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Performance Evaluation Of High Rise RCC Structure with Considering Sliding Isolation System

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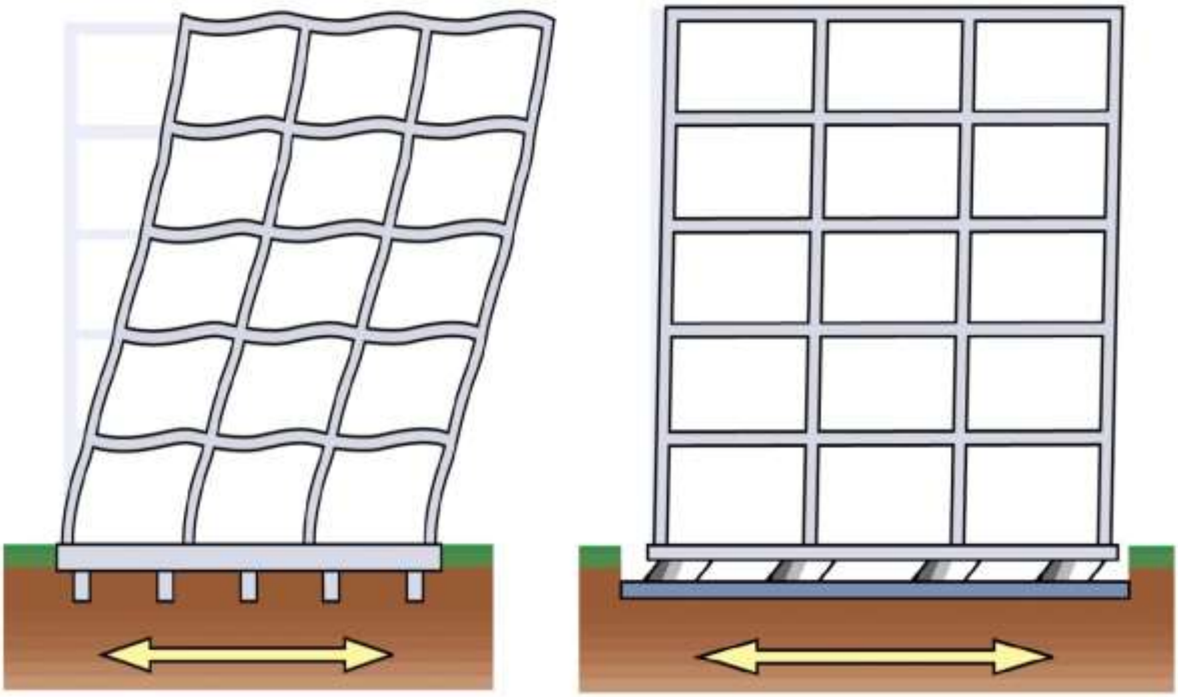
***Abstract**:* The application of the base isolation techniques to protect structures against damage from earthquake attacks has been considered as one of the most effective approaches and has gained increasing acceptance during the last two decades. This is because base isolation limits the effects of the earthquake attack, a flexible base largely decoupling the structure from the ground motion, and the structural response accelerations are usually less than the ground acceleration. Seismic isolation is being used worldwide to protect the structures like buildings, bridges etc. from the destructive effects of earthquakes. In base isolation the base becomes horizontally flexible, which strengthen the structure against earthquakes. There are so many factors and suitability explained for application of base isolation techniques. The conventional technique for a seismic design of structures is to strengthen the structural members in order to protect them against strong earthquakes. The special techniques to minimize inter story drifts and floor accelerations are increasingly being adopted. Base isolation is a design methodology that serves to decouple a structure from the strong ground motions caused by earthquakes. This decoupling of the structure typically occurs at the ground level, between the super-structure and the foundation. Base isolation is to prevent the superstructure of the building from absorbing the earthquake energy. In seismic isolation, the fundamental aim is to reduce substantially the transmission of the earthquake forces and energy into the structure. This is achieved by mounting the structure on an isolation system with considerable horizontal flexibility so that during an earthquake, when the ground vibrates strongly under the structure, only moderate motions are induced within the structure itself.



Conventional structure **Isolated structure**

Figure 1.1.1: Behavior of Building Structure with Base Isolation System

To protect structures from earthquake damages, the use of base isolation systems have been suggested in contrast to the conventional technique of strengthening the structural members. The main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy containing frequencies of earthquake ground motions. The other purpose of an isolation system is to provide means of energy dissipation and thereby, reducing the transmitted acceleration into the superstructure. Accordingly, by using base isolation devices in the foundations, the structure is essentially uncoupled from the ground motion during earthquakes.

***Keywords*– Base Isolation, Frictional Interferance, Sliding,Damping,Bearing**

INTRODUCTION

To protect structure from earthquake damages, the use of base isolation system have been suggested in contrast to the conventional technique of strengthening the structural members. The main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy containing frequencies of earthquake ground motion. The other purpose of an isolation system is to provide means of energy dissipation & thereby, reducing the transmitted acceleration into the superstructure. Accordingly, by using base isolation devices in the foundations, the structure is essentially in the foundation, the structure is essentially uncoupled from the ground motion during earthquake

A significant amount of recent research in base isolation has focused on the use of frictional element in base isolation to concentrate flexibility of structural system and to add damping to the isolated structure. The most attractive feature of the frictional base isolation system is effective for wide range of frequency input.

LITERATURE REVIEW

R.S.Jangid studied the optimum friction coefficient of a sliding system with a restoring force for the minimum acceleration response of a base-isolated structure under earthquake ground motion is investigated. The stochastic model of El-Centro 1940 earthquake which preserves the non-stationary evolution of amplitude and frequency content of the original record is used for the model of earthquake. The base-isolated structure consists of a linear flexible multi-storey structure supported on the sliding system. The sliding system is modelled to provide a friction force and a linear restoring force. The non-stationary stochastic response of the isolated structure is obtained using the time dependent equivalent linearisation technique as the force-deformation behaviour of the sliding system is highly non-linear. The response of the system is analysed for the optimum friction coefficient of the sliding base isolation system. The criterion selected for optimality is the minimisation of the root mean square top floor absolute acceleration. The optimum friction coefficient of sliding isolation system is obtained under important parametric variations such as: period and damping of the superstructure, ratio of the base mass to the superstructure floor mass, the damping ratio of the isolation system, the period of base isolation system and the intensity of earthquake excitation. It has been shown that the above parameters have significant effects on optimum friction coefficient of the of the sliding base isolation system.

