Effect Of LRB Properties And Time History Characteristics On Response Of Base Isolated Structure

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Abstract: Base isolation is structural control device in reducing the response of a structural system induced by strong ground motions. The effects of near-fault (NF) ground motions with large velocity pulses can bring the seismic isolation devices to critical working conditions. In the present paper, nonlinear time history analyses were performed using a commercial structural analysis software (Etabs) package to study the influence of Isolator bearing displacement and Maximum Floor acceleration. Parametric analysis of the buildings fitted with LRB isolation devices is carried out to choose the appropriate design parameters.

Keywords- Base isolation, LRB, Near-fault, far-fault, Time history analysis, Etabs

I. INTRODUCTION

When subjected to severe earthquakes Buildings are vulnerable. Although considerable progress was made in earthquake engineering towards the end of the century, catastrophic building failure are found wherever strong ground motion earthquakes attack. Structural members and their internal contents can be protected against severe earthquake events with the installation of structural isolation devices to add damping to the isolated structure. The base isolation technique is to separate the structure from the ground to avoid earthquake damage. However modify the structure by preventing the motions being transmitted from the foundation into the structure above. During this Amount of energy is dissipated while an appropriate stiffness of the isolated system is provided to maintain structural integrity. In the case of far-field (FF) ground motions the isolators experience acceptable deformations. However, for structures subjected to near-field (NF) ground motions, the isolator displacements tend to be considerable. Therefore, isolators with very large dimensions may be required for structures located in NF areas. These costly geometries are in contradiction with implementing seismic isolators to reach a more economical and practical solution by mitigating the strong ground motion pulses transferred to the building. It was observed that LRB-isolated buildings with selected properties might perform poorly and can cause instability in the isolation system. Since the LRB isolation system equipped with all the desirable features of base isolation, it is necessary to investigate those parameters that affect the dynamic behavior of an isolated system of building. The efficiency of providing different LRB systems for RC buildings for reducing the isolator displacements. The response of this isolation action as well as the superstructure behavior seems to be effective for NF ground motions.

This study of the aseismic performance of different LRBs is the main objective of this paper. Thus, parametric analysis for variations in the fundamental isolation period is performed. The recommended ranges of the design parameters are also presented in this study. The isolated structure peak responses are obtained and the relative effectiveness of the various isolation systems is evaluated for the selected design parameter of isolation systems.

II. MODELING OF ISOLATION SYSTEM:

(A) LRB ISOLATORS:

The main objective of the present research is to study the effect of different properties of LRBs on the seismic performance of isolated buildings in relation to the characteristics of the NF ground motion and FF ground motion. The rubber-based bearing (LRB) isolation system consists of no of rubber layer and steel, with the rubber being vulcanized to the steel plates for horizontal flexibility and vertical stiffness. This isolator consists of a lead-plug insert which provides its characteristic hysteretic energy-dissipation effect. Therefore, the LRB system is able to support the structure vertically, to provide the horizontal flexibility together with the restoring force, and to provide the required hysteretic damping. The design parameters considered here are: the ratio Q/W of the characteristic strength Q over the total weight on the isolation system W, the lead core diameter D_p, the number of rubber layers n, the yield force Fy , the isolator diameter D_b, and the layer thickness ti. For analysis and design, the shape of the nonlinear force–deflection relationship, termed the hysteresis loop (represented as a bilinear curve as shown in Fig. 1), has an elastic (or unloading) stiffness ke and a yielded (or post-elastic) stiffness kp.

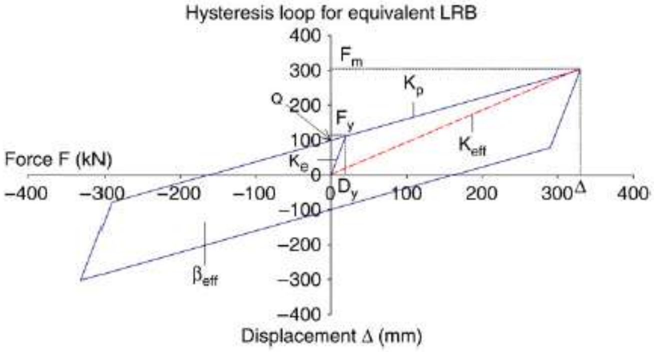


Fig. 1. Typical bilinear LRB hysteresis.

