IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

SEISMIC RESPONSE ANALYSIS OF VERTICALLY IRREGULAR RC BUILDINGS USING LAMINATED RUBBER BEARING

Aboli A. Deshpande[1], S. B. Shinde [2], S. M. Dumne[3]

[1]*Post graduate student, Civil Engg. Department,*
Jawaharlal Nehru Engineering College, Aurangabad
[2]*Associate Professor and Head, Civil Engg. Department,*
Jawaharlal Nehru Engineering College, Aurangabad
[3]*Lecturer, Applied Mechanics Department, Government polytechnic Aurangabad*

ABSTRACT

Application of control devices for seismic hazard reduction has emerged as an attractive proposition over the years. This study considered four models of base isolated RC buildings involving regular, mass irregular, stiffness irregular and soft storey with ten storied are modeled as shear type lumped mass system with single degrees of freedom at each floor level. The governing equation of motion is solved using Numark's integration method and is simulated using coding in MATLAB software. These building models are isolated at base with one type of elastomeric base isolation system named as Laminated Rubber Bearing. Bearing force is calculated using forth order Ranga Kutta method. From numerical results it is stated that peak responses of soft storey model gives better control over structural responses under various earthquakes except in some models.

Keywords: Seismic Response, Regular Building, Irregular Building, Peak Responses, Laminated Rubber Bearing

I. INTRODUCTION

The naturally occurring ground movement which eventually goes on creating disasters such as failure of structure and fatality is known as Earthquake. The energy that is discharged from those seismic activities makes waves, these waves are called as primary waves and secondary waves. These waves cause ground movement transmitted to the structure via foundation.

Depending on intensity of these vibrations, cracks and settlement is caused to the structure. Base isolation system is frequently adopted earthquake resistant system. It reduces the effect of ground motion and thus leads to nullify effect of earthquake on the structure. Irregularities in structures are almost unavoidable due to functional and architectural requirement. Hence it is very necessary to study seismic response of such structures.

In relevant to above study many past researchers have established the research findings but few of them are well outlined and reviewed. Jangid and Datta[1] (1995) presented an updated review on behavior of various base

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

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. Stefeno and Pintucchi [2] (2008) presented an overview of the progress in research regarding seismic response of plan and vertically irregular structures. Ravikumar, et al [3] (2012) examined the effect of three different lateral load patterns on performance of various irregular buildings in pushover analysis. This study creates awareness about seismic vulnerability concept on practicing engineers.

Gadi et al,[4] (2013) presented study of seismic performance of LRB control and NZ control then compared reduction in peak responses of isolated building with non- isolated building. It is found that NZ control yield relatively more effective in reducing the responses. Jaswant N. Arlekar et al [5] (1997) This study depicts for immediate measures to prevent the indiscriminate use of soft first storeys in buildings,which are designed without regard to the increased displacement, ductility and force demands in the first storey columns. Alternate measures, involving stiffness balance of the open first storey and the storey above, are proposed to reduce the irregularity introduced by the open first storey it is concluded that hazardous feature of Indian RC frame buildings needs to be recognized immediately, and necessary measures taken to improve the performance of the buildings.

Devesh P. Soni and Bharat B. Mistry [6] (2006) in their study the authors summarizes state-of-the-art knowledge in the seismic response of vertically irregular building frames. It is observed that building codes provide criteria to classify the vertically irregular structures and suggest dynamic analysis to arrive at design lateral forces and the largest seismic demand is found for the combined-stiffness-and-strength irregularity. Matsagar and Jangid [7] (2008) demonstrated usefulness of base isolation in seismic retrofitting of the structures and substantiated the efficiency of different isolation devices in seismic retrofitting works.

Specific objectives of the study are (i) Determination of seismic response of various building models using laminated rubber bearing. (ii) Compare the peak responses of various irregular building models with regular model. (iii) Identifying the most effective base isolated building models in seismic performance. (iv) Observe the force deformation behavior of considered bearing.

