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Seismic Performance of RCC Multistored Building with Base Isolators

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Abstract
Stability of a structure plays a vital role for economical and human loss during earthquakes, here base isolation is an approach mostly used for protecting structures from seismic forces. Base isolation is a interface system located between a structure and its foundation for the function of decoupling horizontal forces from earthquake ground motions, thereby reduce seismic damage to the structure and its contents. In this study we have designed lead rubber bearing (LRB) and friction pendulum system (FPS) type of isolators for G+9 RCC multistoried building in which modeling of G+9 building is carried out in ETABS 2016 as per IS 1893 (part 1) 2002 as per codal provisions. An equivalent static and time history analysis is done for fixed base, LRB, FPS isolators. Finally this reveals the seismic performance of building with different types of seismic base isolators by comparing the storey displacement, storey shear, storey drift and base shear.

Keywords: *Bearing, Base Isolation, Story Drift, Story Displacement, story shear, Time History.*

1. Introduction

Structures constructed in the recent past have fallen during earthquakes due to inadequate techniques results a major loss of life and property with unforgettable sufferings to survivors of earthquake hit area this compelled engineers and scientists to find out innovative methods to save structures from seismic forces. Base isolation is a innovated technique as early in the year there after different types of base isolators are developed based on type of structure apart from that this development is adopted mainly on American and European countries. Some of public buildings in India are Bhuj, experimental building at IIT guwahati.

Many significant benefits are there for base isolated structures with safe and strong enough in seismic zone areas this technique is done for new as well as existing building by retrofitting. The fixing of base isolation for 3 storied building is modeled in SAP2000 at different levels of building and for a fixed base. Here the seismic response of multistory building is investigated under different levels by earthquake Time history conducted for El-Centro and Northridge earthquakes, from the results obtained base isolation placed between sub and superstructure given suitable results[1]. For earthquake resistant structures the seismic isolation technique is considered from base isolators types like LRB, FPS, HDRB etc are there here LRB is taken as base isolator for seismic analysis by modeling G+10 building in etabs finally the results obtained are the frequency has reduced due to insertion of baseisolatos,time period was increased for isolated structure, displacement has reduced in case of isolated structure[2]. In this paper a new experimental prototype is installed for Earthquake early warning of p-waves and S-waves for base isolation by using a smart mechatronic base isolation technique. It is a fully automated system which the wind and earthquake waves occur the signal transmits EEWS to controller through internet, the actuator, accelerometer provided at sides of structure resist with shear keys provided and base isolation works effectively. finally it is demonstrated that mechatronic isolation reduces the ground responses [3].

In this paper a G+10 multi storied building with specified dimensions and loads are modeled in ETABS.and analysis is carried out under different seismic zones and for each zone area the displacement is analyzed for different load cases by with and without baseisolators after that results obtained are deflection or displacement is reduced with increase in height for base isolated structure[4].In base isolation concept Friction pendulum isolator is a type of base isolator a study of non-linear analysis is carried for RCC G+25 structure in ETABS 2015 in which comparion is done for single, double and triple friction types of bearings the results obtained are the base shear,story displacement,story drift reduction is observed in Triple friction pendulum type of bearing. Hence triple friction pendulum is superior than among the two isolators [5].

2. Methodology

A. Base Isolation

Base isolation Base isolation is an adequate technology for earthquake zone areas and it is widely used in many countries, based on type of structure, conventionally sesimal style of building structures relies on the conception of promoting the resistance capability of the structures against earthquakes by using

A seismal base isolator may be a versatile support of the building, which ought to fulfil the subsequent requirements

- ✓ The material is stiffer under low service loads like wind loads.
- ✓ Period of vibration is increased gradually to reduce the seismic Reponses.
- ✓ It should have the ability to withstand the greater displacement and pulse-type base motions from near-fault earthquakes.
- ✓ It should have a damping system of mechanism such that the relative deflection between the building and the ground is reduced.