Maria Qing Feng, Masanobu Shinozuka, ShunjiFujii studied the friction-controllable sliding base isolation system. To overcome the problems associated with conventional passive sliding isolation systems that have hindered their practical effectiveness, a hybrid sliding base isolation system is developed using friction-controllable bearings. This innovative hybrid system uses a variable friction force that is computer controlled by changing the pressure in the fluid chamber of the bearing. The variable friction force makes the sliding isolation system more effective in controlling the structural response under earthquakes with a broad range of intensity. A prototype hybrid sliding isolation system is physically developed and tested on a shaking table using a structural model equipped with this system. Control algorithms specially developed for controlling the frictional force that has an inherent nonlinear feature are used in this study, and their effectiveness is verified. Simulation of structural response under passive or hybrid control technique shows good agreement with the experimental results.

The base isolation systems currently under implementation can be mainly classified as elastomeric bearing systems and sliding systems. The elastomeric bearings provide the most straightforward method of seismic isolation. With its horizontal flexibility, the elastomeric bearings provide protection against earthquakes by shifting the fundamental frequency of structural vibration to a much lower value and away from the frequency range where the most energy of the earthquake ground motion exists. The sliding isolation, in contrast to elastomeric isolation, has the following dynamic characteristics: A structure supported entirely by sliding bearings experiences forces at the sliding interface that are always bounded by the frictional force, regardless of the intensity and frequency content of the ground excitation. However, a freely sliding structure might produce large sliding displace-ment, and induce some residual displacement after each earthquake. In some cases, the sliding displacement might become unacceptably large. A number of studies have been performed to reduce the displacement, especially the residual displacement, through the use of recentering devices. In fact, several sliding isolation systems with such devices have been developed. The most notable of these systems are the Friction Pendulum System (FPS) (Zayas et al. 1987), the TAISEI's Shake Suppression (TASS) system (Kawamura et al. 1988) and the Resilient-Friction Base Isolator (R-FBI) system (Mostaghel and Khodaverdian 1987). Each of these systems provides a unique recentering capability.

Satish Nagarajaiah, Micheal Riley, Andrei Reinhorn studied the hybrid control of bridges using sliding bearings, with recentering springs, in parallel with servohydraulic actuators. A new control algorithm with absolute acceleration feedback, based on instantaneous optimal control laws, is developed. The developed control algorithm is implemented in a shake-table study of an actively controlled sliding-isolated bridge. The objective of implementing the hybrid system is to evaluate its advantages in addition to those due to the passive sliding system. The experimental system used in the shake-table test is described and the results of the experiments are presented. It is shown that substantial reduction of response acceleration is possible, using hybrid control, while confining the sliding displacement within an acceptable range, and eliminating almost completely post earthquake permanent offsets.

Sliding-isolation systems in bridges reduce the deck response acceleration and limit the damage to piers supporting the bridge deck. However, in the event of large earthquakes larger forces can be transferred, due to excessive sliding displacements, engagement of displacement restraints, and due to permanent offsets. One of the ways to effectively tackle these issues is to use combined active and passive control systems, referred to as hybrid control systems.

Glenn J. Madden, Michael D. Symans, & Nat Wongprasert Studied the ability of an adaptive seismic isolation system to protect structures subjected to disparate earthquake ground motions. The isolation system consists of sliding isolation bearings in combination with an adaptive hydraulic damper. The damping capacity of the hydraulic damper can be modified in real time to respond to the effects that the earthquake ground motion has on the structure. An experimental laboratory implementation of the adaptive isolation system within a scale-model building structure is described. Analytical models of the isolation system components and the test structure are developed and calibrated through experimental system identification tests. Results from experimental shaking table tests are then used to validate the results from numerical simulations which utilized the analytical models. Although the adaptive base-isolation system results in a complex nonlinear dynamic system, the analytical predictions agreed reasonably well with the experimental test data. The experimental and analytical results demonstrate that, for both near-field and far-field earthquake ground motions, an adaptive sliding base isolation system is capable of reducing the interstory drift response of structures while simultaneously limiting the displacement response of the isolation system.

M.K.Shrimali, R.S.Jangid Studied the response of liquid storage tanks isolated by the sliding systems is investigated under two horizontal components of real earthquake ground motion. The continuous liquid mass is lumped as convective mass, impulsive mass and rigid mass. The corresponding stiffness associated with these lumped masses is calculated depending upon the properties of the tank wall and liquid mass. The governing equations of motion of the tank with a sliding system are derived and solved by Newmark's step-by-step method with iterations. The frictional forces mobilized at the interface of the sliding system are assumed to be velocity dependent and their interaction in two horizontal directions is duly considered. A parametric study is also conducted to study the effects of important system parameters on the effectiveness of seismic isolation of the liquid storage tanks. The various parameters considered are (i) the period of isolation (ii) the damping of isolation bearings and (iii) the coefficient of friction of sliding bearings. It has been found that the bi-directional interaction of frictional forces has noticeable effects and if these effects are ignored then the sliding base displacements will be underestimated which can be crucial from the design point of view. Further, the dependence of the friction coefficient on relative velocity of the sliding bearings has no significant effects on the peak response of the isolated liquid storage tanks.