II. PROBLEM IDENTIFICATION

A structural model of lumped mass system having 5% of damping with ten storey's of RC building in which each floor mass as 1219.129 ton and stiffness equal to 8.537E+06 KN/m, respectively, which gives fundamental period of fixed base building with regular model as 0.502 seconds as shown in figure 1.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

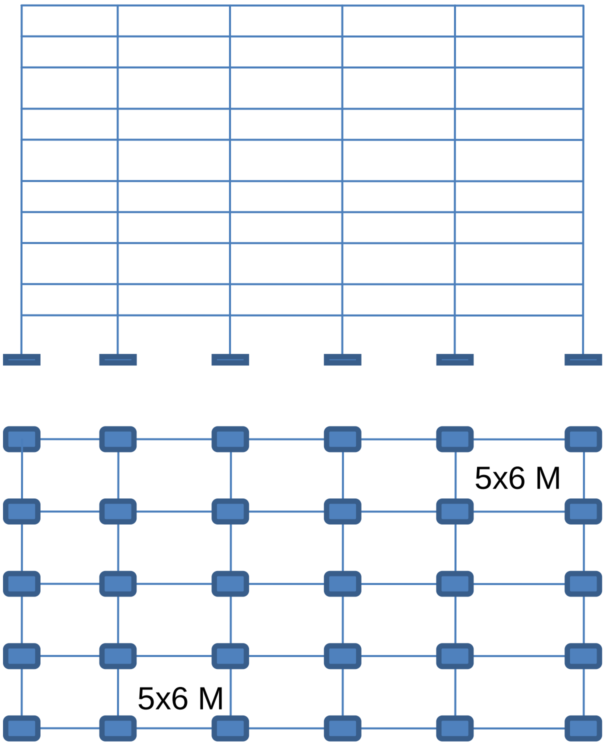

Fig1. Plan and elevation of regular building model

III. STRUCTURAL MODELS

The structural modeling includes various base isolated irregular RC buildings used to analyse the seismic performance of base isolated buildings as shown in figure 2.

3.1. Modeling of base isolated building

Four different building models are idealized as a linear shear type lumped mass with single lateral degrees of freedom at each floor levels of which one regular building model is shown in figure 2. The structural building models are 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 are expressed in matrix form as:

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

Where, $[M]$, $[C]$ and $[K]$ are the mass, damping and stiffness matrices of the building 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 with respect to the ground motion.

International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

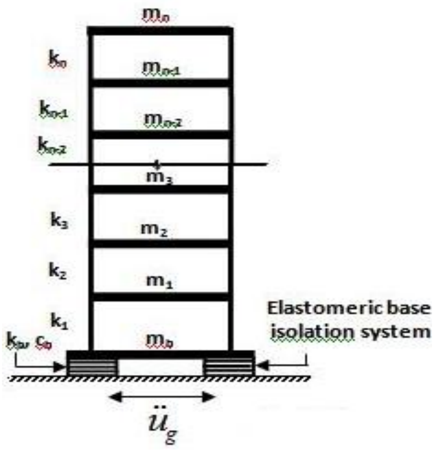

Fig2. Structural model of base isolated building

3.2. Modeling of laminated rubber bearing

The basic components of Laminated Rubber Bearing (LRB) system are steel and rubber plates built in alternate layers with rubber being vulcanized to the steel plates. It is extensively used in practices under comparatively with low frequency input. The bearing force generated by this system is expressed as

$$f_b = c_b \dot{u}_b + k_b u_b \qquad (2)$$

parameters of LRB system respectively whereas $\dot{u}_b$ and u_b are the velocity and displacement of isolation floor respectively.

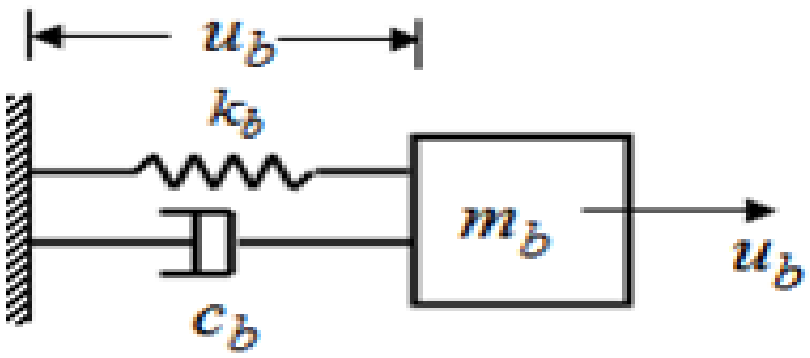

Fig3. Schematic diagram of LRB system

The dominant feature of LRB system is the parallel action of spring, stiffness and viscous dashpot is shown in figure 3.

