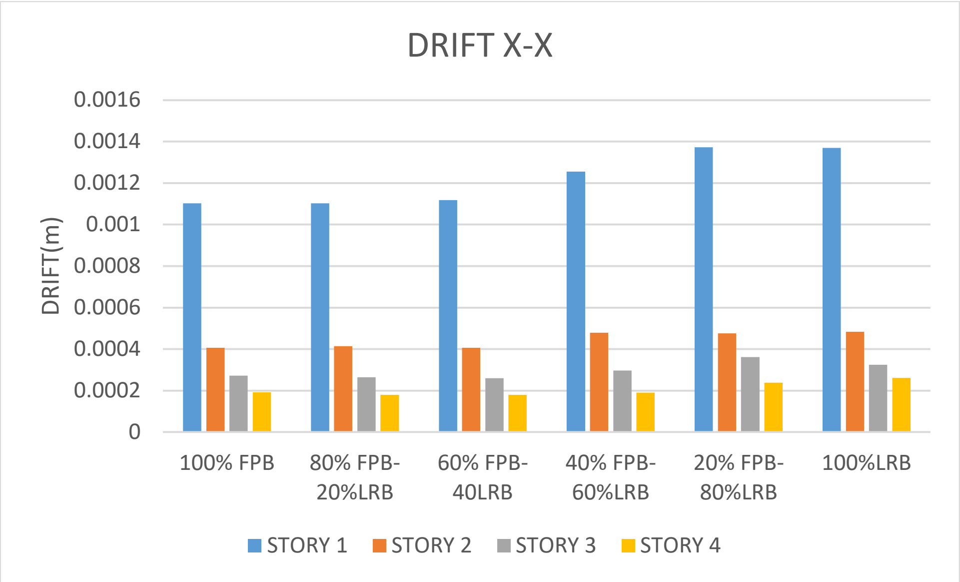


Fig 5.9 Drift at each story in X axis at different cases of isolator in meter

In Y axis

	100% FPB	80% FPB-20%LRB	60% FPB-40LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
STORY 1	0.003184	0.00318	0.00318	0.003174	0.00308	0.00239
STORY 2	0.00073	0.000745	0.000741	0.000757	0.000736	0.000563
STORY 3	0.000463	0.000473	0.000471	0.000478	0.000468	0.000336
STORY 4	0.000267	0.000473	0.000268	0.000267	0.000269	0.000249

Table 5.4 Drift at each story in Y axis at different cases of isolator in m

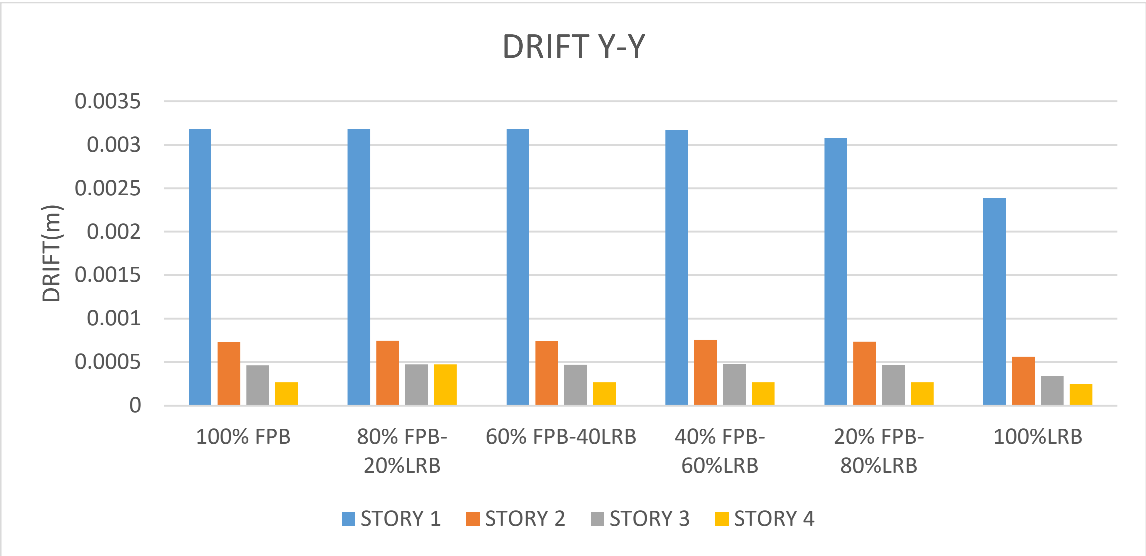


Fig 5.10 Drift at each story in Y axis at different cases of isolator in m

Shear

In X-axis

	100 % FPB	80% FPB-20%LRB	60% FPB-40LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
STORY 1	45.09	44.536	43.79	44.21	39.25	45.57
STORY 2	42.39	40.959	41.09	41	45.55	56.62
STORY 3	31.3	31.082	30.465	30.412	34.59	41.88
STORY 4	22.95	22.8	22.688	22.6	26.57	38.48

