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Seismic Behavior of RC Building Isolated by R-FBI System

S. M. Dumne[1], M. K. Shrimali[2]
1Department of Applied Mechanics, Government Polytechnic, Aurangabad, (Maharashtra)
[2]Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur (Rajasthan)
Email: smdumne@gmail.com

Abstract:- Seismic hazard mitigation is one of the important issues in today's practices therefore researchers are struggling for optimum solution since last few decades. Base isolation technique is one of the effective techniques which give better results in seismic hazard mitigation under earthquake excitation particularly in medium rise RC buildings. Base isolation system reduces not only the effects of earthquake acceleration to be transmitted to the building but also protect its contents. This study proposed a realistic ten storey RC building modeled as shear type lumped mass having single degrees-of-freedom at each floor level. This building is isolated by Resilient Friction Base isolator and excited under unidirectional ground motion due to four realistic earthquakes namely, Imperial Valley, 1940, Loma Prieta, 1989, Kobe, 1995 and Northridge, 1994. The governing equation of motion for the building has been solved using Newmarks method whereas isolation system is modeled by Wen's model. The effectiveness of proposed isolation system with RC building has been evaluated through coding in MATLAB 8.2 computing software. Further, effectiveness of isolation system is studied by comparing the peak responses of base isolated building with fixed base building. The results obtained from the study underscored that seismic behavior of Resilient Friction Base Isolator found effectively in limiting the responses of building during excitation due to earthquakes.

Keywords Seismic behavior, Resilient Friction Base Isolator, fixed base building, Building Peak responses

1. Introduction

Earthquake is natural and erratic phenomena, which has tremendous destructive energy in the form of ground shaking during an earthquake leads to enormous amounts of energy released. This release of energy can cause by sudden dislocation of segments of crust, volcanic eruptions. In the process of dislocations of crust segments, however, leads to the most destructive earthquakes may cause significant life hazard therefore, past disastrous earthquakes underlined the need of seismic hazard mitigation. Structural vibrations produced due to earthquake can be controlled by various means that is, increasing strength, stiffness and ductility. The researchers are considerably involved in developing seismic resistance through various techniques as conventional and Non-conventional technique. The non-conventional technique in which controlling devices are added based on which control system is employed that is, active, passive or combined. Further, passive control system in which base isolation system is one of the most popular technique and works with the concept of reducing fundamental frequency of structural vibration to a value lower than the seismic energy containing frequency. During earthquake, flexible device get momentum as a result building gets decoupled from the ground motion leads to avoid certain devastating hazard.

In relevant to above study, many past researchers have established their research findings but few of them are outlined and reviewed as Jangid and Datta [1] presented an updated review on behavior of various base isolated systems applied to the buildings subjected to seismic excitation. The study includes literatures on theoretical aspects, parametric behavior of base isolation building and experimental studies to verify some theoretical findings. Bhaskar Rao and R. S. Jangid [2] studied the performance of sliding systems under near-fault motions and found that friction coefficient of various sliding isolation systems is typically dependent on relative velocity at the sliding interface. Maria Qing [3] studied Controllable sliding isolation system to investigate the performance of sliding system and concluded that sliding base isolation found effective in controlling seismic response. Matsagar and Jangid [4] performed the computational study on structural responses and bearing displacement for the various isolation systems during impact upon adjacent structures. From the study, it is observed that increase in the building flexibility causes to increase in superstructure acceleration and decreases in bearing displacement marginally. The Mostaghel and Khodaverdian [5] have developed this system which provides the isolation effects through the parallel action of friction, damping and restoring spring. This system found very effective in reducing seismic response. S. M. Dumne et al [6] studied the effectiveness of semiactive hybrid control involving base isolation for seismic performance of MR damper connected dissimilar buildings involving elastomeric base isolation. From the numerical study, it is observed that semiactive hybrid control involving rubber bearing led (NZ system) not only effective in controlling the seismic responses but also avoids the damages due to pounding. The specific objectives of study are (i) determination of seismic response of building with and without base isolation (ii) study the seismic performance of Resilient Friction Base Isolation system in terms of peak response reduction and (iii) comparative study of peak responses of base isolated and fixed base building under various earthquakes.