IV. NUMERICAL STUDY

Four RC building models of ten storeys are considered for their performance in reducing responses during earthquake. First model is regular model in which mass is lumped at each floor equal to 1219.129 ton and that of stiffness 8.537×10^{6}kN/m. Mass of isolation floor is considered as 10% in excess of mass of superstructure floor.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Second model is irregular in mass having mass of fifth floor equal to 916.77 ton whereas third model is irregular in stiffness having stiffness of last top five floors equal to 6.429×10^6kN/m similarly, forth model is having soft storey with stiffness of the lower floor is 5.9×10^7kN/m. The building is subjected to unidirectional excitation for which four real earthquake ground motions are considered, details of which shown in Table 1. The parameters of considered base isolation system as identified by the Shrimali and Jangid (2002) are, for LRB system as T_b = 2s, and ξ_b = 0.1

Table 1 Details of earthquake ground motions

Earthquake	Recording station	Component	PGA(g)
Imperial Valley	EI-centro	N00E	0.348
Loma Prieta	Loss gatos presentation centre	N00E	0.570
Kobe	Japan metrological Agency	N00E	0.834
Northridge	Sylmer converter center	N00E	0.843

The peak response parameters of interest are, time varying top floor displacement (u_f), top floor acceleration (a_f), peak response of top floor displacement, top floor acceleration and bearing displacement. The base shear (B_{sy}) and isolation strength (F_y) are normalized by the total weight of building (W_t).

V. RESULTS AND DISCUSSION

The comparison of peak displacement response shown in Table 2. Increasing trend is observed in Imperial Valley earthquake but there is a decrement in model 4. In Loma Prieta earthquake there is decreasing order but increment is observed in model 3. Increasing pattern is observed in kobe earthquake, slightly decrement is observed in model 2 further decreasing trend is observed in peak displacement under Northridge earthquake.

Table 3 shows that decreasing pattern in values of irregular models than regular model for LRB Control. In Imperial Valley earthquake peak floor acceleration response shows decreasing pattern. Similar trend is observed in Loma Prieta earthquake.

Increasing pattern of peak acceleration response is observed under Kobe and Northridge earthquake. From the observations shown in Table 4, it is noted that there is slightly decrease in base shear of all irregular building models as compared to regular building model under all earthquakes. From Table 5, it is observed that peak bearing displacement is slightly more for irregular models than regular model using LRB Control.

From figure 4, it has been conclude that variation of floor displacement with time for various models considered under different earthquakes are following almost same trend with increasing or decreasing in response. It is observed that model 4 has minimum top floor displacement. Whereas model 3 has maximum top floor displacement. Top floor acceleration response with respect to the time for all building models under various earthquakes using LRB Control is shown in figure 5. The similar trend is observed in this figure. Figure 6 shows variation of base shear response with respect to time.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Peak floor displacement with respect to number of floors is shown in figure 7 for LRB Control. It is observed that model 3 has maximum peak floor displacement and model 4 has minimum peak floor displacement. Same trend is observed in peak floor acceleration in figure 8.From figure 9, the storey shear goes on decreases with floor numbers and similar trend has been observed except relatively better decreasing trend. Force deformation behaviour of all building models for LRB Control is shown in figures from 10 to 13. It is noted that shape and size of hysteresis loop for the isolators renders the well-functioning for which it intended.

Table 2 Top Floor Peak Displacement Response (Cm) of Building Models For LRB Control Under Various Earthquakes

Sr No	Earthquake	Model 1	Model 2	Model 3	Model 4
1	Imperial Valley, 1940 (EQ 1)	0.7185	0.7317	0.8646	0.5878
2	Loma Prieta, 1989 (EQ 2)	2.5645	2.5303	2.8578	2.0265
3	Kobe, 1995 (EQ 3)	1.467	1.4595	1.562	1.1776
4	Northridge, 1994 (EQ 4)	2.2657	2.2632	2.4839	1.8525

Table 3 Top Floor Peak Acceleration Response of Building Models For LRB Control Under Various Earthquakes.

Sr No	Earthquake	Model 1	Model 2	Model 3	Model 4
1	Imperial Valley, 1940 (EQ 1)	0.1908	0.1916	0.1907	0.1576
2	Loma Prieta, 1989 (EQ 2)	0.4401	0.4393	0.4807	0.396
3	Kobe, 1995 (EQ 3)	0.2374	0.238	0.2769	0.2484
4	Northridge, 1994 (EQ 4)	0.3552	0.3674	0.3887	0.3652

International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Table 4 Peak Base Shear Response of Building Models For LRB Control Under Various Earthquakes.