Table 5.5 Shear at each story in X axis at different cases of isolator in KN

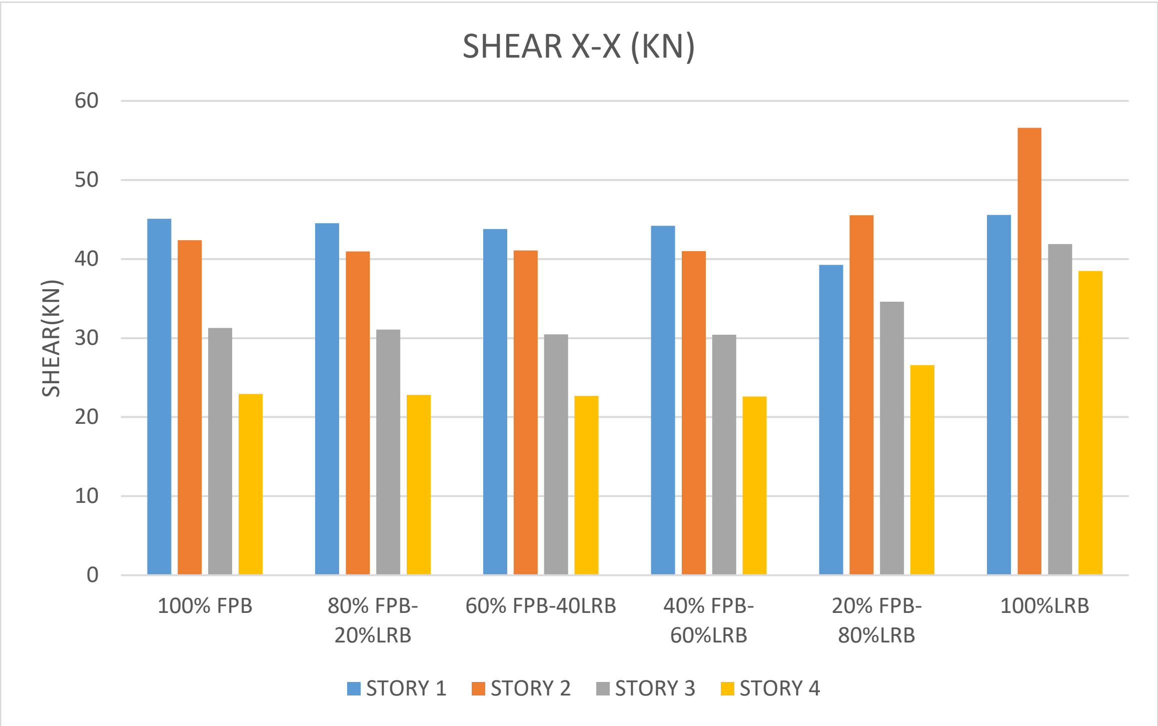


Fig 5.11 Shear at each story in X axis at different cases of isolator

In Y-axis

	100% FPB	80% FPB-20%LRB	60% FPB-40LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
STORY 1	67.23	67.37	67.1	66.51	65.17	52.05
STORY 2	56.69	58.26	58	57.36	55.81	48.08
STORY 3	44.7	46.15	46.03	45.685	44.43	32.74
STORY 4	25.35	24.47	24.5	24.59	24.71	25.54