Touraj Taghikhany Studied the Seismic isolation is one of the effective methods to protect equipments. It helps to control seismic response accelerations in equipment below its allowable level. Among different types of isolation systems, the combination of restoring spring and slider, also called as resilient sliding isolation (RSI) system, is the one which has been effectively used for protection of equipment. Principal design parameters for this type of isolation system are stiffness of spring and friction coefficient of slider. There may be number of combinations of these design parameters which can enable the isolated equipment to remain functional during and after the predicted seismic event. The optimum design of RSI can be considered as the one which maintains the response acceleration in the equipment below its allowable limit and at the same time keeps the relative displacement between floor and the equipment to the minimum. This study deals with optimum design of resilient sliders. First the RSI system is modeled analytically and accuracy of the model is then validated by shaking table tests. The validated model is used to determine optimum design parameters for different levels of allowable accelerations. Results show that the optimum period decreases and the optimum friction coefficient increases with higher allowable acceleration.

RESEARCH METHODOLOGY

The proposed work is planned to be carried out in the following manner

1. Introductory information on Base Isolation system and their various property as introduced to the structures. It covers Need, objective of this study.

2. Detailed literature review of various methods for the convectional base isolation and sliding isolation system
3. Seismic evaluation methods and computational modeling of RCC buildings using ETABS. It describes in detail the modeling of fixed based, using base isolation such as rubber isolator and friction isolators is applied at base of the building. Detailed procedure of nonlinear time history analysis explained.
4. Results and discussion the results obtained from nonlinear dynamic time
History analysis based on the natural ground motions.
5. Conclusions and future scope of work.

Energy dissipation-adding damping

Damping is the characteristics of a structural system that opposes motion and tends to return the system to rest when it is disturbed. For isolation system, damping is generally categorized as viscous (velocity dependent) or hysteretic (displacement dependent). Whereas the Period shifts usually decreases acceleration but increases displacement. Damping almost decreases both acceleration and displacement. Behavior of structure during earthquake is shown in Figure 3.2.1.1

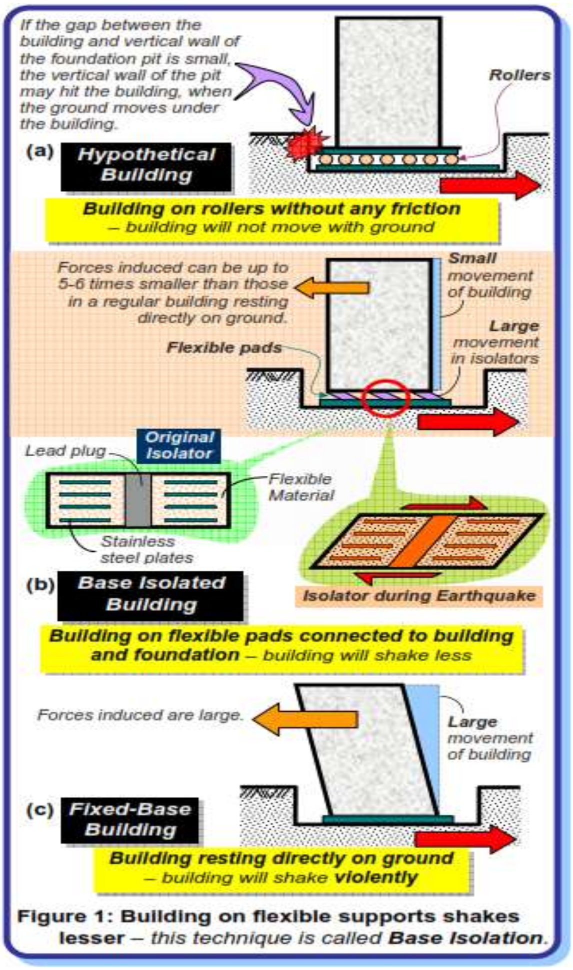


Figure 3.2.1.1: Behaviour of Structure During Earthquake

Design Consideration

A number of factor need to consider by an engineer, architect or owner to decide on seismic isolation for a project. Among the foremost is the evaluation of seismic hazards, which includes local geology, proximity to faults, soil conditions, characteristics of possible earthquake such as period and severity. Subsequently, performance levels for different intensities of earthquakes need to be evaluated. Since the isolator carry large vertical loads and below the isolator need to be designed appropriately. Plane of isolation may be chosen based on the practical aspect of installation and relative strength of super and sub structure components.

For the isolation system to work properly, the structure should be free to move in any direction up the maximum specified displacement. Typically a seismic moat is provided around the structure to allow this movement. It is imperative that owners and occupiers of seismically isolated structure are aware of the functional importance of seismic gap and the need for this space to be left clear. To maintain the functional purpose of the structure after a seismic event, all the utilities, electrical connection and waste pipelines should be designed to accommodate the maximum seismic displacement. The main connection between the building and the ground, such as stair, entryways and elevators need to be unconnected across the isolation plane. In general, all the interaction between the structure and the ground need to be designed and detailed.

Base isolation techniques

Successful seismic isolation of a particular structure is strongly dependent on the appropriate choice of the isolation system. The isolation system should essentially be

i. Able to support the structure
ii. Provide horizontal flexibility
iii. Able to dissipate energy

These three functions could be concentrated into single device or could be provided by means of different components. In addition to these basic requirements, it is desirable that isolation system should be rigid for low lateral loads so as to avoid perceptible vibration during frequent minor earthquake or wind loads. Different types of devices have been developed to achieve these properties. Brief reviews of the development of some isolation system are discussed here.

Presently earthquake protective techniques are mainly categorized into three types

1) Passive Protective System
2) Hybrid Protective System
3) Active Protective System

3.4 Type of Base-Isolators

The concept of seismic base isolation has been in use for the last several decades, the technology is mature and there exists a variety of base isolation devices. The devices can be divided into two major groups; elastomeric systems and sliding systems. Both isolation systems have some inherent damping and both are employed to shift the fundamental building frequency beyond the range of earthquake excitation, these reducing the acceleration and reducing the corresponding lateral inertia force. The devices of both groups are defined by a particular set of characteristics such as stiffness and corresponding service load deformation, yield strength and maximum displacements under extreme earthquake loads, residual displacement and ability to return to initial position, vertical stiffness etc.