Sr No	Earthquake	Model 1	Model 2	Model 3	Model 4
1	Imperial Valley, 1940 (EQ 1)	0.1015	0.1015	0.1028	0.0962
2	Loma Prieta, 1989 (EQ 2)	0.331	0.324	0.3327	0.2944
3	Kobe, 1995 (EQ 3)	0.1816	0.1799	0.1814	0.1643
4	Northridge, 1994 (EQ 4)	0.2836	0.2823	0.2848	0.2691

Table 5 Peak Bearing Displacement Response of Building Models For LRB Control Under Various Earthquakes.

Sr No	Earthquake	Model 1	Model 2	Model 3	Model 4
1	Imperial Valley, 1940 (EQ 1)	7.069	7.219	7.07	6.3
2	Loma Prieta, 1989 (EQ 2)	28.504	28.116	28.515	25.256
3	Kobe, 1995 (EQ 3)	14.0707	14.041	14.084	12.583
4	Northridge, 1994 (EQ 4)	23.808	23.797	23.813	21.378

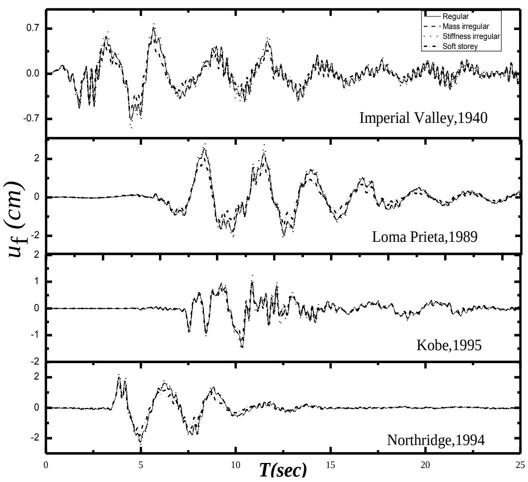

Fig 4. Time variation of top floor displacement

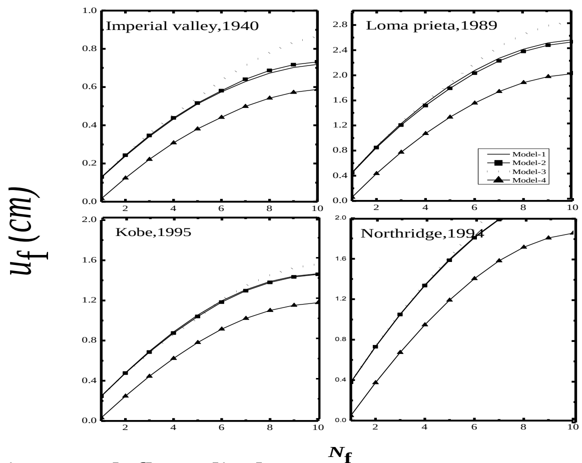

Fig 7. Peak floor displacement Response

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

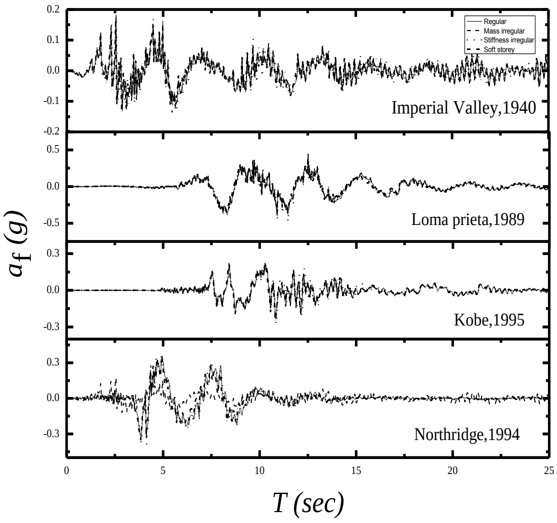

Fig5: Time variation of top floor acceleration response

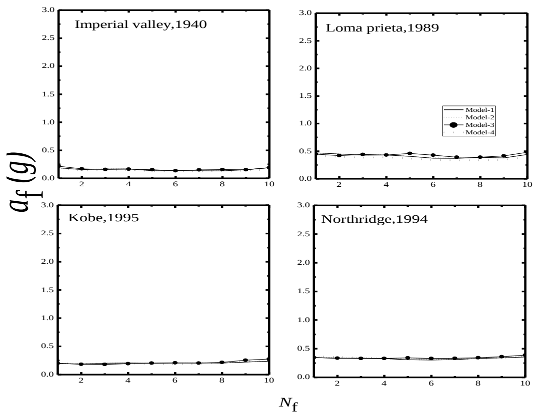

Fig 8. Peak acceleration responses

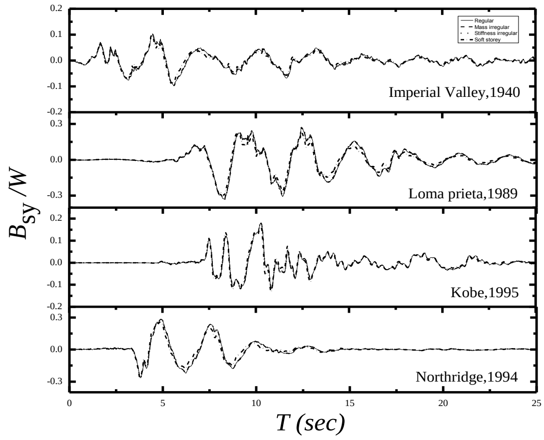

Fig 6.Time variation of base shear responses

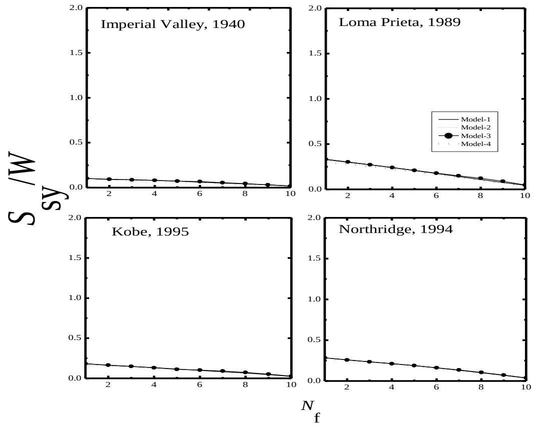

Figure 9 Peak storey shear responses

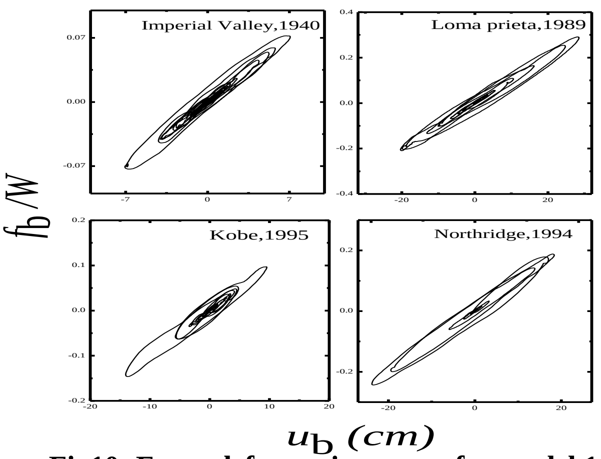