The elastic stiffness ke is defined as the ratio of the yieldstrength to the yield displacement, as expressed in equation ke = $\frac{Fy}{Dy}$

while the post-yield stiffness kp is given by the formula

$$kp = \frac{G.Ar}{Tr} \quad (1)$$

where tr is the total thickness of rubber consisting of n layers, G is the shear modulus of the rubber, Ar is the cross sectional area of the rubber layers, The characteristic strength Q (force intercept at zero displacement) is given by the equation

$$Q = A_p x Y_{pb} \quad (2)$$

where A_p is the area of lead core, and Y_{pb} the yield strength of the lead core (ranging between 7 and 8.5 MPa). The effective stiffness keff is defined as the ratio between the force Fm, occurring at a specified LRB isolator displacement D.

$$k_{eff} = \frac{Fm}{D} \quad (3)$$

The effective stiffness keff can also be expressed as a the characteristic strength Q as in the following equation:

$$k_{eff} = kp + \frac{Q}{D} \text{ (when } D > Dy) \quad (4)$$

where Dy is the yield displacement as shown in Fig. 1. On the other side, when the design displacement D < Dy , the effective stiffness keff = ke. The force Fm can be defined as

$$Fm = Q + kp.D \quad (5)$$

while the yield force Fy can be obtained from

$$Fy = Q + kpDy. \quad (6)$$

The area ED of the hysteretic loop can be obtained from the equation

$$ED = 4Q(D - Dy). \quad (7)$$

This area represents the energy dissipation at each cyclic motion of LRB isolator. Then, the effective damping ratio Beff, which produces the same amount of damping energy dissipation as the hysteretic energy dissipated at each cyclic motion of the LRB isolator, is expressed as

$$B_{eff} = \frac{ED}{2\pi keffD2} \quad (8)$$

Finally, the fundamental isolation period Tiso is given by the equation

$$T^{iso} = 2\pi\sqrt{\frac{M}{\sum k_{eff}}} \quad (9)$$

where M is the total mass on the isolation system, including the mass of the superstructure and the mass of the isolation system. The term ∑ keff = Keff is the total effective stiffness of the isolation system. Some equivalent hysteretic curves for LRB isolators used in the present parametric study for the cases of Q/W = 7.5%,10% and 12.5% respectively, as a function of the fundamental isolation period.

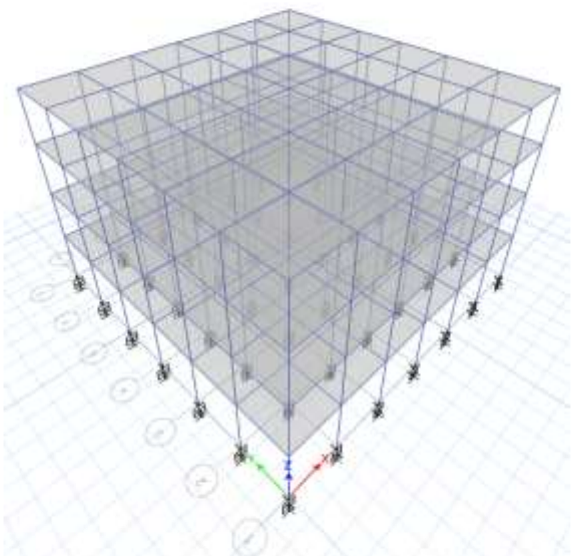


Fig:Etabs Model Building

Table:1 Basic characteristics for different LRB base isolation case for (18x18)building

No of layers	Tiso	effective stiffness Keff(kN/m)	Elastic stiffnes Ke(kN/m)
Q/W:7.5%			
lead core diameter:81mm			
Device diameter:482mm			
Fy:47.19kN			
kp/ke=0.100			
13	1.5	1033	7438
18	1.7	789	5372
26	1.9	589	3719
35	2.2	470	2763
46	2.5	385	2102
Q/W:10%			
lead core diameter:93mm			
Device diameter:492mm			
Fy:61.34kN			
kp/ke=0.092			
16	1.5	1017	6951
23	1.7	774	4836
33	1.9	598	3370
48	2.2	468	2317
67	2.5	383	1660
Q/W:12.5%			
lead core diameter:104mm			
Device diameter:505mm			
Fy:77.42kN			
kp/ke=0.086			
20	1.5	1017	6345
30	1.7	774	4230
47	1.9	589	2700
50	2.2	467	2538
69	2.5	384	1839

The iterative procedure starts by assuming a design displacement D. Next, the basic design parameters of LRB isolators such as ratio Q/W, yield force Fy isolator diameter D_b, lead-core diameter D_p,and ratio Kp/Ke are fixed in such a way that the fundamental isolation period T iso falls in the range 1.5 s < T iso < 2.5 s, where the fundamental isolation periods in base-isolated buildings lie. More specifically, by appropriately changing the LRB isolator height and keeping constant the other design parameters, building A were investigated using isolator diameters d = 482 mm,492mm and 505mm with a ratio of the characteristic strength Q to the total structure weight W of Q/W =7.5%,10%and 12.5%, respectively, as shown in Tables 1. The iterations of the preliminary design analysis are performed in such a way that the maximum displacement computed from ETABS finite-element analysis in the last step of iteration is almost identical to the selected maximum design displacement keeping the fundamental isolation period in the selected range.