3.4.1 Elastomeric bearings

Elastomeric devices are characterized by their name as they source their effectiveness from being composed of elastomeric material. Their main advantage is their resilience. The common elastomeric devices include natural rubber bearings, lead rubber bearings and high density natural rubber bearings. The details of the aforementioned devices will be discussed in this section.

3.4.1.1 Natural rubber bearings

Natural rubber bearings, also known as laminated rubber bearings are manufactured of their natural rubber or neoprene, synthetic rubber material employed of its toughness and durability, which has behavior similar to natural rubber.

Natural rubber bearings are comprised of the alternating rubber and steel shim layers. These layers are joined together by means of the vulcanization process under pressure and heat to produce a composite bearing. Steel shims add vertical stiffness to the bearings and hence prevent the rocking response of an isolated structure. In addition steel shims prevent rubber from bulging out under high axial compressive loads. The shims have no effect on lateral stiffness of bearings as it is controlled by loads. The shims have no effect on lateral stiffness of bearings as it is controlled by the shear modulus of the elastic material. The bearings are mounted between two thick endplates to facilitate the connection between the foundations and the isolation mat. The primary drawbacks of natural rubber bearings are low damping and inability to handle service wind loads due to low stiffness. Normally natural rubber bearings exhibit 2-3% of critical damping. Damping Characteristics can be increased by changing the properties of elastomeric material but normally, natural rubber bearing support system requires additional damping devices, such as viscous or hysteretic damper to deal with service and extreme seismic loads. However, natural rubber bearing are easy to install and manufacture. Their behavior can also be easily modeled analyzed and hence designed. The effects of creep, stiffness deterioration over time are small because natural rubber and neoprene are known to have a consistent shear modulus over time.

3.4.1.2 Lead rubber bearings

In comparison to natural rubber bearings, lead rubber bearings have a much better capability to provide adequate stiffness for wind loads and better damping characteristics. The lead rubber bearing configuration is the same as that of natural rubber bearings, except there is one or more cylindrical lead plugs in the centre as shown in Figure 3.4.1.2.1 The lead plug in combination with the rubber causes the device to demonstrate bilinear behavior. Under low service wind loads, high stiffness of the lead plug attracts most of the lead and the arrangement shows high stiffness. Under extreme seismic loads lead is deformed plastically and hence the stiffness of the device drops just the stiffness of rubber. In addition, during the Plastic deformation of the lead plug, energy is being dissipated in a hysteretic manner. During extreme events the lead plug experiences the same deformation as rubber but generates heat or dissipates kinetic energy by converting it into heat. Thus, hysteretic behavior of the plug help reduce the energy absorbed by the building. Therefore, lead rubber bearings shows desirable hysteretic damping characteristics, which enhance the structural response of the system. The amount of dissipated energy is a function of maximum bearing displacement. Lead rubber bearing are also easy to install, manufacture, analyze and design.

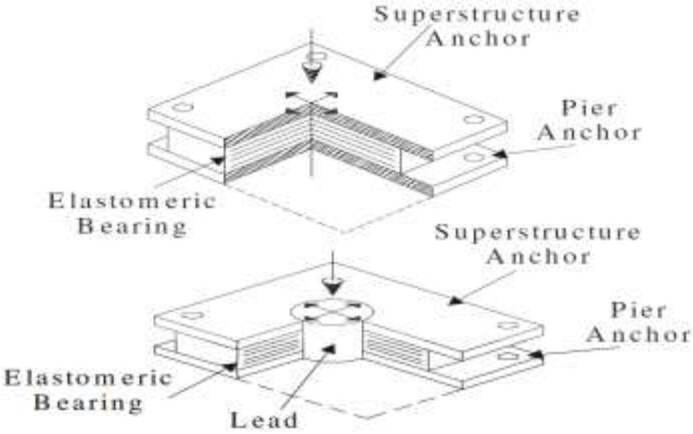


Figure 3.4.1.2.1: Lead Rubber Bearing

3.4.1.3 High density rubber bearings

The use of high density natural rubber bearings eliminates the need for supplementary damping devices. Their composition is similar to that of the natural rubber bearings except for the type of elastomeric material used. The increase in damping is achieved through the addition of fillers such as carbon, oils and resins. The addition of fillers increased the damping to 20-30% of critical damping. At shear strains below 20% the high damping natural rubber bearings exhibit high stiffness and high damping. This behavior is advantageous for limiting deflections under service wind loads. At shear strains between 20 and 120% their shear modulus (and hence stiffness) remains constant and damping decreases. At strains above 120% there is an increase in damping and stiffness. Therefore, such behavior provides sufficient stiffness for service wind loads and also limits deflection and effectively dissipates energy during under extreme earthquake loads. High damping rubber bearings share the advantages with the aforementioned devices with regard to ease of manufacture and implementation. The construction of HDRB is shown in Figure 3.4.1.3.1 The basic function of HDRB is shown in Figure 3.4.1.3.1. The Basic functions of HDRB are as follows:

(1) Vertical load bearing function: Rubber reinforced with steel plates provides stable support for structures. Multilayer construction rather than single layer rubber pads provide better vertical rigidity for supporting a building.

(2) Horizontal elasticity function: With the help of HDRB earthquake vibration is converted to low speed motion. As horizontal stiffness of the multi-layer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased

(3) Restoration function: Horizontal elasticity of HDRB returns the building to its original position. In a HDRB, elasticity mainly comes from restoring force of the rubber layers. After an earthquake this restoring forces returns the building to the original position.

(4) Damping function: Provides required amount of damping up to a higher value.