Table 5.6 Shear at each story in Y axis at different cases of isolator in KN

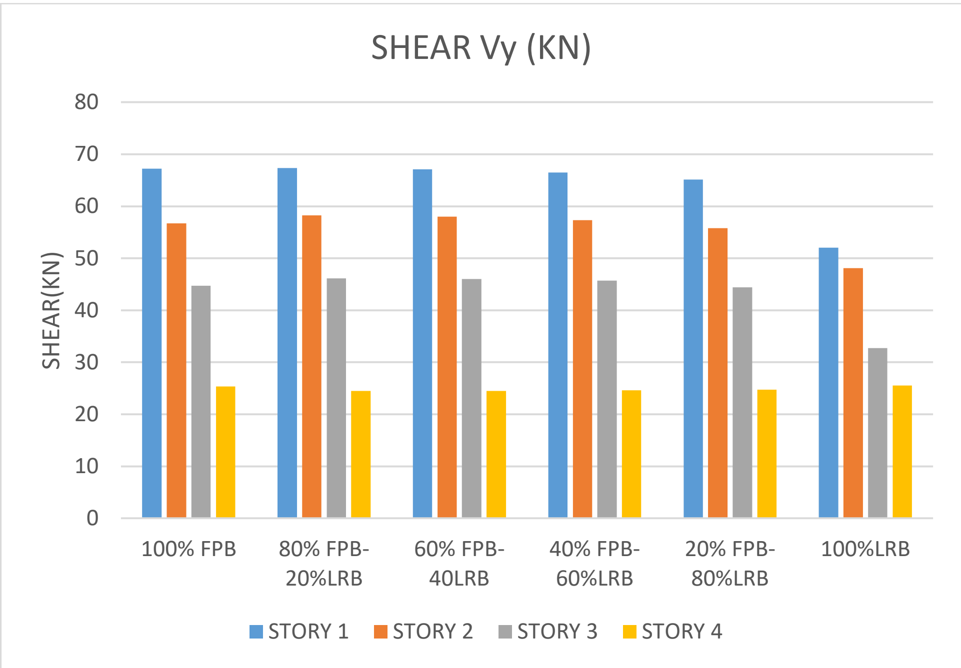


Fig 5.12 Shear at each story in Y axis at different cases of isolator

MODEL PERIOD

	100% FPB	80% FPB-20%LRB	60% FPB-40LRB	40% FPB-60%LRB	20% FPB-80%LRB	100%LRB
MODE 1	4.453	4.449	4.451	4.455	4.46	4.9632
MODE 2	3.496	3.492	3.4969	3.53	3.665	4.1183
MODE 3	3.32	3.321	3.3293	3.3454	3.55	3.9161
MODE 4	0.975	0.9731	0.9731	0.9733	0.9738	0.9912
MODE 5	0.807	0.806	0.805	0.8057	0.813	0.8448
MODE 6	0.771	0.7706	0.7704	0.772	0.7731	0.8075
MODE 7	0.498	0.4987	0.4987	0.4987	0.4988	0.5068
MODE 8	0.382	0.3826	0.3828	0.3838	0.3881	0.4155
MODE 9	0.375	0.376	0.3762	0.3765	0.3771	0.407
MODE 10	0.346	0.3461	0.3461	0.3461	0.3461	0.3833
MODE 11	0.289	0.288	0.2857	0.277	0.2566	0.3428
MODE 12	0.278	0.2776	0.2664	0.2475	0.2471	0.329