(B)Time History Analysis:

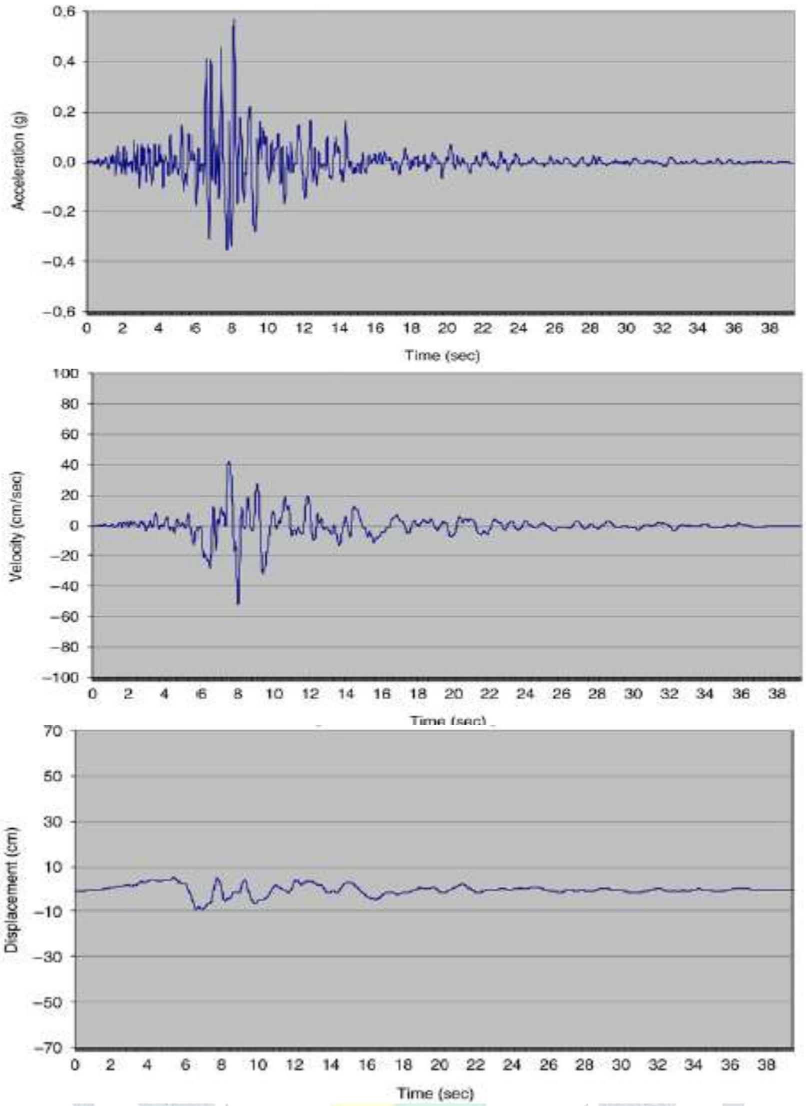
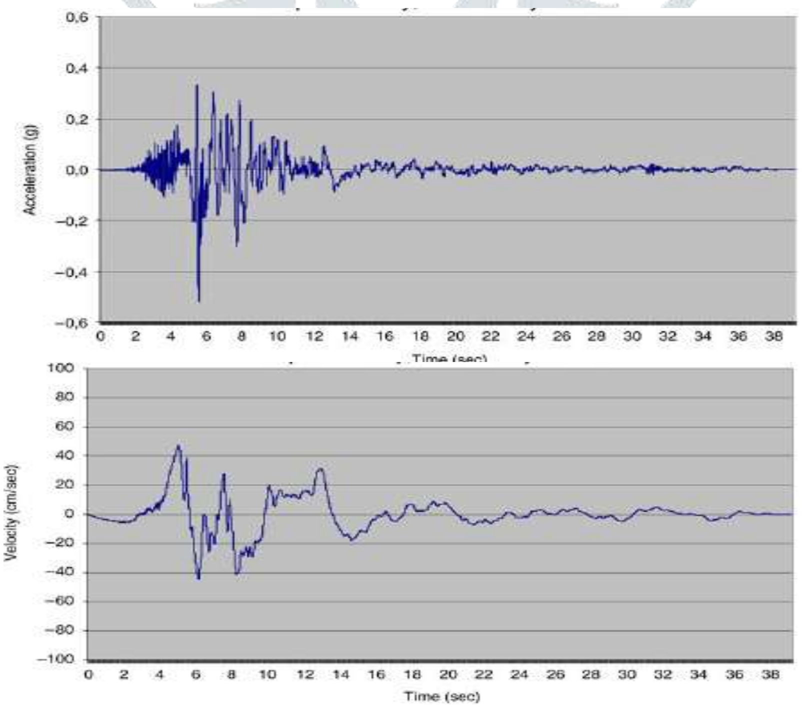


