ISSN 2229-5518

Seismic Response Analysis of Isolated Building with Resilient Friction Base Isolator

Sudarshan B. Sanap, Pradip D. Jadhao, S. M. Dumne

Abstract— Seismic hazard mitigation is very sensitive issue now a day's 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 building structures, bridges and water tanks etc. Base isolation reduces not only the effects of earthquake acceleration to be transmitted to the structures, but also protects the content of building in addition to supporting the mass of structure. This study proposed a realistic ten storey RC building modelled as shear type lumped mass having single degrees-of-freedom at each floor level. This building is isolated by Resilient Friction Base isolation system of sliding base isolated type 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 modelled by Wen's model. The effectiveness of proposed isolation system and building response has been evaluated by coding in MATLAB 8.2 computing software. Further, effectiveness of isolation system is also studied in terms of peak responses of building. The results obtained from the study underscored that Resilient Base Isolation System works effectively in limiting the building responses during excitation due to earthquakes.

Index Terms— Analysis, , Isolated building , lumped mass , Peak responses, Resilient Friction Base Isolator , Seismic response.,

———————————— ◆ ————————————

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] (1995) presented an updated review on behaviour of various base isolated systems applied to the buildings subjected to seismic excitation. The study includes literatures on theoretical aspects, parametric behaviour of base isolation building and experimental studies to verify some theoretical findings. P. Bhaskar Rao and R. S. Jangid [2] (2001) 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. The response of building system is analysed to investigate the performance of sliding system and concluded that sliding base isolation found effective in controlling seismic response. Matsagar and Jangid [4] (2004) 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] (1988) has 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] (2012) studied the effectiveness of semiactive hybrid control involving base isolation for seismic performance of MR damper connected dissimilar buildings involving base isolation. From the numerical study, it is observed that semiactive hybrid control involving R-FBI sliding base isolation 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 system (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.

————————————————

- *Sudarshan B. Sanap is currently pursuing masters degree program in structural engineering in K K Wagh Inst. Of Engg. Edu & Research, India, PH9881566798. E-mail: ersudarshansanap@gmail.com.*
- *Dr. Pradip D. jadhao is currently working as professor &Head in civil engineering in K K Wagh Inst. Of Engg. Edu & Research, India, PH-9822670976. E-mail: jpradip11@rediffmail.com*
- *Dr. S.M. Dumne is currently working as lecturer in applied mechanics department at government polytechnic Aurangabad, India,PH-9422873345. Email: smdumne@gmail.com.*

ISSN 2229-5518

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 and elevation of proposed building model are shown in fig 1.