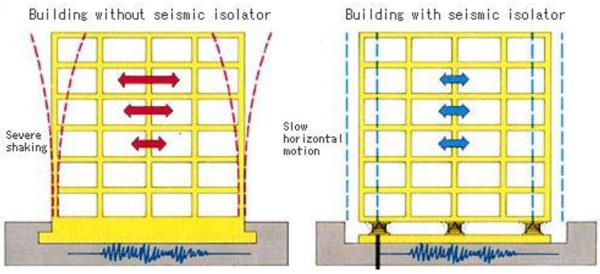

Figure 1. Concept of Base Isolation

B. Types of Base Isolators

The most usual types of base isolators used in buildings are

1. Laminated rubber isolator
2. Lead rubber isolator (LRB)
3. High damping rubber isolator(HDRB)
4. Friction pendulum isolator (FPS)
5. Single friction type
6. Double friction type
7. Triple friction type

C. Lead Rubber Bearing(LRB)

It was invented in the year 1975 in newzealand the elements of lead rubber bearing are top and bottom plates, inner shim plates, lead core gives high stiffness for more flexibility.

Some structures in india with base isolation are

- World Bank,Delhi 1998
- Dwarka Hospital Delhi 2006
- Gtb Hospital Delhi 2008
- Bhuji Hospital Gujarat

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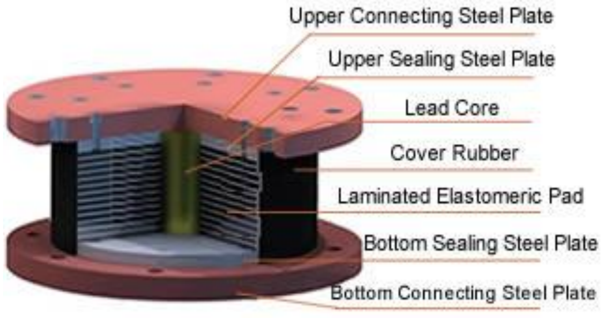

Figure 2. Lead Rubber Bearing(LRB)

D. Friction pendulum system(FPS)

Friction pendulum bearings are modern sliding based seismic damage preventing technique which was developed by victor zayas in 1985.based on the typical height and seismic weight of structure FPS are three types single,double,triple friction pendulum bearings which consists of sliding bottom plate with Teflon coating, an slider bearing at top plate,FPS are fixed between sub and super structure. Among each of FPS isolators the design of TFPB is more complicated than single,double friction pendulum isolator. The major difference among them are three lies on number of sliding surfaces the single friction isolator has one concave bottom of flat surface but it differs in double friction isolator.TFPB are identical as of double with another pair of sliding plates between inner and outer surfaces. The dissimilarity among three is the efficiency and design.TFPB have much bearing displacement capabilities among the three.

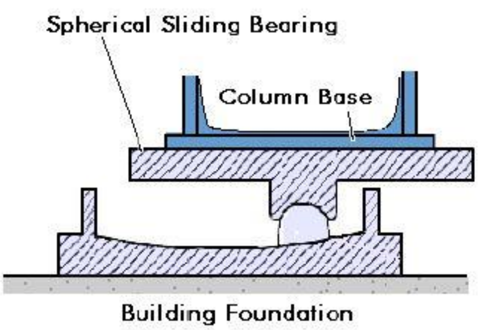

Figure 3. Single friction pendulum isolator

E. Design Steps For Base Isolation Systems

For design of base isolators first the maximum seismic weight(W) of building(G+9) is calculated W=24437kN.target period 2.5sec,effective damping β 5% is to be assumed for RCC structure according to IS 1893:2002 code,some of the parameters taken from UBC code.

Design of Lead Rubber Bearing(Lrb)

1.Design displacement(Dd)

$$Dd = \frac{g}{4\pi^2} \times \frac{Cvd\ \ Td}{Bd}$$

Cvd =Seismic coefficient

Td =Design timeperiod

Bd =Damping cofficient

2.Effective stiffness(Keff)

$$Keff = \frac{w}{g} \times \left(\frac{2\pi}{Td}\right)^2$$

3.Energy Dissipation per cycle(Wd):Dd

$$Wd = 2\pi\ Keff\ Dd^2 \beta eff$$

βeff= Damping

4. Force at Dd or characteristic strength (Q)

$$Q = \frac{Wd}{4Dd}$$

5. Stiffness of lead rubber(K2):

$$K2 = Keff - \frac{Q}{Dd} \quad , K1 = 10K2$$

6. Yield displacement(Dy):

$$(Dy) = \frac{Q}{K1-K2}$$

7. Recalculation of Q to Q r :

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$$Q_r = \frac{Wd}{4(Dd - Dy)}$$