2. Problem Identification

A realistic ten storey RC building isolated with Resilient Friction Base Isolation system (R-FBI) and assuming strata at the foundation level is hard which is excited by unidirectional ground motion due to earthquake. The details of design parameters are, plan dimension 20m X 30 m, grade of concrete M20, size of column 300 X 300 mm, beam size 300 X 450 mm, slab thickness 135 mm, structural damping equal to 5% and thickness of infill wall is 230 mm. The plan of proposed building model is shown in fig 1.

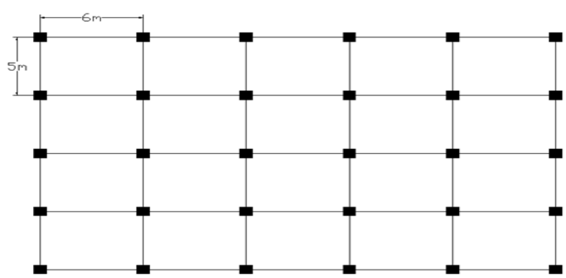

Figure 1. Plan of Proposed Building Model.

3. Structural Model of Building

The building model is idealized as a linear shear type lumped mass with single lateral degrees of freedom at each

Figure 1. Plan

floor levels including isolation floor. The structural building model is assumed to remain in linear elastic state, therefore, does not yield during excitation. During this study, it is assumed that spatial variation of ground motion and effect due to soil structure interaction is neglected. The governing equations of motion of multi degrees-of-freedom building with isolated base as expressed in matrix form is

$$[M]\{\ddot{u}\}+[C]\{\dot{u}\}+[K]\{u\}=-[M]\{r\}\ddot{u}_g+[B_p]\{f_b\} \quad (1)$$

where, $[M]$, $[C]$, and $[K]$ are the mass, damping and stiffness matrices of proposed building model respectively, $\{u\}=\{u_b, u_1, u_2, u_3 \ldots\ldots u_n\}$, $\{\dot{u}\}$ and $\{\ddot{u}\}$ are the vectors of relative floor displacement, velocity and acceleration response respectively, $\ddot{u}_g$ is the ground accelation due to earthquake, $\{r\}$ is the vector of influence coefficient with all elements equal to one, $[B_p]$ is the bearing location vector, $\{f_b\}$ is the vector of bearing force and (u_b) is the bearing displacement.

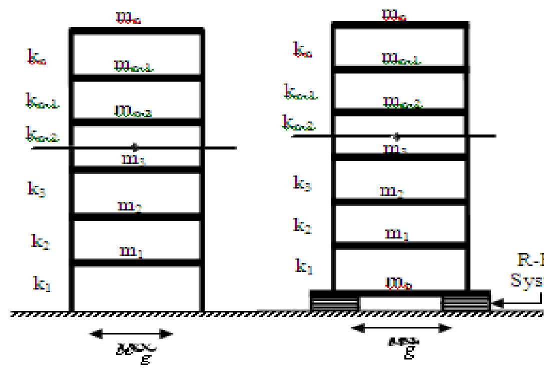

Figure 2. Structural model of Building with and without R-FBI system.

4. Computation of Bearing Force

Resilient-friction base isolator (R-FBI) system consists of concentric layers of Teflon-coated plates in friction contact with each other and a central rubber cores. The cross-section of R-FBI is as shown in Figure 3.

The resilient- friction base isolator (R-FBI) has been developed by Mostaghel and and Khodaverdian in 1990. As soon as ground motion exceeds certain level, lateral load exceeds the friction force then base starts to slide and rubber core deform and build resistance. The resilient-friction base isolator (R-FBI) provides the isolation effects through the parallel action of friction, damping and restoring spring. The rubber cores distribute the sliding displacement as well as velocity along height of system and are vulcanized to sliding rings.

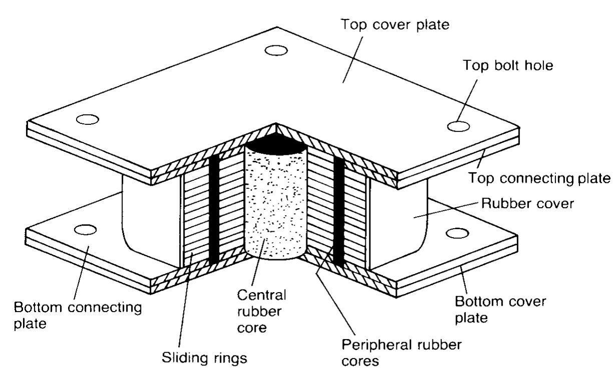

Figure 3. Cross section of R-FBI system.