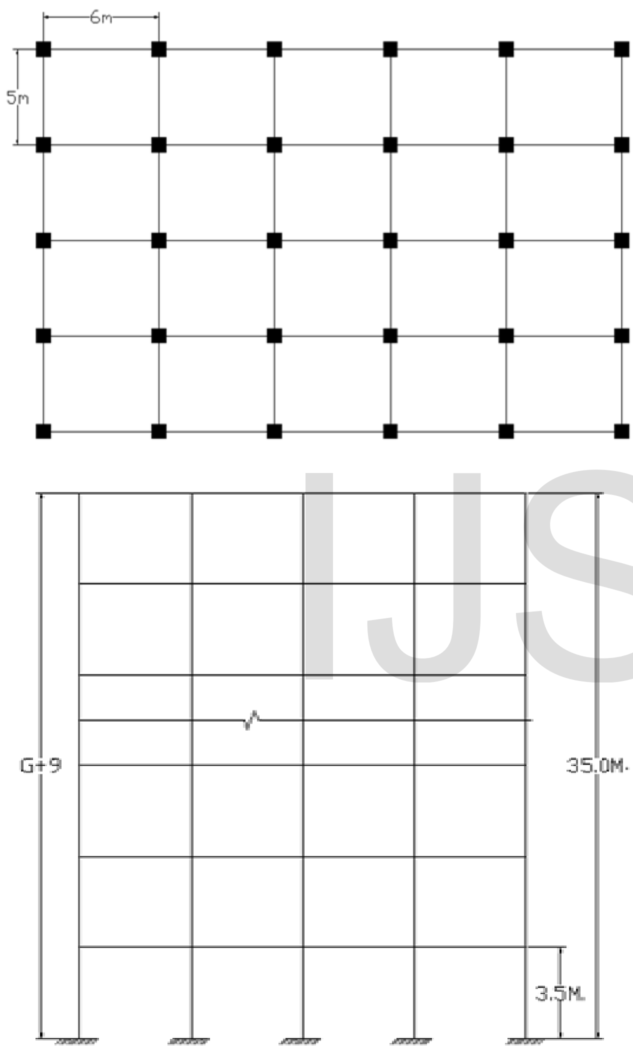

Fig. 1 Plan and Elevation of Building Model

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

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

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 acceleration due to earthquake, $\{r\}$ is the vector of influence coefficient having 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

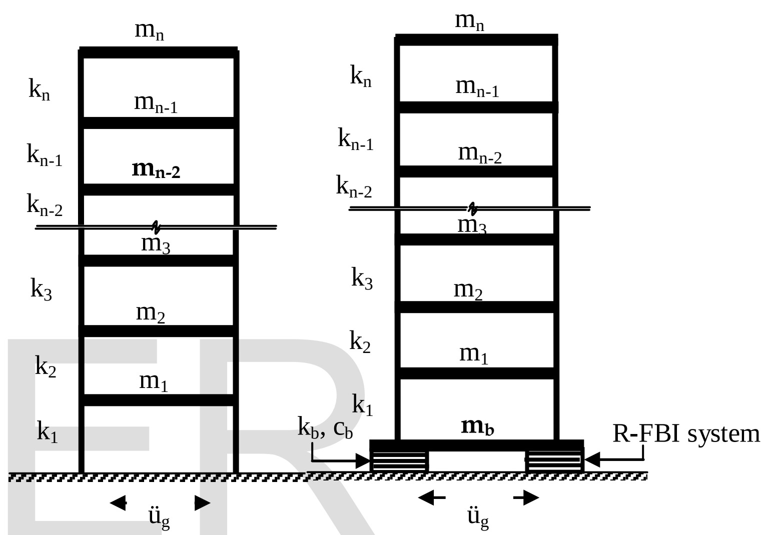

Fig. 2 Structural model of building with and without R-FBI System

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 core. The cross-section and schematic diagram of R-FBI is as shown in Fig.3a and 3b

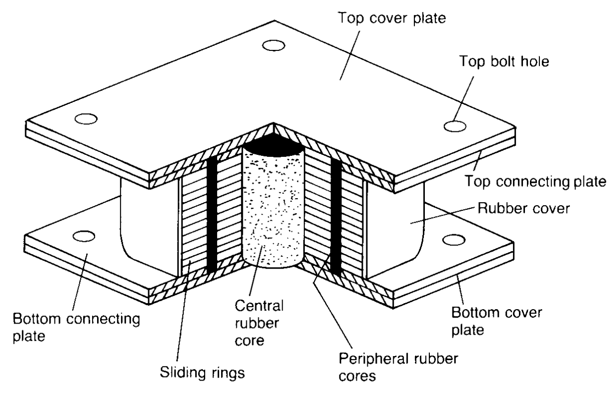

Fig. 3a Cross-section of R-FBI system

ISSN 2229-5518

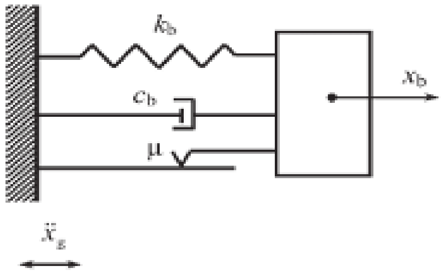

Fig. 3b Schematic diagram of R-FBI system

The resilient- friction base isolator (R-FBI) has been developed by Mostaghel and and Khodaverdian. This system provides isolation effects through parallel action of friction, damping and restoring springs. 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 bearing force yielded by R-FBI system is given by

$$f_b = c_b\, v_b + k_b\, u_b + f_r \qquad (2)$$

where, c_b and k_b are the damping and stiffness of base isolator, respectively, v_b and u_b are the velocity and displacement of bearing system respectively, f_r is the friction force produced at the interface of sliding system is obtain from the equation. The stiffness (k_b) and damping ratio (ξ_b) of R-FBI are so selected to obtain the desired value of isolation period (T_b) and (C_b).