Fig:2 Imperial Valley Earthquake ground motion characteristics



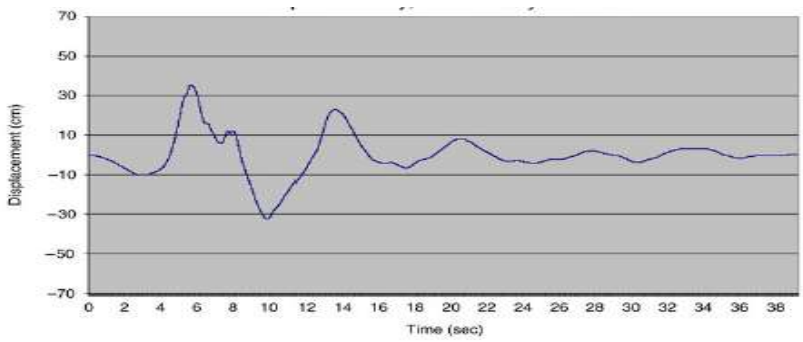


Fig:3 Kobe Japan Earthquake ground motion characteristics

Table:2 Near fault and far fault ground motion records considered in this study:

N0	ground motion	earthquake	distance to fault (km)	Mw
1	Near fault	kobe Japan	10km	7
2	far fault	kobe Japan	70.3km	7
3	Near fault	imperial valley	2.5 km	6.5
4	far fault	imperial valley	70.3km	6.5

In the present study, LRB isolators in the nonlinear time-history analysis was achieved by activating the ISOLATOR1 (ISO1) nonlinear link element of ETABS. The evaluation of the ETABS link element properties, at a specified maximum displacement D and also the inspection of the bearing performance in terms of geometry, vertical buckling, shear load capacity and stability, is derived by using an iterative procedure employing both a Microsoft Excel spreadsheet and ETABS software simultaneously.

III.RESULTS AND DISCUSSION:

(A)Synthetic Imperial Valley Earthquake ground motion characteristics :

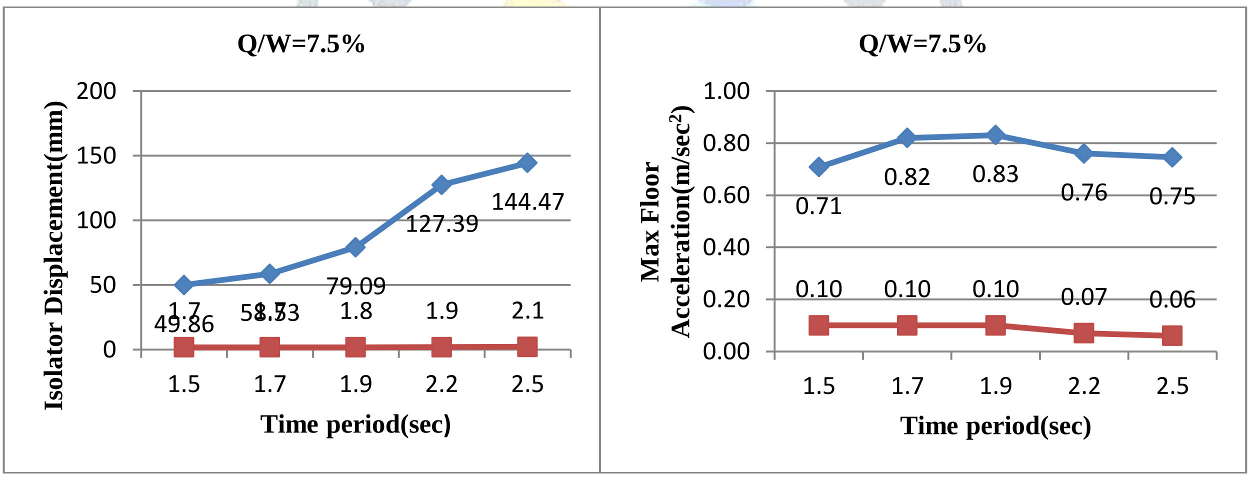


Fig.4:Q/W=7.5% ratio with different LRB Properties under NF and FF ground motion.