8.Area of Lead plug

$$Apb = \frac{Qr}{10^2 \times 10^2}$$

Dia of lead plug d $= \sqrt{0.0127 \times 4/\pi}$

9. Revising Keff to Keff(r) :

$$Keff(r) = Keff - \frac{Qr}{Dd}$$

10. Total thickness of rubber (Tr):

$$Tr = \frac{Dd}{\gamma} \qquad \gamma = 1(\text{max shear strain of rubber})$$

Area of bearing

$$Alrb = \frac{Keff\,(r) \times Tr}{G}, \quad G = \text{shear modulus} = 0.7\text{mpa}$$

Dia of Bearing ØLRB $= \sqrt{A \times 4/\pi}$

Shape factor S = 1 /2.4 *10 / 0.5=8.33

Each rubber layer thickness $T = \frac{ØLRB}{4S}$

No of rubber layers $= \frac{Tr}{T}$

11.Compression modulus ratio (Ec):

$$Ec = 6GS2\left(1 - \frac{6GS^2}{K}\right)$$

K = Bulk modulus

G = Shear modulus

12.Horizontal stiffness KH :

$$KH = \frac{GAlrb}{Tr}$$

13.vertical stiffness KV :

$$KV = \frac{EcAlrb}{Tr}$$

14.Yield strength FY = Q+K2*DY

Design of Friction Pendulum System(Fps)

$$TD = 2\pi\sqrt{R/G}$$

$$Beff = \frac{2}{\pi}\left(\frac{\mu}{(\mu + D)/R}\right)$$

K = W/R

Table- I: Properties Required In Etabs

DIRECTION	PARAMETER	LRB	FPS
U1	Linear Effective Stiffness	5261181.52kN/m	16679.47kN/m
	Effective Damping	0.15	0.15
	Non Linear Stiffness	-	16679.47kN/m
	Damping Cofficient	-	0.02
U2,U3	Linear Effective Stiffness	14804.98kN/m	1357.611kN/m
	Effective Damping	0.02	0.1
	Non Linear Stiffness	144988.9kN/m	1667.47kN/m
	Yield Strength	461kN	-
	Post Yield Stiffness Ratio	0.01	-
	Friction Cofficient,Slow	-	0.03
	Friction Cofficient,Fast	-	0.06
	Rate Parameter	-	20
	Radius of Sliding Surface	-	1.553

F. Structural Modeling And Analysis

ETABS is a popular finite element analysis software among civil engineers with main focus on user graphical interface.it is mainly suitable for analysis and designing of multi-storied buildings either steel or RCC.For these reason it is being used by civil engineers through out the world.In this project, ETABS 16.2.1 is used for modeling and analysis of G+9 RCC building.

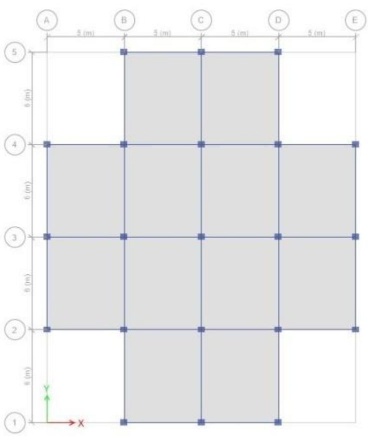

Figure 4 Section plan

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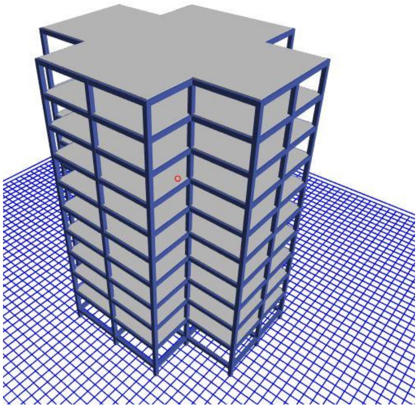