3.7.1 Ground Motion Characterization

The selection of ground motion record is very important for accurate analysis of building. It is difficult to determine a single parameter that best characterizes earthquake ground motion. The recorded of time histories, even at the same site, shows variations in information. Earthquake ground motion amplitude, duration, frequency and the number of peaks in the time history above certain amplitude are some of the characteristics important for determining structural response and damage. Ground motion amplitude is measured in terms of acceleration, velocity and displacement. The frequency content of an earthquake time history is important in identifying the amount of energy imparted at different frequencies. The strong motion duration of an earthquake time history is the time interval during which most of the energy of that time history contained. Peak ground acceleration (PGA) has frequently been used as a parameter to characterize ground motion. Other parameters included Arias intensity, ratio of PGA to PGV.[7]

3.8 Formulation of Equation of Motion

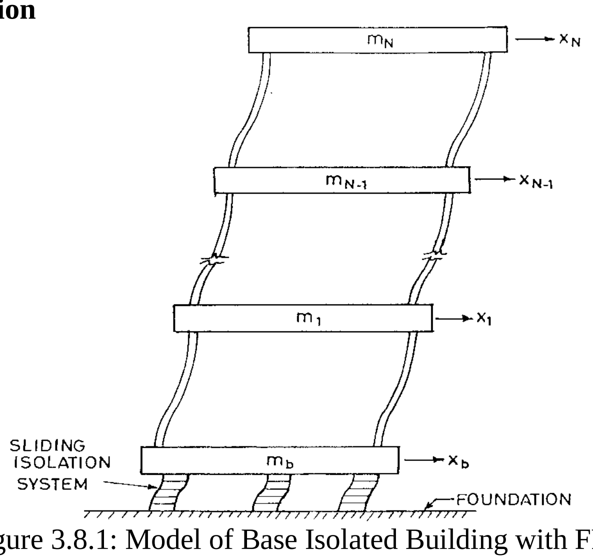


Figure 3.8.1: Model of Base Isolated Building with FPS

The mathematical formulation of multi-degree-of-freedom (MDOF) system with sliding isolation system shown in Figure 3.8.1 has been presented below. The motion consist of two phases: (1) non- sliding or stick phase when the sliding friction resistance at base is not overcome and the structure behave as conventional fixed-base structure, and (2) sliding or slip phase when relative motion across the sliding surface takes place. The overall response consist of series of sliding surfaces takes place. The overall response consists of series of sliding and non-sliding phases following one another.

3.9 Modelling of Isolator in ETAB

A High Density Rubber Bearing is a type of Rubber isolator and Friction Pendulum System is a type comes under Friction isolators. Both type of isolator can be modelled in ETAB software. Both types of isolators are modelled in ETAB by using link element. There is facility of defining link support type as rubber isolator, friction isolator, damper in ETAB program. All the necessary properties of HDRB & FPS were calculated according to procedure given by UBC-97 code in Division IV of Appendix.

3.9.1 Modelling of 3D Regular Building

The four models of building (G+20) storey without strut, (G+20) storey with strut, (G+30) storey without strut and (G+30) storey with strut RCC structure are considered for analysis. Building has plan 24m x 24m as shown in Figure 3.9.2.1 slab is modelled as rigid diaphragm. Building is symmetric with respect to stiffness and mass. Non linear time history analysis is carried out in ETAB software using Bhuj Earthquake records. The Plan is depicted in Figure 3.9.2.1 The elevation of 20-storey with and without strut are shown in Figure 3.9.2.2 and 3.9.2.3 respectively. The elevation of 30-storey with and without strut are shown in Figure 3.9.2.4 and 3.9.2.5 respectively. The ETABS model of building for fixed base, friction isolator and HDRB are also shown in Figure 3.9.1.1, Figure 3.9.1.2, Figure 3.9.1.3 respectively.