Fig10: Force deformation curve for model 1

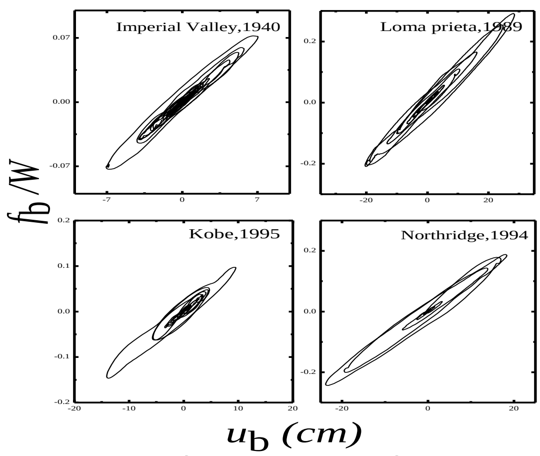

Fig 12. Force deformation curve for model 3

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

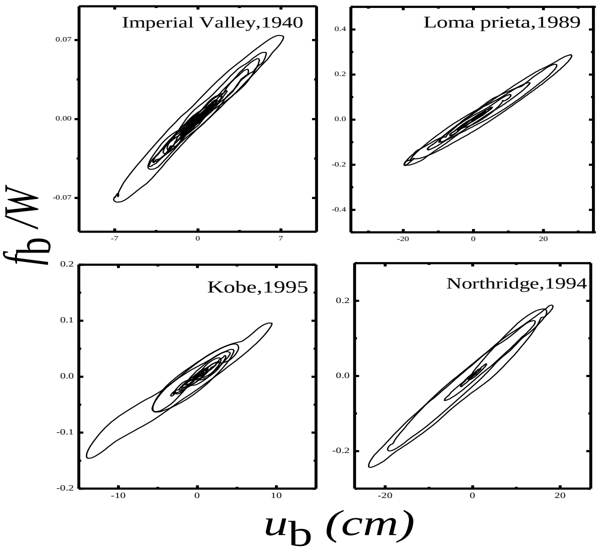

Fig 11.Force deformation curve for model 2

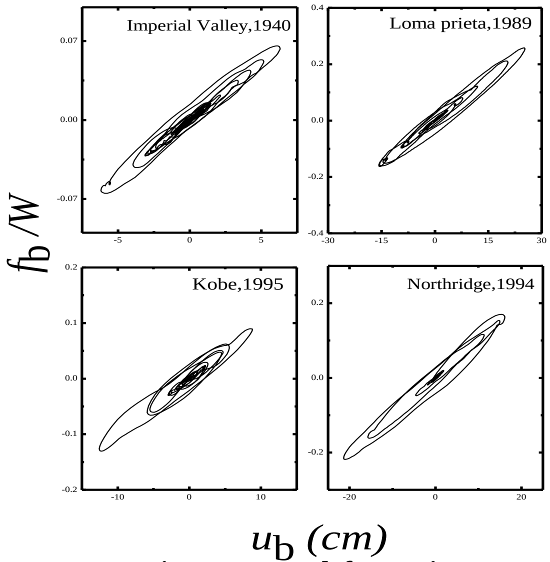

Fig 13. Force deformation curve for model 4

VI. CONCLUSIONS

The study proposed four models of ten storied RC buildings are isolated by elastomeric base isolation system such as LRB Comparison of peak responses each irregular building models with regular model under excitation due to various earthquakes is studied. From the numerical results, following concluding remarks are outlined

1. Peak storey shear is continuously goes on decreasing as floors increases.
2. Peak bearing displacement reduces not significantly of irregular models as compared to regular model.
3. Force deformation behavior found almost same for all building models under LRB Control.
4. The proposed LRB Control is found quiet effective in reducing responses in comparison with non-isolated control.
5. From the various irregular models, the building model with soft storey performs better in comparison with remaining models considered.

REFERENCES