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This system is designed such that vertical load is carried only by the sliding ring; which leads to very rigid in vertical direction. As soon as ground motion exceeds certain level, lateral load exceeds the friction force, base starts to slide and rubber core deforms and builds resistance. The schematic diagram of R-FBI is as shown in Figure 4.

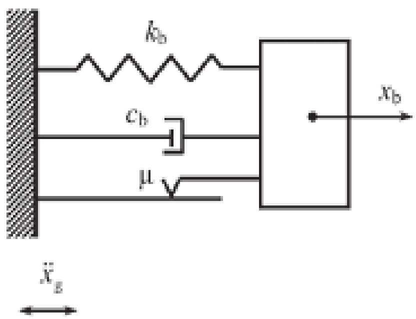

Figure 4. Schematic diagram of R-FBI system.

The bearing force yielded by R-FBI system is given by

fb= cb vb + kb ub + fr (2)

where, cb and kb are the damping and stiffness of base isolator, respectively, vb and ub are the velocity and displacement of bearing system respectively, fr is the friction force produced at the interface of sliding system is obtain from the equation (3).

The hysteretic displacement (z) of frictional force equation is evaluated using Wen's equation as in Wen, [7]. The frictional force mobilized at the interface of system is

fr = fs ×z (3)

where, fs is the limiting frictional force and expressed by f s= μ Mt g. where, Mt is the total mass of building including mass of isolation floor, g is the gravitational acceleration, μ is the friction coefficient of sliding system that depends on the instantaneous velocity of base floor. The friction coefficient (μ) of sliding system with Teflon-steel bearing can be modeled by using an equation as given by Constantinou et al. [8] is described below

$$\mu = \mu_{max} - (\Delta\mu) exp\left(-a\left|v_b\right|\right) \quad (4)$$

where, μmax is the maximum friction coefficient at large velocity of sliding (after leveling off), μmin is the minimum friction coefficient at small velocity of sliding, Δμ is the difference of maximum and minimum friction coefficient respectively at large and small velocity at the interface of system, and its value is assumed to be independent of relative velocity (Δμ=0) at the sliding interface which leads to coulomb-friction idealization, a is the calibration coefficient or constant for a given bearing pressure and interface condition is taken as 20 sec/m and z is the hysteretic displacement is evaluated by the equation of Wen's model.

5. Isolation Parameters

The parameter of isolation system, namely stiffness (kb) and damping (Cb) of sliding system are so selected to provide desired value of isolation period (Tb) and damping ratio (ξb), respectively. Further, natural period of isolation system is controlled by the selection of appropriate radius of curvature of the concave surface.

$$T_b = 2\pi\sqrt{\frac{M_t}{k_b}} \text{ and } \xi_b = \frac{c_b}{2M_t\omega_b} \quad (5)$$

where, Mt and Wt are the total mass and weight of proposed building including isolation floor, respectively, kb and Cb is the stiffness and damping of isolation system respectively, ωb is the natural frequency of bearing.

6. Solution Procedure

The governing equation of multi-storied building involving R-FBI base isolation control is solved numerically by using Newmark's step by step integration method assuming linear variation in acceleration over a small time interval. Similarly, bearing force is solved using numerical method. For both methods, time interval is kept very small to achieve stability of numerical method. The algorithms developed for governing motion equation and bearing force are simulated through MATLAB® version 8.2 computing software. The output of the first iteration becomes input to the second cycle of solving equations. Further, results are represented in tabular and graphics. The bearing force is solved by using Runga Kutta 4th order differential method.