4 Isolation Parameters

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

$$T_b = 2\pi\sqrt{\frac{M_t}{k_b}} \text{ and } \xi_b = \frac{c_b}{2M_t\omega_b} \qquad (3), (4)$$

Where, M_t and W_t are the total mass and weight of building including isolation floor, respectively, k_b and C_b is the stiffness and damping of isolation system respectively, ω_b is the natural frequency of bearing.

5 Solution Procedure

The C (Eq. 1) for multi-storied building involving R-FBI base isolation control are solved numerically by using Newmark's step by step method assuming linear variation in acceleration over a small time interval. The time interval is kept very small to achieve stability of newmark's integration method. The algorithms developed for governing motion and bearing force equation and are simulated through MATLAB® version 8.2 computing software. Further, results are represented in tabular and graphics.

6 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 of mass at the superstructure floor. The displacement and acceleration 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. The building is subjected to unidirectional excitation for which four real 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 T_b=4 sec, μ_b=0.04 and ξ_b=1.0.

The peak response parameters of interest for the study are top floor displacement (u_f), acceleration (a_f), story drift (u_r), Normalized bearing force (F_b), bearing displacement (u_b), Normalized base shear (B_{sy}) and storey shear (S_{sy}). In this study, base shear (B_{sy}), bearing force (F_b) and storey shear (S_{sy}) are normalized by the total weight of the building (W).

The comparison of peak responses of building for different parameters under all considered ground motions are shown along with percentage reduction in parenthesis with respect to non-isolated responses. It is 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 this control is not so effective under Loma Prieta earthquake. The Fig. 4 shows time varying displacement response of top floor which indicate the effectiveness of R-FBI under various earthquakes. Fig. 5 shows the acceleration response of top floor and it is noted that there is much reduction in acceleration response as compared to response of fixed base building response. Similarly, Fig. 6 shows the time varying shear response and indicates the decrease in base shear. The Fig. 7 show the graphs of peak value of displacement against each floor of building which represents higher value of displacement at top floor and lower at base. Fig. 8 represents the peak acceleration response of building floor and reflects the approximately linear variation in peak acceleration. It is observed that only in case of Loma Prieta initial acceleration is lesser at lower floor. Further, fig. 9 shows the peak storey drift of building floors and observed that at base level reduction in storey drift found maximum except Loma Prieta earthquake. The peak storey shear response of building floor gives an idea of effectiveness of R-FBI system as shown in Fig. 10. The Fig. 11 gives hysteresis energy loop of force-displacement which gives the description about well functioning of R-FBI bearing system during an earthquake.

7 Conclusions

The proposed scheme consisting of ten story RC building isolated by Resilient Friction Base Iisolator. In order to examine the performance of the control scheme, the building model is excited by unidirectional excitation for which four real

ISSN 2229-5518

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 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 relativelr lesser under Loma Prieta when compared with other earthquake motion.
4. From the shape of bearing force-displacement energy loop diagram, it implies the smoth functioning of R-FBI system.

TABLE 1 COMPARISON OF PEAK RESPONSES OF BUILDING FOR UNCONTROLLED AND R-FBI CONTROLLED UNDER VARIOUS EARTHQUAKES

Earthquake	Peak responses	Uncontrol	R-FBI control
Imperial Valley, 1940	u_f	5.7589	0.5279 (90.83)
	a_r	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_r	2.8304	0.2599 (90.81)
	B_{sy}/W	1.9778	0.1298 (93.43)
	u_b	---	10.292