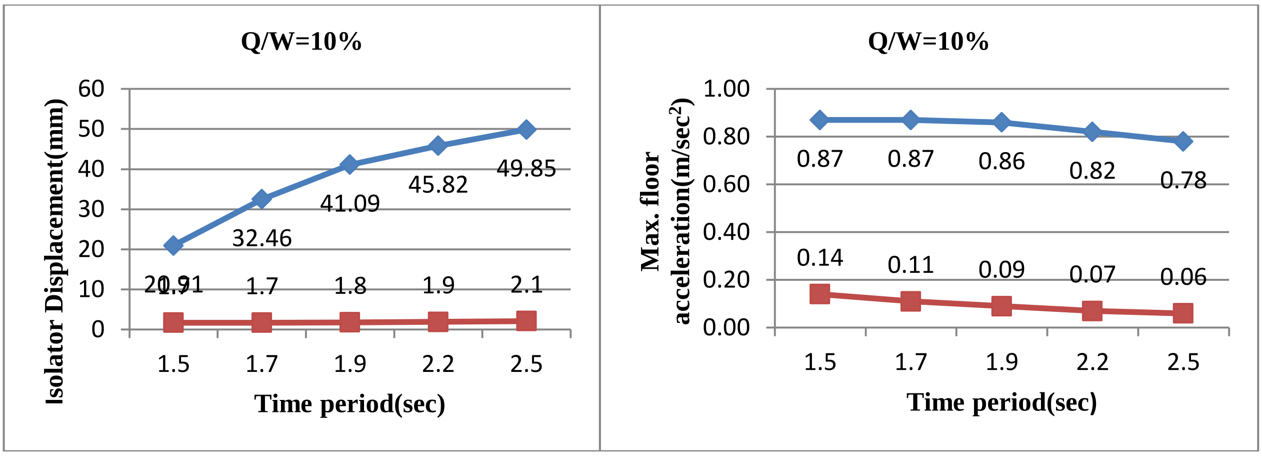


Fig.:5 Q/W=10% ratio with different LRB Properties under NF and FF ground motion.

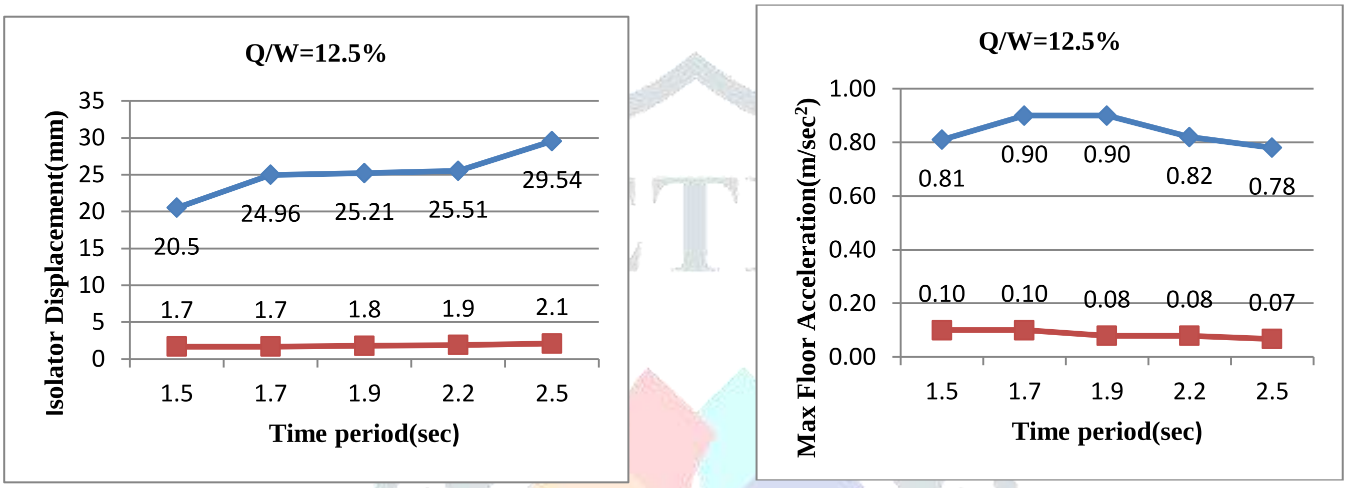


Fig:6 Q/W=12.5% ratio with different LRB Properties under NF and FF ground motion.