Figure 5 3D view plan

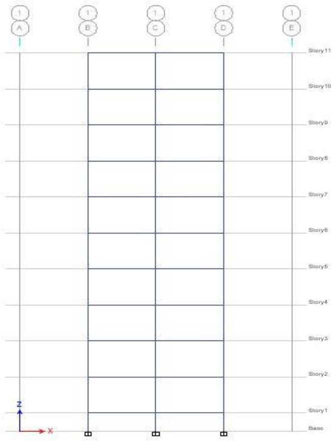

Figure 6 Model 1

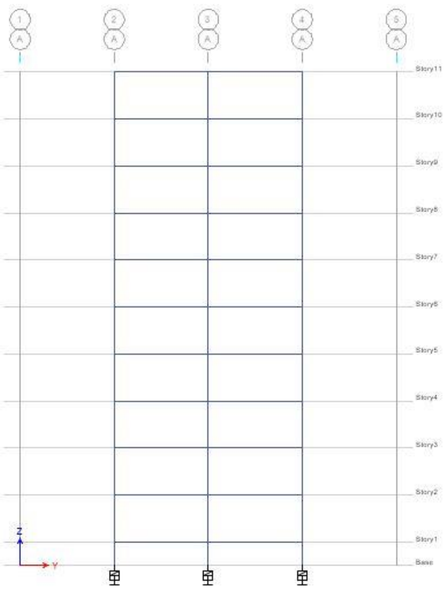

Figure 7 Model 2

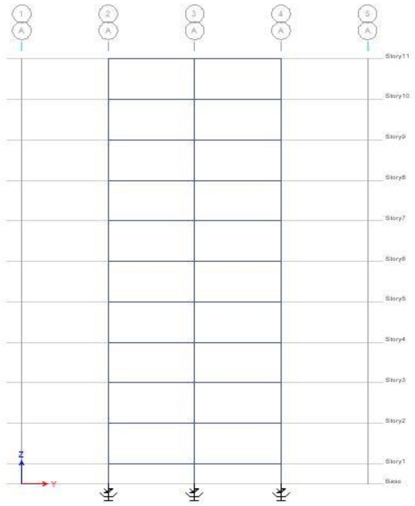

Figure 8 Model 3

G. Modalling Details

1.Model description:

Model 1 - Fixed end base

Model 2 – Lead rubber isolator(LRB)

Model 3 –Friction pendulum isolator(FPS)

2. Structural details:

Structure type: RCC(SMRF)

Plan diameter: 20m×24m

Height of building: 30m (G+9)

Height of one storey: 3m

x-direction: 4bay of 5m length

y-direction: 4bay of 6m length

3. Properties of materials

Grade of concrete: M30

Grade of rebar: HYSD415

Concrete density: 25kN/m^3

4. Sectional properties:

Beam size : 400mm×450mm

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column size : 400mm×450mm

Slab thickness: 150mm

5. Load consideration:

Dead load : 2kN/ m3

Live load : 3kN/ m3

H. Equivalent Static Analysis:

- Create the grid points and generation of Structure
- Define Material Properties, Section Properties
- Assigning of Properties
- Assigning of Supports(Fixed,Lrb,Fps)
- Defining of loads
- Assigning of DL, LL, WL and seismic loads as

  per IS :1893:2002
- Assign load combinations
- Analysis and design
- Results

I. Time History Analysis:

It is also called as non linear dynamic analysis. The peak ground acceleration is find out by representive earthquake this analysis is conducted to know seismic response under dynamic conditions of representive earthquake.

- After defining loads for structure the following steps are carried out
- Define time history function from file(El-centro)
- Define modal case data
- Define load case data
- Define mass source
- Output of time history
- Results

Table- II: El-Centro Data

Time History Considered For Study			
S.No	Earthquake	Magnitude Richter scale	P.G.A
1.	El-centro,USA	6.9	0.110

3. Results and Discussions

The following results are obtained from ETABS from static and dynamic analysis from G+9 RCC building with the fixed base and isolated base(LRB,FPS) models are compared for storey displacement, storey shear, storey drift and base shear.