Note: Value in parenthesis represents the percentage reduction in response

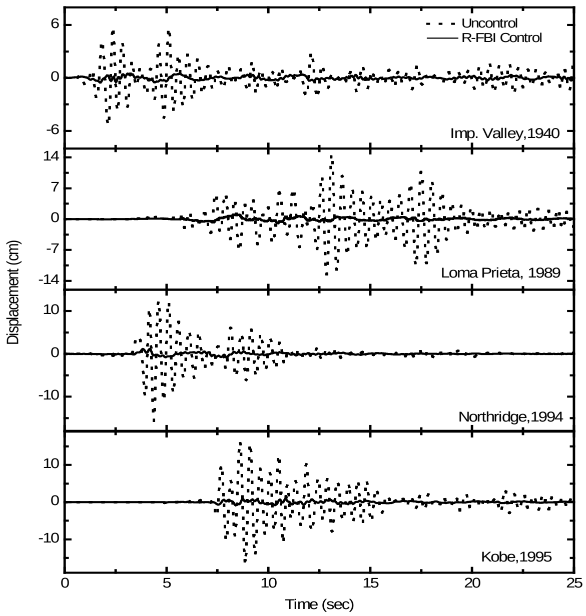

Fig. 4 Time varing displacement response of top floor
(T_b= 4s, ξ_b= 0.1, μ_b= 0.04)

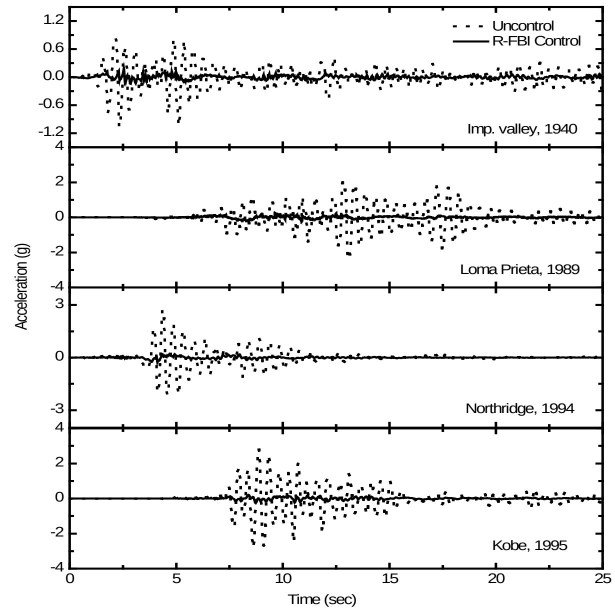

Fig. 5 Time varying acceleration response of top floor
(T_b= 4s, ξ_b= 0.1, μ_b= 0.04)

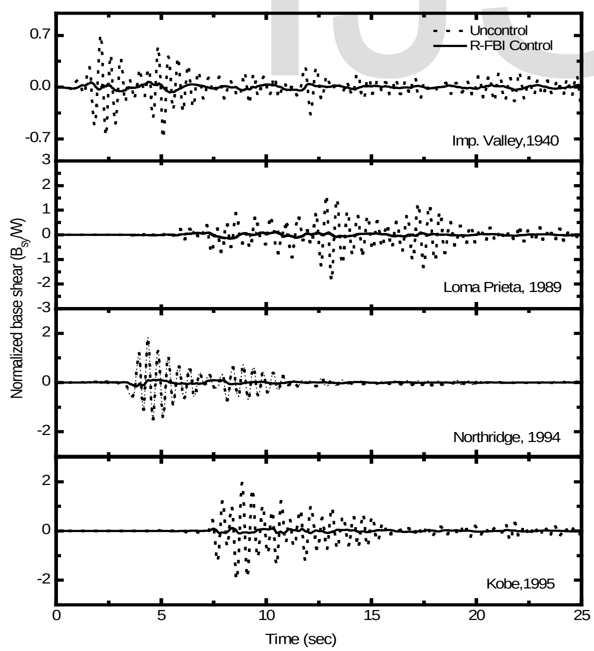

Fig. 6 Time variation of base shear responses
(T_b= 4s, ξ_b= 0.1, μ_b= 0.04)