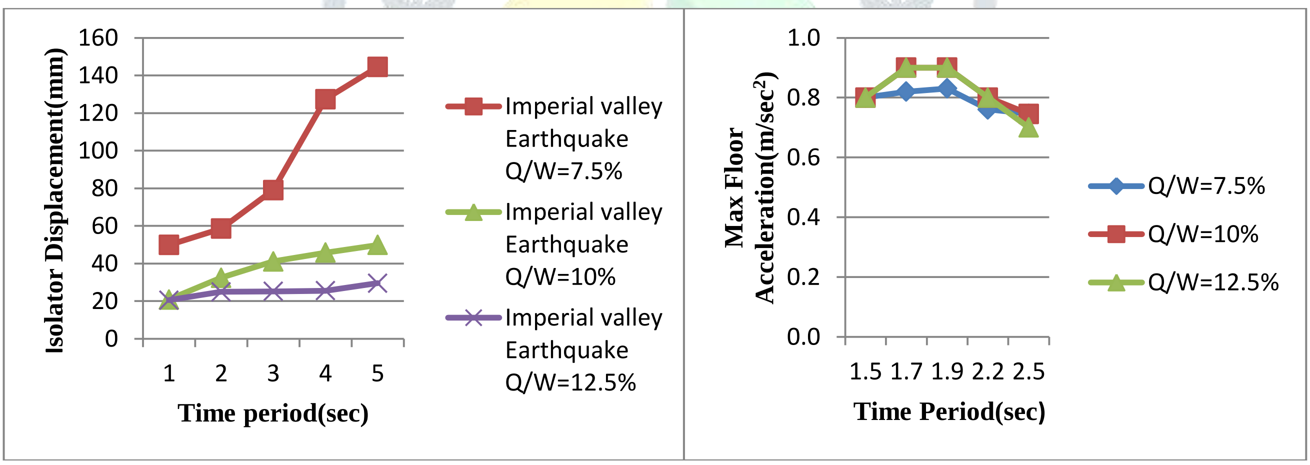


Fig:7 Comparison of Time Vs Isolator Displacement And Time Vs Max Floor Acceleration for Q/W=7.5%,10%,12.5% under NF ground motion.

(B) Comparison of Synthetic Imperial Valley and Synthetic Kobe Earthquake Ground motion Characteristics:

Table:3 Isolator Displacement in mm

Kobe Earthquake				Imperial valley Earthquake			
T_{iso}	Q/W=7.5%	Q/W=10%	Q/W=12.5%	T_{iso}	Q/W=7.5%	Q/W=10%	Q/W=12.5%
1.5	235.47	121.81	21.23	1.5	49.86	20.91	20.5
1.7	236.15	127.68	25.96	1.7	58.53	32.46	24.96
1.9	237.44	130.8	29.84	1.9	79.09	41.09	25.21
2.2	240.46	131.45	33.41	2.2	127.39	45.82	25.51
2.5	241.4	135.82	37.45	2.5	144.47	49.85	29.54

Table:4 Max floor Acceleration values in (m/sec^2)

Kobe Earthquake				Imperial valley Earthquake			
T_{iso}	Q/W=7.5%	Q/W=10%	Q/W=12.5%	T_{iso}	Q/W=7.5%	Q/W=10%	Q/W=12.5%
1.5	4.6	2.4	2.1	1.5	0.7	0.8	0.8
1.7	2	2.1	2.1	1.7	0.8	0.8	0.9
1.9	1.8	1.7	2	1.9	0.8	0.8	0.9
2.2	1.3	1.7	1.3	2.2	0.7	0.8	0.8
2.5	1.2	1.3	1.2	2.5	0.7	0.7	0.7

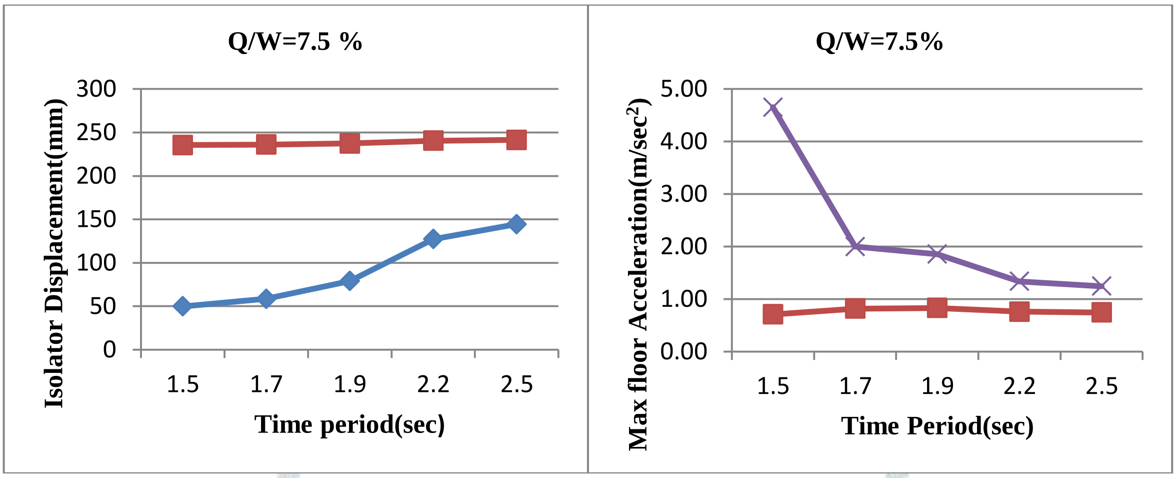


Fig:8 Comparison of two time History with different LRB Properties under NF ground motion(Q/W=7.5%)