Table 5.7 Modal period for different conditions of isolator in sec

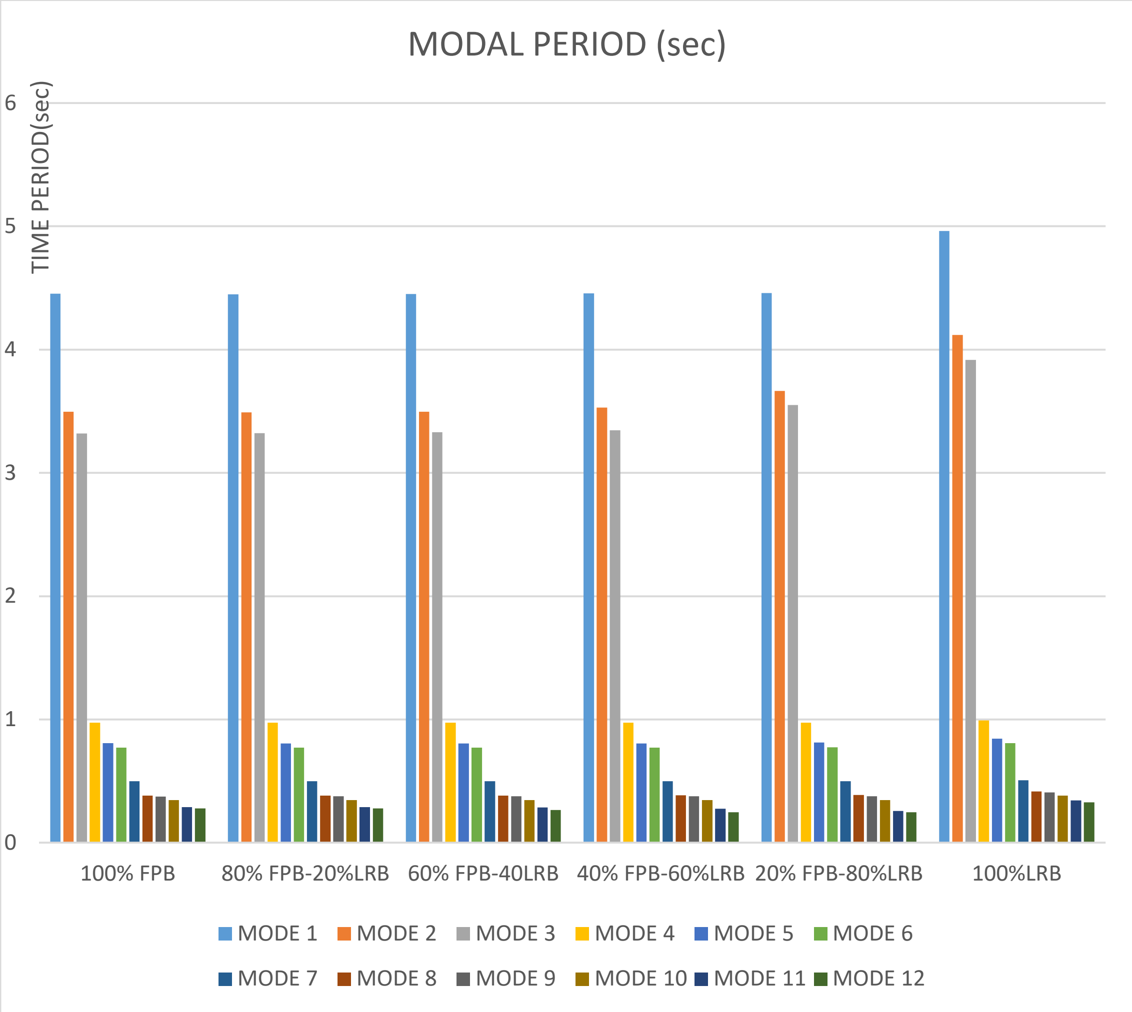


Fig 5.13 Model period at different cases of isolator

Chapter-6

RESULTS AND CONCLUSION

6.1 Following are the results of the experiment:

1. **Modal period-** In the RC frame having fixed base the max time period is of 2.6719 where as in isolation cases (a) LRB –the time period is 4.9632 and (b) FPB- the time period is 4.453 in both cases of isolation the time period is greater than the fixed base time period by 46.17% and 40%.

2. **Displacement-** in x axis the displacement is zero at the base of fixed base and also at the base of FPB whereas the only displacement at the base is in the LRB isolator which is 2.585mm. It is observed that the fixed base is always having less displacement than the isolator case in each story.

   In y axis the displacement is also zero at the base of fixed base and at the base of FPB whereas the displacement at the base is in the LRB isolator which is 3.06mm. Yet again it is observed that the fixed base is having low displacement from the isolator cases.

   Hence it is proved that when the stiffness of the building increases the time period and displacement increases.

3. **Drift-** in x axis the drift in the isolator case are very high from the fixed base in the 1st story as drift is lateral displacement with respect to the floor below so the drift are high in the isolator case. The same can be said about the y axis. From the second story the drift reduces rapidly in isolator so in the fixed base drift is more. We also observed that the drift in fixed base is a kind of straight line where as in isolator case drift starts decreasing from the 1st story and decreases till the 4th story in which the decrease from 1st to 2nd story is rapid and from 2nd to 4th is just like a straight line with a downward slope.

4. **Shear-** In x and y axis the shear is maximum in fixed base which is 104.76KN where as in isolator case the shear is 45.5KN in FPB case and 52.47KN in LRB case which shows the shear decreases after the use of isolator.

To safeguard a structure from earthquake the structure should have more time period, more displacement and less shear. All of these conditions are fulfilled by the use of isolator weather it is LRB or FPB isolator in comparison to fixed base. It’s enough to prove that isolator are better for the structure to safeguard it from the earthquake.

6.2 Parametric study result

1. **Displacement**- In x axis the displacement at the base is zero while using 100%FPB while the percentage of LRB is increasing the displacement at the base is also increasing. 100%LRB is having maximum displacement which is 2.585mm

   In y axis the displacement at the base is zero while using 100%FPB and 80%FPB-20%LRB. The displacement value starts from the case of 60%FPB-40%LRB which is 0.113mm at base whereas 100%LRB have the maximum displacement at base which is 3.06mm.

2. **Drift**- in x axis the drift is maximum in 20%FPB-80%LRB and in 100%LRB of 1st story. It seems like drift is decreasing as the percentage of FPB is increasing whereas in y axis drift is almost equal in each case

3. **Modal period**- it is easily seen that almost all the cases have time period of 4.4XX sec like 100%FPB, 80% FPB-20%LRB, 60% FPB-40LRB, 40% FPB-60%LRB, 20% FPB-80%LRB whereas in 100%LRB the time period is 4.9632 which is maximum among all and 80%FPB-20%LRB is having the minimum time period which is 4.449sec.