7. Numerical Study

A structural model of lumped mass having ten storey's RC storey frame in which each floor mass is of 674.05 tonne and stiffness is of 5.17E+06 kN/m, respectively, that gives fundamental period of fixed base building is equal to 0.48 sec. In addition, mass of isolation floor considered as 10% in excess of mass at the superstructure floor. The displacement, acceleration and base shear response for the considered ground motions correspond to 5% of critical damping. The building is isolated by the Resilient Base Isolator as shown in fig 2 and is subjected to unidirectional excitation for which four real

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earthquakes ground motions namely Imperial Valley 1940 (PGA= 0.348g), Loma Prieta 1989 (PGA= 0.57g), Kobe 1995 (PGA= 0.837) and Northridge 1994 (PGA= 0.843g) are considered. The parameters of isolation system are Tb=4 sec, μb=0.04 and ξb=1.0. In this study, base shear (Bsy) and bearing force (Fb) are normalized by the total weight of proposed building (W). The peak response parameters of interest for the study are top floor displacement (uf), acceleration (af), bearing displacement (ub) and Normalized base shear (Bsy).

The comparison of peak responses of building for different parameters under all considered ground motions are shown in Table 1 along with percentage reduction in parenthesis with respect to fixed base building responses. It is observed that R-FBI system is quite effective in reducing the building responses. Further, it is also noted that reduction in to floor displacement, acceleration and base shear are in range of 80-95% for the building under three different earthquakes whereas for Loma Prieta, it is between 40-60 %. This implies that control is not so effective under Loma Prieta earthquake. The Fig. 5 shows time varying displacement response of top floor which indicate the effectiveness of R-FBI under various earthquakes. Fig. 6 shows the acceleration response of top floor and it is noted that there is much reduction in acceleration response. Similarly, Fig. 7 shows the time varying shear response which indicates the there is much decrease in base shear due to use of this bearing system. The reduction in peak responses of displacement, acceleration, and base is relatively lesser under Loma Prieta as compared with other earthquake motion. The Fig. 8 gives hysteresis energy loop of bearing force-displacement, from the shape of energy loop it gives an idea about well functioning of R-FBI system to reflect seismic energy during earthquakes.

Table 1. Comparison of Peak Responses of isolated building and fixed base building under various Earthquakes (Tb=4s, Ξ B = 0.1, μb= 0.04)

Earthquake	Response	Fixed base	Isolated base
Imperial Valley, 1940	u_f	5.7589	0.5279 (90.83)
	a_f	1.0817	0.1836 (83.26)
	B_{sy}/W	0.7086	0.0804 (88.65)
	u_b	---	5.387
Loma Prieta, 1989	u_f	14.6720	0.115 (99.21)
	a_f	2.3784	0.4906 (79.37)
	B_{sy}/W	1.8605	0.1799 (90.33)
	u_b	---	29.777
Northridge, 1994	u_f	15.6566	1.1550 (92.62)
	a_f	2.7142	0.2587 (90.46)
	B_{sy}/W	1.8246	0.1814 (90.05)
	u_b	---	19.473
Kobe, 1995	u_f	16.3702	0.8785 (94.63)
	a_f	2.8304	0.2599 (90.81)
	B_{sy}/W	1.9778	0.1298 (93.43)
	u_b	---	10.292

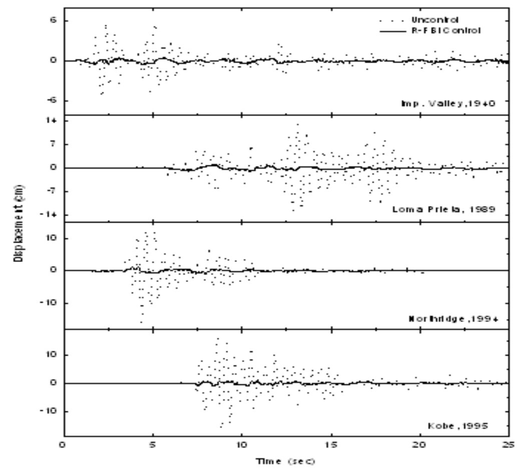

Fig. 5 Time varing displacement response of top floor (T_b= 4s, ξ_b= 0.1, μ_b= 0.04)