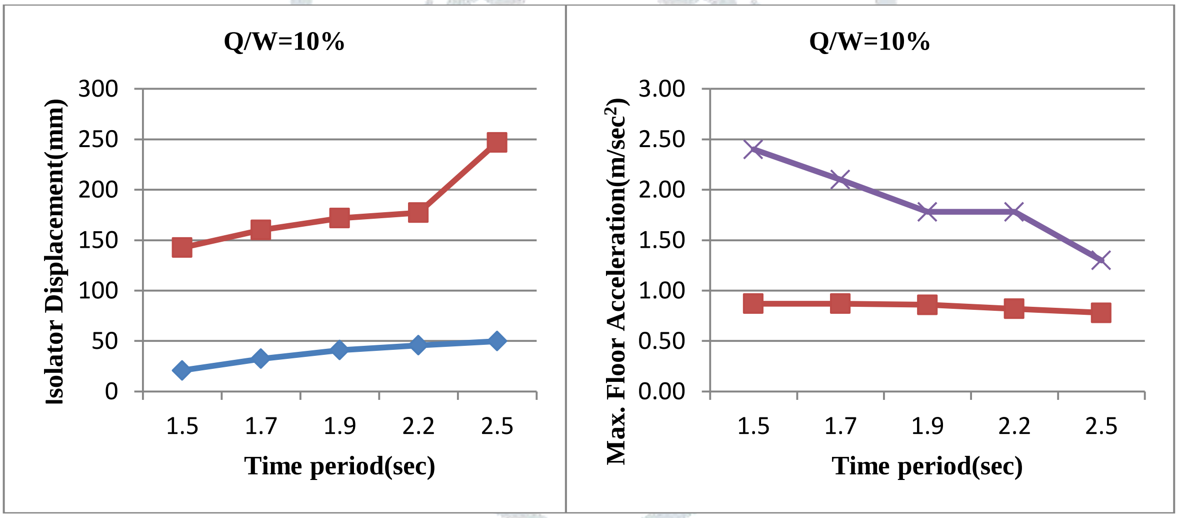


Fig:9 Comparison of two time History with different LRB Properties under NF ground motion(Q/W=10%)

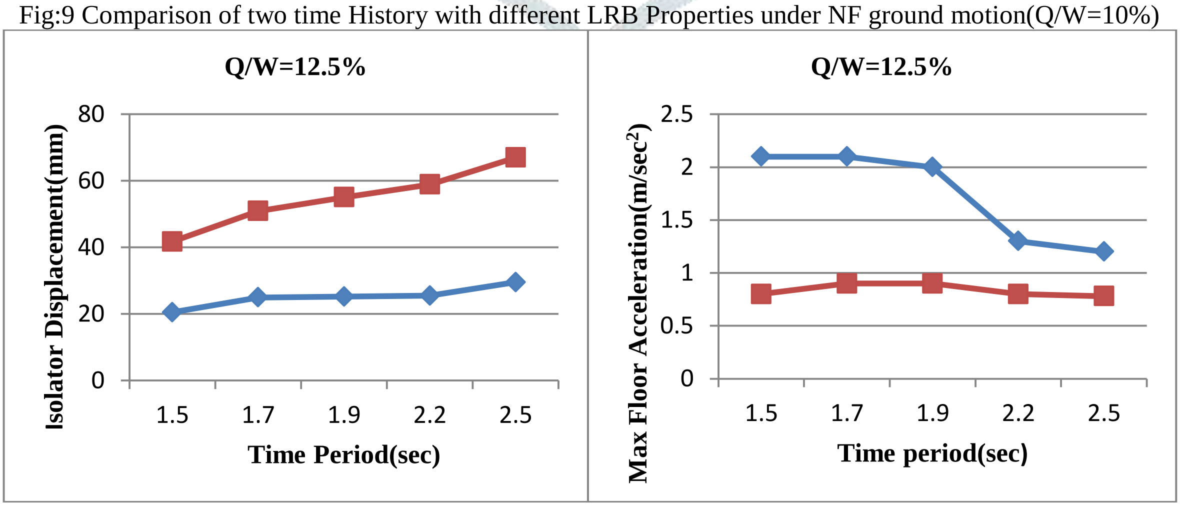


Fig:10 Comparison of two time History with different LRB Properties under NF ground motion(Q/W=12.5%)