Storey displacement

Displacement values will be maximum at the top storey and minimum at bottom storey.

Equivalent Static Analysis

Storey displacement plot obtained from equivalent static analysis for different cases (Fixed,LRB,FPS) in x and y direction.

Time History Analysys:

Storey displacement plot is obtained from time history analysis of model cases (Fixed,LRB,FPS) both in x and y direction.

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Storey Drift:

Its value is usually maximum at mid stories.

Equivalent Static Analysis:

Storey drift plot is obtained from equivalent static analysis of model cases(Fixed,LRB,FPS) in both x and y direction

Time History Analysis:

Storey drift plot obtained from time history analysis for different cases (Fixed,LRB,FPS) in x and y direction.

Storey Shear:

The shear developed at each storey is said to be storey shear

Equivalent Static Analysis:

Storey shear plot obtained from equivalent static analysis for different cases(Fixed,LRB,FPS) in x and y direction.

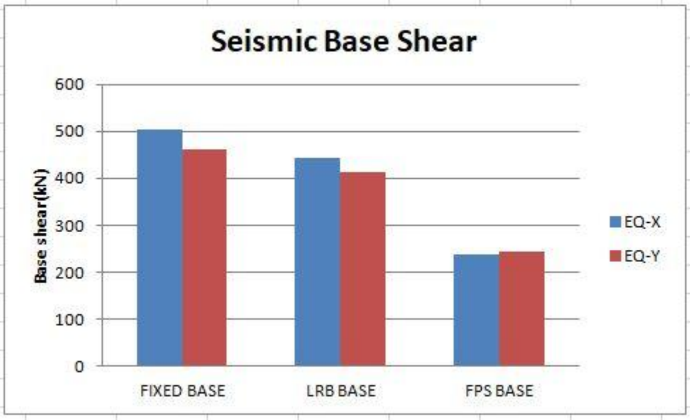
Time History Analysis:

Storey shear plot obtained from time history analysis of model cases (Fixed,LRB,FPS) both in x and y direction.

Base Shear:

Equivalent Static Analysis:

Seismic base shear plot is obtained from equivalent static analysis of modal cases(Fixed,LRB,FPS) in earthquake x and y direction.



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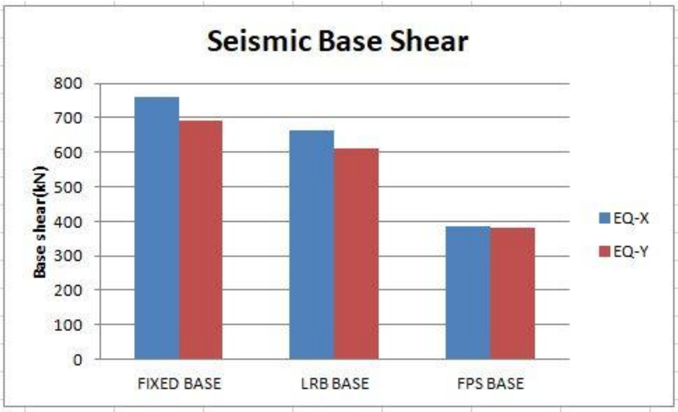
Time History Analysis:

Seismic base shear plot is obtained from time history analysis of model cases(Fixed,LRB,FPS) in earthquake x and y direction.



4. Conclusions

From the above study the conclusions are

- storey displacement results on both the analysis is prove that the displacement is more at top of the building but due to base isolators(LRB,FPS)then is a fall in storey displacement is observed at top floor.
- The storey drift results obtained from both the analysis with fixed and base isolators (LRB,FPS) are sudden increase in storey drift is observed at midspan of building.
- It is observed that Storey shear is maximum at bottom storey of fixedbase when compared to isolators(LRB,FPS) from both the analysis.
- The base shear of LRB and FPS building are less when compared with fixed base in both the analysis. Hence the seismic performance of building with base isolators is better than fixed base.
- From the above study it conclude that the building with friction pendulum bearing(FPS) has better seismic performance than lead rubber isolator LRB) and fixed base during earthquake.

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