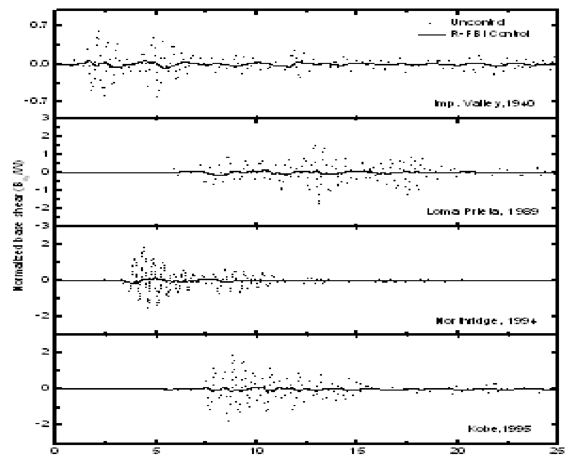

Fig. 7 Time variation of base shear responses (T_b= 4s, ξ_b= 0.1, μ_b= 0.04)

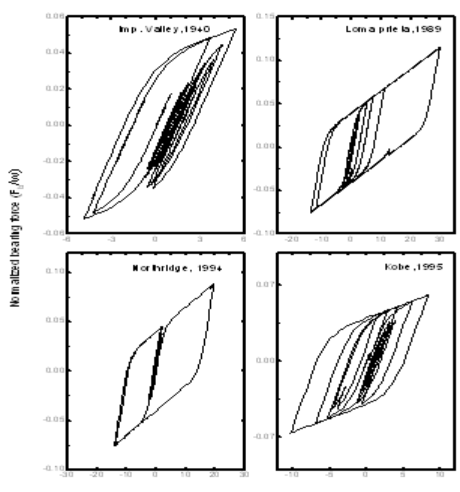

Fig. 8 Force-displacement behaviour of R-FBI control for various earthquake (T_b=4s, ξ_b=0.1, μ_b= 0.04)

8. Conclusion

The proposed scheme consisting of ten story RC building isolated by Resilient Friction Base Isolator. In order to examine the performance of the control scheme, the building model is excited by unidirectional excitation for which four real earthquake ground motions are taken. The simulation is carried out with the help of MATLAB® version 8.2 and from the numerical results, following conclusions are drawn

1. The proposed R-FBI system is quite effective in reducing the building responses in comparison with fixed base building.
2. The earthquake Loma Prieta, 1989 has more bearing displacement than under other earthquakes and further, it is also noted that Imperial Valley, 1940 has minimum bearing displacement.
3. The reduction in peak responses of displacement, acceleration, and base is relatively lesser under Loma Prieta as compared with other earthquake motion.
4. Shape of bearing force-displacement energy loop implies the smooth functioning of R-FBI system, that is, it reflects well seismic energy to be entered in the superstructure during earthquake excitation.

REFERENCES

i. *Jangid, R. S. and Datta, T. K. Seismic behavior of base-isolated buildings: a state-of-the art review, proceedings of institute of civil Engineers, Structures & buildings, Vol.110, 186-203, 2003.*

ii. *Bhaskar P. and Jangid R. S. Performance of sliding systems under near-fault motions, Nuclear Engineering and Design; Vol. 203, 259-272, 2001.*

iii. *Maria Qing Feng, Masanobu and Shunji Fujii. Friction-Controllable sliding isolation system, Journal of Engineering Mechanics, Vol.119, 43-68, 1994.*

iv. *Matsagar V. A. and Jangid, R. S. Influence of isolator characteristics on the response of base-isolated structure, Engineering Structures; Vol. 26, 1735-1749, 2004.*

v. *Mostaghel N. and Khodaverdian M. Seismic response of structures supported on R-FBI system, Earthquake Engineering and Structural Dynamics, Vol. 16, 839-854, 1988.*

vi. *Dumne S. M., S. D. Bharti and M. K. Shrimali. Seismic response analysis of coupled building involving MR damper and elastomeric base isolation, Ain Shams Engineering Journal, Vol. 6, 457-470, 2015.*

vii. *Wen Y. K. Method for random vibration of hysteretic systems, Journal of Engineering Mechanics Division, ASCE, Vol. 102, No. 2, 249-263, 1976.*

viii. *Constantinou, M. C., Mokha, A., and Reinhorn, A. M. Teflon bearings in base isolation II: testing & modeling, Journal of Structural Engineering, ASCE, Vol. 116, No. 2, 455-474, 1990.*