[1] R. S. Jangid,, and T. K. Datta, Seismic behavior of base-isolated buildings: a state-of-the art review, Proceedings of Institution of Civil Engineers, Structures & Buildings,1995, 110, 186-203.

[2] M Stefeno, B. Pintucchi, A review of research on seismic behavior of irregular building structures since 2002, Bull Earthquake Engineering journal, 2008, 285-308

[3] C M Ravikumar, K S Bbunarayan,Sujit B V, Venkat Reddy D, Effect of irregular configuration on seismic volunerablity of RC Buildings, Architecture Research,2(3), 2012, 20-26.

[4] P. D. Jadhao, Sunila. Gadi, S. M. Dumne , Earthquake Performance of RC Buildings Using Elastomeric Base Isolation Controls, ISSN : 2248-9622,2013, Vol. 3, Issue 6, ., pp.1518-1524.

[5] Jaswant N. Arlekar, Sudhir K. Jain and C.V.R. Murty, Seismic Response of RC Frame Buildings with Soft First Storeys, Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.

[6] Devesh P. Soni and Bharat B. Mistry, qualitative review of seismic response of vertically Irregular building frames ISET Journal of Earthquake Technology, Technical Note, Vol. 43, No. 4, December 2006, pp. 121-13.

[7] V. A. Matsagar and. R. S. Jangid , Base Isolation for Seismic Retrofitting of Structures, (ASCE)1084-0680(2008)13:4(175)