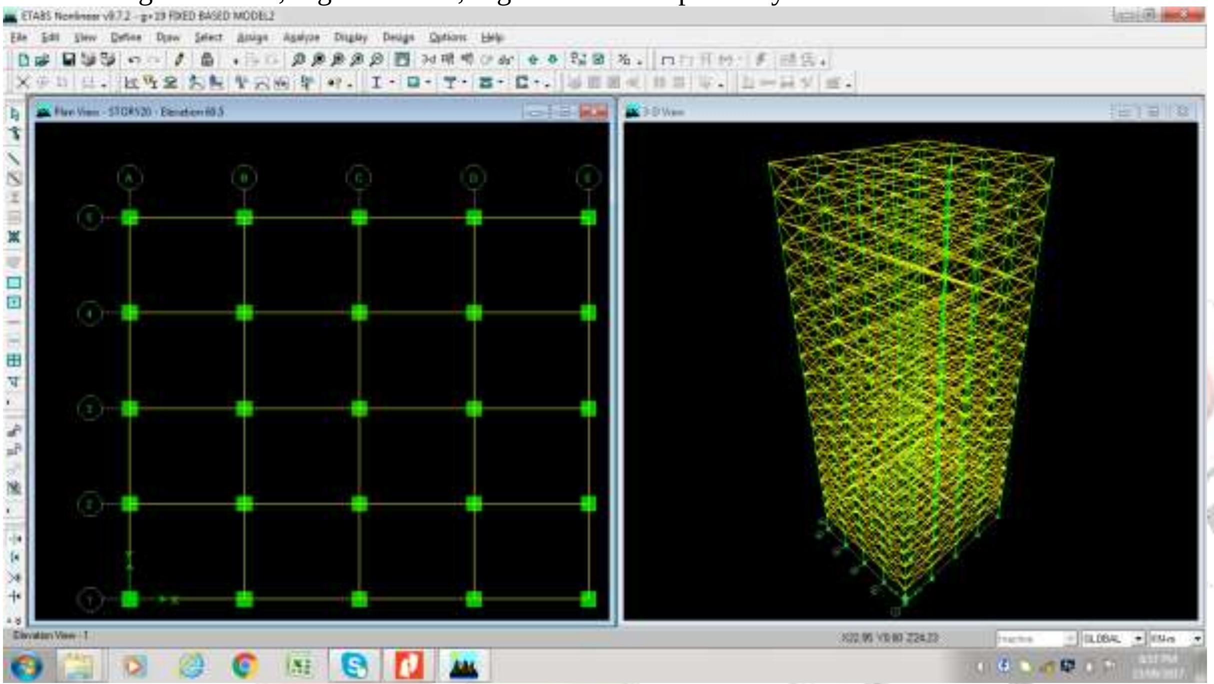


Figure 3.9.1.1: Fixed Base model in ETAB

3.9.2 Model of FPS and HDRB in ETAB

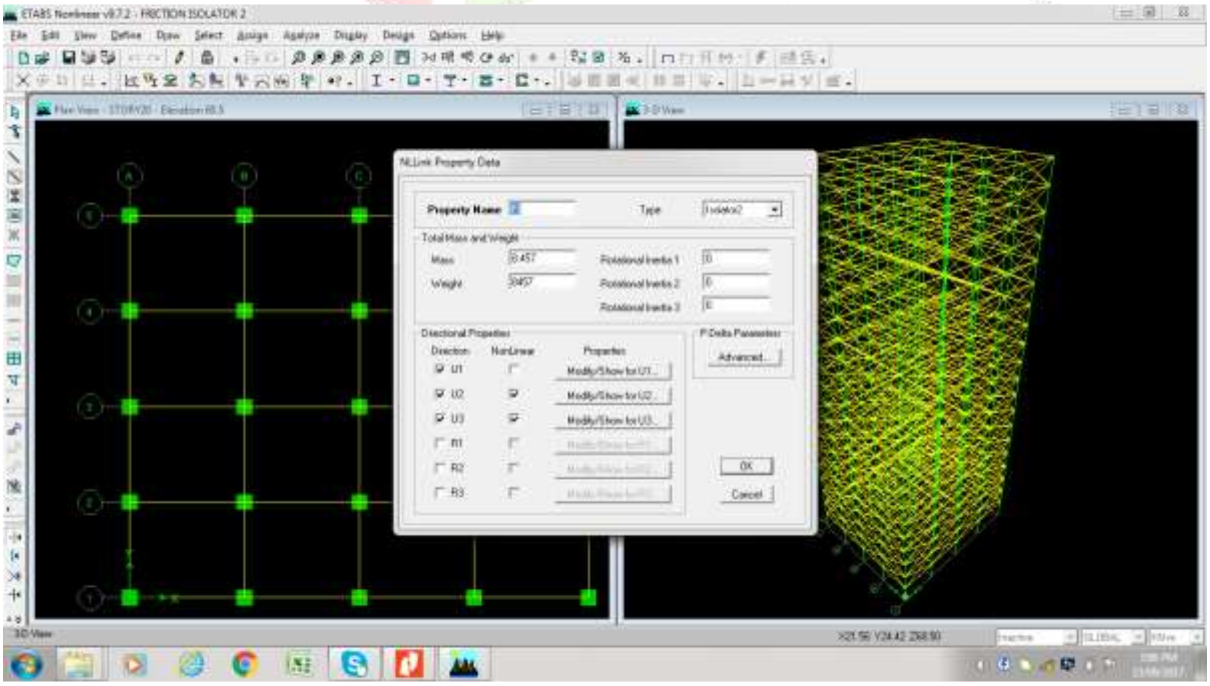


Figure 3.9.1.2: ETAB model for friction isolator

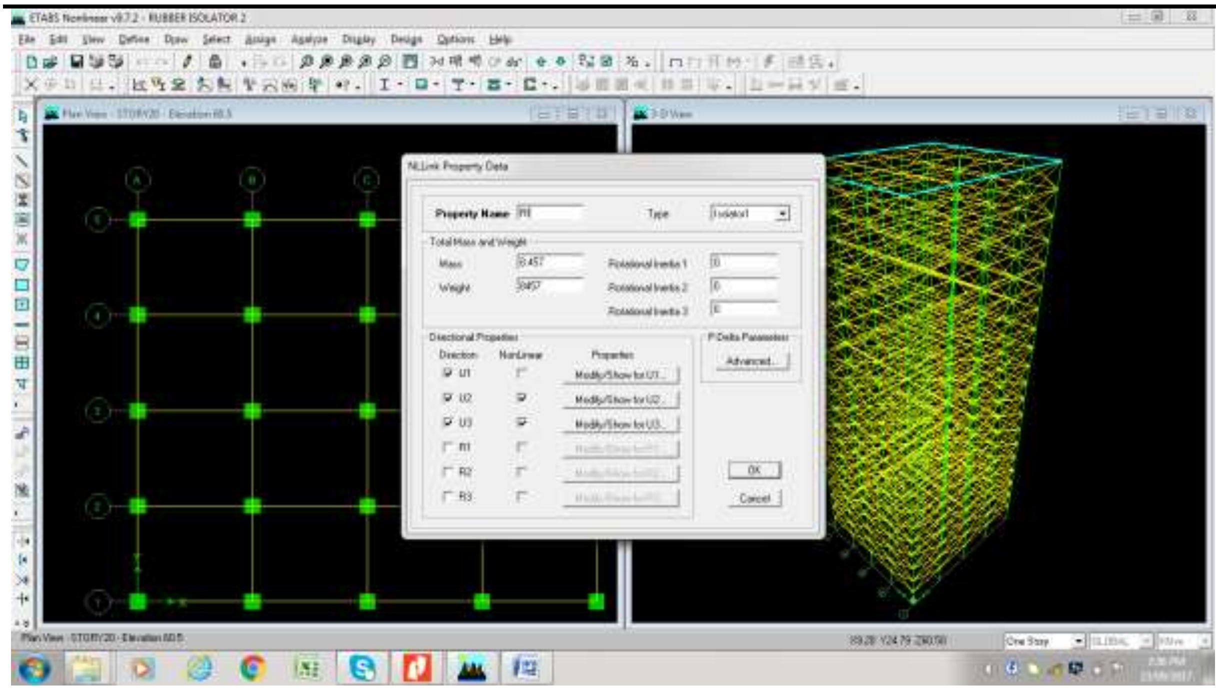


Figure 3.9.1.2: ETAB model for HDRB

3.9.3 Numerical Data

The study is carried out for RCC building in ETAB software using High Density Rubber Bearing (HDRB) & Frictional Pendulum System (FPS) isolators. The numerical data for (G+20) storey without strut, (G+20) storey with strut, (G+30) storey without strut and (G+30) storey with strut RCC buildings are shown in Table 3.9.3.1