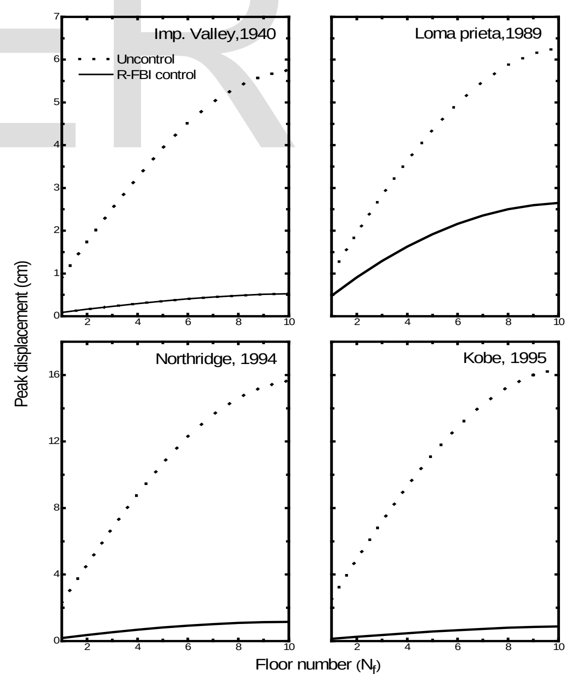

Fig. 7 Peak displacement response of building floors
(T_b= 4s, ξ_b=0.1, μ_b= 0.04)

ISSN 2229-5518

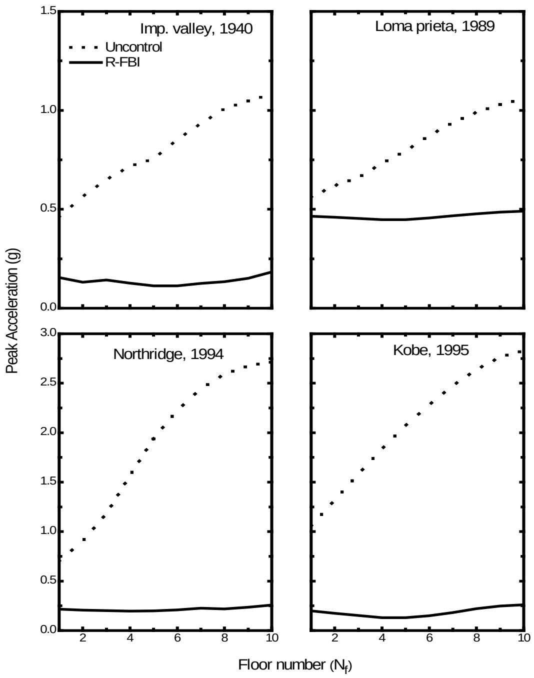

Fig. 8 Peak acceleration responses of building floors
(T_b=4s, ξ_b=0.1, μ_b= 0.04)

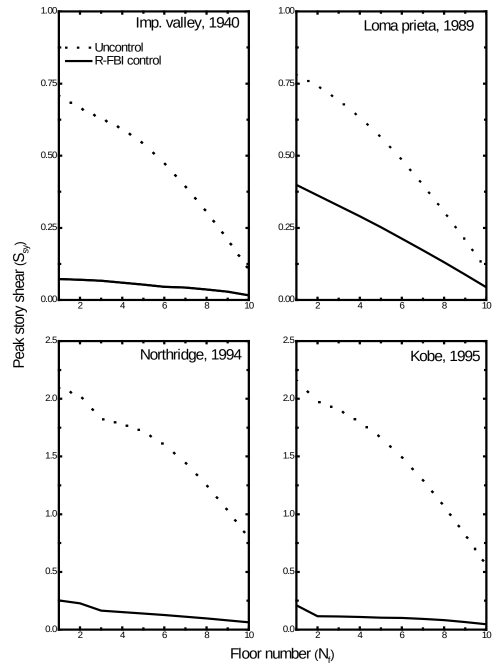

Fig. 10 Peak story shear response of building floors
(T_b=4s, ξ_b=0.1, μ_b= 0.04)