4. **Shear**- The 100%LRB is having maximum shear of 52.47KN and 60%FPB-40%LRB is having minimum shear of 43.79KN which is 16.5% less than 100%LRB condition.

   In parametric study between two isolators having six different cases we get to know that mainly 100%LRB is better than other cases like it provides highest time period, displacement and drift too whereas in shear its only 16% less effective than the 60%FPB-40%LRB. So overall 100%LRB provides with better results than any other case.

6.3 CONCLUSION

Base isolation is very reliable and useful, can save many multistory buildings when used. Base isolation approach is to increase the time period of the structure and it also increases flexibility which is given by base isolator which are Lead Rubber Bearing and Friction Pendulum Bearing.

1. In this analytical study it observed the better condition for the building or the structure is the base isolation condition in comparison with fixed base as the isolated condition has more time period.

2. The displacement of first story is also more and the drift of the story too. The fixed base was having almost straight flat line for drift where as in the isolated condition in 1st story drift is more in both isolator case but by in 2nd story the drift is less drift value of isolator.

3. In shear the fixed base experiences more shear then isolated cases.

So this shows isolator condition is better than fixed base.

In parametric study it was attempted to find the best optimum condition using Lead Rubber Bearing and Friction Pendulum Bearing isolator in difference of 20% in each case which were 100%FPB, 80%FPB-20%LRB, 60%FPB- 40%LRB, 40%FPB-60%LRB, 20%FPB-80%LRB, 100%LRB but the results showed 100%LRB is still better than 100%FPB in many cases like Modal Period, Displacement and drift too

1. In case of shear Friction Pendulum Bearing is better than Lead Rubber Bearing which is the only case whereas 80%LRB- 20%FPB is also effective as the results of it is near around the 100%LRB case and in shear case it had low shear than 100%LRB,

2. In modal period 100%LRB beats all other cases as it provided almost 5sec time period to the structure whereas all other cases have a time period of 4.4 or 4.5 second.

3. In displacement and drift 100%LRB give the best results.

The overall result of the analysis is that the 100% Lead Rubber Bearing is most effective and reliable for the structure on the bases of Modal Period, Displacement, Drift and Shear after comparative and parametric study.

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APPENDIX-I

Mathematical Calculation of lead rubber bearing and Friction Pendulum System

Lead Rubber Bearing Isolator

Max vertical load on isolator = 2179.52 KN

Time period = 2.67s

Bearing Effective Stiffness = 1276.93 KN/m

$$K_{eff} = \frac{W}{g} * (\frac{2\pi}{T_D})^2$$

W = 2179.52 KN

g = 9.81m/s^2

Td = 2.67sec

π = 3.14

Energy dissipiated per cycle = 47.19 KN-m

$$W_D = 2\pi K_{eff} {D_D}^2 \beta_{eff}$$

Beff = 0.05

Do = 0.35

Keff = 1276.93

Force at Design Displacement = 33.7 KN

$$Q = \frac{W_D}{4D_D}$$

WD = 47.19

DD = 0.35

Pre Yield in Rubber, K2 = 1130.64429 KN/m

$$K_2 = K_{eff} - \frac{Q}{D_D}$$

Yield Displacement = 0.0033 m

$$D_Y = \frac{Q}{K_2 - K_1}$$

Yield Strength = 37.43KN

$$F_Y - Q + (K_2 * D_Y)$$

Friction Pendulum System

Maximum Vertical Load Column Support = 2179.52

Design time period = 2.67sec

Shear modulus = 0.7

Effective damping = 0.05 or 5%

Keff = 12036.39 KN/m

$$K_{eff} = 10 * \frac{W}{g} * (\frac{2\pi}{T_D})^2$$

Energy dissipated per cycle, WD = 178.2KN-m

$$W_D = 2\pi K_{eff} {D_D}^2 \beta_{eff}$$

Force at Design Displacement or Characteristic Strength = 205.11

$$Q = \frac{W_D}{4D_D}$$

Pre Yield in Rubber, K2 = 11092

$$K_2 = K_{eff} - \frac{Q}{D_D}$$

Post Yield Stiffness = 110920 KN/m

$$K_1 = \frac{K_2}{n}$$

Yield Displacement = 0.002 m

$$D_Y = \frac{Q}{K_2 - K_1}$$

Yield Strength = 228 KN

$$F_Y = Q + (K_2 * D_Y)$$

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