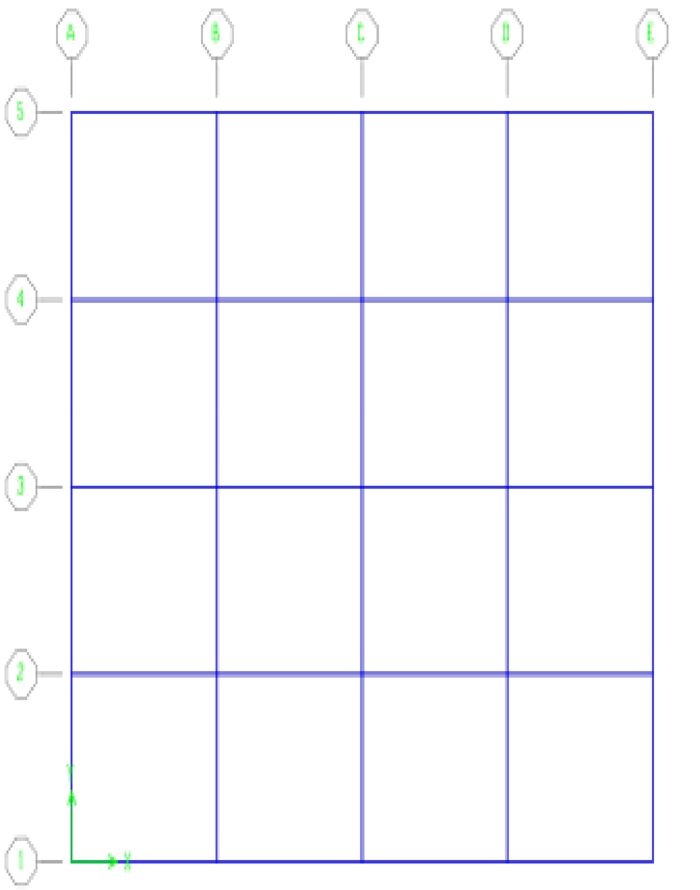


Figure 3.9.3.1: Plan of RCC Building

Table 3.9.3.1: Numerical Data for Ground + 30 Storey RCC Building

Live load	3 kN/m^2
Earthquake Data	Bhuj Earthquake ground motion 1.078g
Depth of foundation below GL	1.5 m (consider as fixed)
Storey height	3.5 m of ground storey& 3 m for other storey
Size of Beam	0.25m x 0.5m
Size of Column Ground to 4th storey	1.2m x 1.2m
Size of Column 5th to 9thstorey	1.0m x 1.0m
Size of Column 10th to 20th and 21st to 30th storey	0.75m x 0.75m
Wall	250 mm thick RCC wall
Slab	130 mm thick as rigid diaphragm
Material Properties	Concrete- M20 HYSD reinforcement of grade Fe 415, Steel strut - X type bracing using IAS 150 x 150 x 6 mm

Figure 3.9.3.2 Elevation of 20 - Storey building without strut

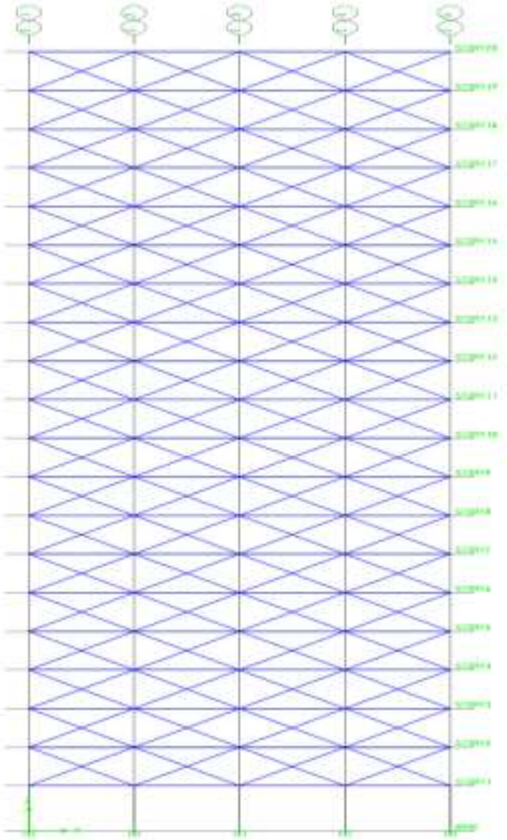
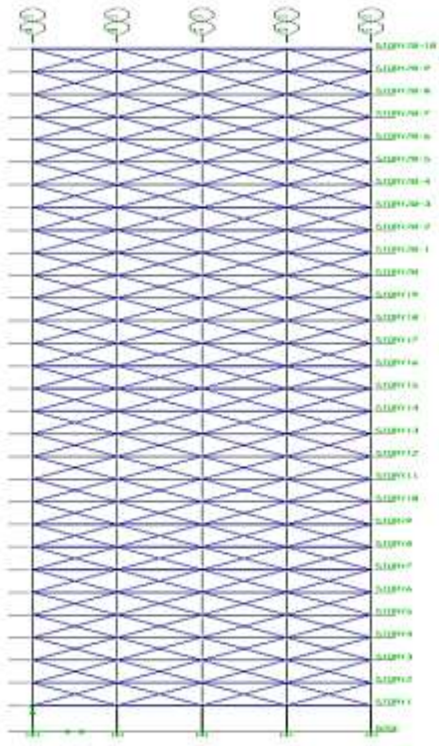


Figure 3.9.3.3 Elevation of 20 - Storey building with strut

Figure 3.9.3.4 Elevation of 30 - Storey building without strut



3.9.3.5 Elevation of 30 - Storey building with strut

3.9.4 Properties of HDRB & FPS

As design example we consider a G+5, G+8 & G+12 storey structures. Which designing the High Damping Rubber Bearing & Friction Pendulum System, we consider the site to be situated in zone 4 with S_D soil type and assumed that site is not less than 15 km from known active fault.