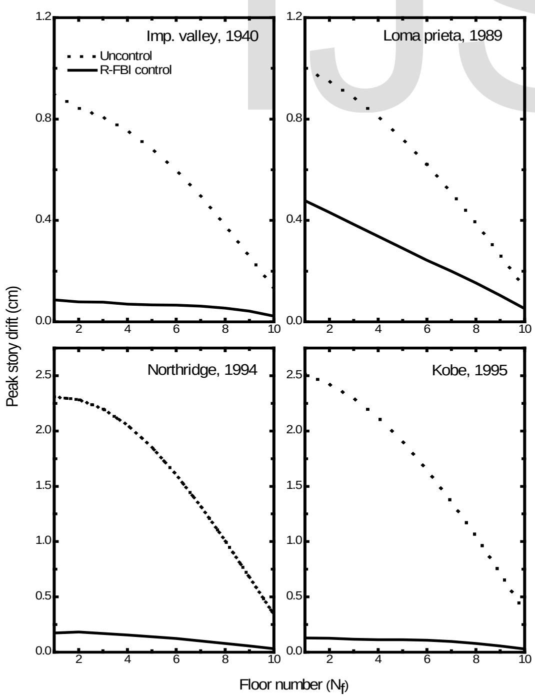

Fig. 9 Peak story drift response of building floors
(T_b=4s, ξ_b=0.1, μ_b= 0.04)

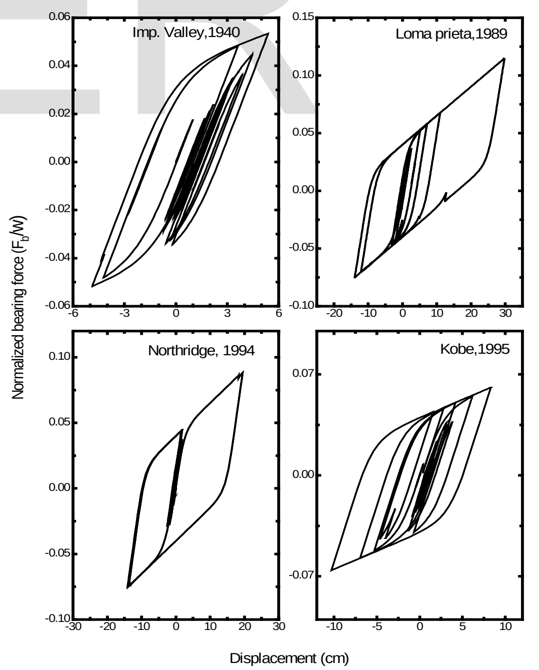

Fig. 11 Force-displacement behaviour of R-FBI control for various earthquake (T_b=4s, ξ_b=0.1, μ_b= 0.04)

References

ISSN 2229-5518

1. Jangid, R.S. and Datta, T. K. (2003). Seismic behaviour of base-isolated buildings: a state-of –the art review. Proceedings of Institute of Civil Engineers, Structures & building; vol. 110 pp. 186-203.
2. Bhasker, P. and Jangid R.S. (2000).Performance of sliding systems under near-fault motions. Nuclear Engineering and Design; 203 (2001) pp. 259-272.
3. Housner, G.W., Bergman, L.A., Caughey, T.K., Chassiakos, A.G., Claus, R.O., Masri, S.F., Skelton, R.E., Soong, T.T., Spencer, B.F. and Yao, J.T.P. (1997). "Structural control: past, present and future", Journal of Engineering Mechanics, ASCE; Vol. 123(9), pp. 897-971.
4. Maria Qing Feng, Masanobu and Shunji Fujii(1994). Friction- Controllable sliding isolation system. Journal of Engineering Mechanics, vol.119 pp.4368.
5. Matsagar, V.A. and Jangid, R.S. (2004). Influence of isolator characteristics on the response of base-isolated structure. Engineering Structures; 26 (2004) pp. 1735-1749.
6. Mostaghel N. and Khodaverdian M. (1988). Seismic response of structuressupported on R-FBI system. Earthquake Engineering and Structural Dynamics; 16, pp 839-854.
7. S. M. Dumne, S. D. Bharti and M. K. Shrimali (2012). Semiactive hybrid control for response analysis of seismically excited coupled building. Proceeding of 4th International Conference on Structural Stability and Dynamics (ICSSD 12), Malaviya National Institute of Technology, Jaipur, Rajasthan, India, 4-6th January-2012, (2012) pp 143-150.
8. Sudarshan B. Sanap et al. (2014). Earthquake response Metigation of R C Building using Friction Pendulum system.American Journal of Engineering Research; Vol.3(11), pp.30-37.