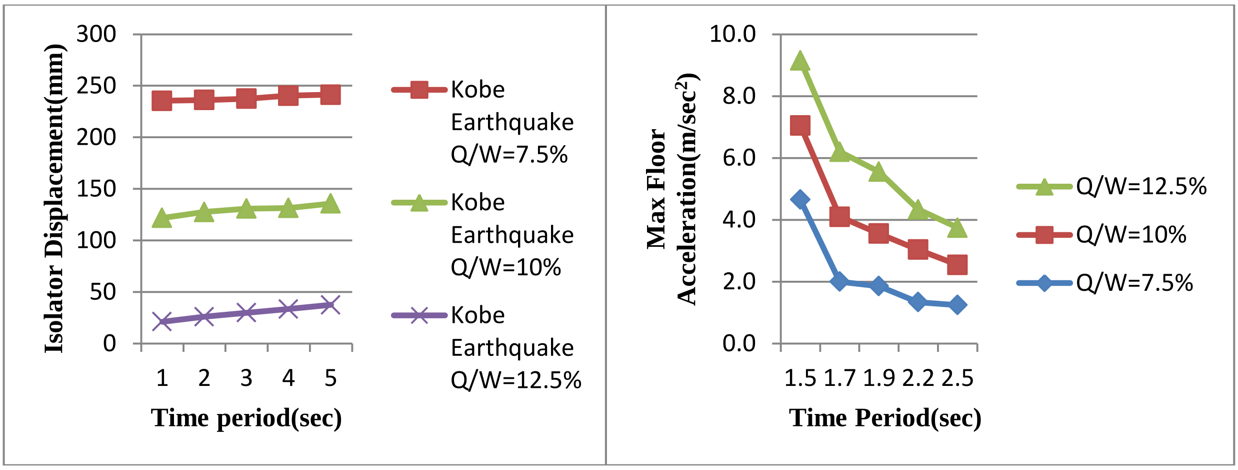


Fig:11 Comparison of time Vs Isolator Displacement and Max. Floor Acceleration for Q/W=7.5%,10%,12.5% under NF ground motion.

In order to distinguish the difference in the displacement of the LRB system under NF and FF direction earthquake Motion. Comparing the Isolator Displacement values produced by NF and FF excitations, it is observed that the way those motions excite the whole structure is different. Positive effects of the base isolation system are presented under FF excitation. By shifting the fundamental period of the structure, better response is achieved. As the Max Floor Acceleration values provide an accepted measure of the potential for both non-structural and structural damage in buildings, we concentrate our attention on comparing the effect on the NF and FF motion excitation.

IV. CONCLUSION

In the present paper, different LRBs base-isolation devices are examined for their seismic performance in terms of bearing Displacement and Maximum Floor acceleration under near-fault and far-fault motions. Near-fault sites produce strong ground motions with undesirable effects on the base isolation system as well as on the response of the superstructure.

- For far field ground excitation, the displacement of structure is very negligible compare to near field ground excitation.
- Acceleration of structure is greater in near fault ground motion compare to far fault ground motion.
- Evaluation of two time history there are the different behaviors of building and Isolator.
- Isolator displacement decrease with increase in Q/W ratio, because increase in Q/W ratio the isolation becomes relative stiff so bearing displacement is reduced (because not many Force reversal cycle).
- Increasing the time period of isolation, Displacement increase due to decreasing in post yield stiffness.
- In Kobe japan earthquake Max floor acceleration initially higher value compare to Imperial Valley earthquake and then decrease with increasing time period. .Max. Floor acceleration is not influenced by varying Bearing yield strength of lead core.

V. ACKNOWLEDGMENT

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REFERENCES:

[1] Kelly JM. Earthquake-resistant design with rubber. 2nd edition. London: Springer-Verlag; 1997.
[2] Naeim F, Kelly JM. Design of seismic isolated structures; from theory to practice (UK): Wiley,1999.
[3] Jangid RS, Kelly JM. Base isolation for near-fault motions. Earthquake Engineering and Structural Dynamics 2001.
[4] Makris N, Black CJ. Dimensional analysis of bilinear oscillators under pulse-type excitations. ASCE Journal of Engineering Mechanics 2004.
[5] Providakis CP, Xirogiannis J, Stavroulaki M. Comparative studies on performance on base isolation devices for near fault ground motions. In: Kounadis A, Providakis C, Exadaktylos G, editors. Proceedings of 7th HSTAM international conference on mechanics. 2004. p. 281–7.