Using UBC-97 Appendix Chapter 16 requirements, the parameter associated with location are Z-0.4, Soil type - S_D, N-1. The structural system can be taken as special moment resisting frame. The properties required for the modelling of structures with base isolation in ETAB software for both High Density Rubber Bearing and Friction Pendulum System for (G+20) storey without strut, (G+20) storey with strut, (G+30) storey without strut and (G+30) storey with strut RCC structure are shown in Tables 3.9.4.1, 3.9.4.2, 3.9.4.3 and 3.9.4.4 respectively.

Table 3.9.4.1: Properties of Isolators for (G+20) storey structure without strut

Types	HDRB	FPS
Vertical Stiffness (U1)	2855317.347 KN/m	29000000 KN/m
Linear Stiffness (U2 & U3)	2379.40 KN/m	1450 KN/m
Non-linear Stiffness (U2 & U3)	2005.637 KN/m	29000 KN/m
Yield Strength (Q)	193.50 KN	-
Damping (β)	0.10	0.10
Radius of dish (R)	-	3.645 m
Friction Coefficient, Fast	-	0.05
Friction Coefficient, Slow	-	0.03

Table 3.9.4.2: Properties of Isolators for (G+20) storey structure with strut

Types	HDRB	FPS
Vertical Stiffness (U1)	6031857.895 KN/m	61000000 KN/m
Linear Stiffness (U2 & U3)	5869.15 KN/m	3050 KN/m
Non-linear Stiffness (U2 & U3)	4961.59 KN/m	61000 KN/m
Yield Strength (Q)	297.93 KN	-
Damping (β)	0.10	0.10
Radius of dish (R)	-	1.464 m
Friction Coefficient, Fast	-	0.05
Friction Coefficient, Slow	-	0.03

Table 3.9.4.3: Properties of Isolators for (G+30) storey structure without strut

Types	HDRB	FPS
Vertical Stiffness (U1)	4093046.42 KN/m	41000000 KN/m
Linear Stiffness (U2 & U3)	3611.46 KN/m	2050 KN/m
Non-linear Stiffness (U2 & U3)	3057.46 KN/m	35000 KN/m
Yield Strength (Q)	266.29 KN	-
Damping (β)	0.10	0.10
Radius of dish (R)	-	3.14 m
Friction Coefficient, Fast	-	0.05
Friction Coefficient, Slow	-	0.03

Table 3.9.4.4: Properties of Isolators for (G+20) storey structure with strut

Types	HDRB	FPS
Vertical Stiffness (U1)	2855317.347 KN/m	29000000 KN/m
Linear Stiffness (U2 & U3)	2379.40 KN/m	1450 KN/m
Non-linear Stiffness (U2 & U3)	2005.637 KN/m	29000 KN/m
Yield Strength (Q)	193.50 KN	-
Damping (β)	0.10	0.10
Radius of dish (R)	-	3.645 m
Friction Coefficient, Fast	-	0.05
Friction Coefficient, Slow	-	0.03

RESULTS AND DISCUSSION

Comparative study of isolation systems.

To access the performance of multi-storeyed reinforced concrete structure with different arrangement of base isolator at the base of structure such as Fixed Based, High Density Rubber Bearings (HDRB) and Friction Pendulum System (FPS) type. For this study structure are analyzed with the help of ETAB software and result were compared on key parameters like base shear, storey shear, story displacement, and story drift.

1) Results for comparative study of different isolation system.
   a) Study for (G+20) storey building without strut
      i) Fixed Base (FB)
      ii) High Density Rubber Bearings (HDRB)
      iii) Friction Pendulum System (FPS)
   b) Study for (G+20) storey building with strut
      i) Fixed Base (FB)
      ii) High Density Rubber Bearings (HDRB)
      iii) Friction Pendulum System (FPS)
   c) Study for (G+30) storey building without strut
      i) Fixed Base (FB)
      ii) High Density Rubber Bearings (HDRB)
      iii) Friction Pendulum System (FPS)
   d) Study for (G+30) storey building with strut
      i) Fixed Base (FB)
      ii) High Density Rubber Bearings (HDRB)
      iii) Friction Pendulum System (FPS)

All the analysis was done by nonlinear time history analysis. Type of analysis for all the structure is model nonlinear time history analysis considering Indian Bhuj earthquake ground motion data. The earthquake ground vibration data named Bhuj earthquake occurred at January 26, 2001. This vibration data is recorded at Ahmadabad. It has total 26706 acceleration data point at interval 0.005 sec. The PGA value for Bhuj earthquake is 0.09g.

Conclusions

1. It is concluded that time period of the structure in case of FPS and HDRB it is increased over conventional fixed base structure.
2. It is concluded that base shear of structure reduces by the use of base isolator. But it is greatly reduces by use of FPS over HDRB.
3. It is also concluded that FPS gives maximum base displacement compared to HDRB.
4. Storey drift is reduce by both HDRB and FPS. But it is greatly reduces by the use of FPS.
5. It is seen that base isolation technique lengthens the time period of structure at greater extent for mid rise structure. But, as the number of stories goes on increasing the proportion of increment in time period of base isolated structure goes on decreasing.
6. It is concluded that as the number of storey's increase, the friction pendulum system give minimum value for top displacement. Hence, it is concluded that this type of system helps to minimize top displacement for multi storey structure.
7. It is concluded that Friction Pendulum system helps in reducing storey drift &storey acceleration at greater extent than High Density Rubber Bearing for both mid-Storey and multi-storey structure.
8. Friction pendulum system is beneficial than lead rubber bearing isolator & slightly higher than high density rubber isolator in terms of cost.

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