Performance of 2-D Frame Equipped With Base isolation System under Dynamic Loadings

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Abstract Building responses have become a major concern in design research. Passive control techniques are implemented to improve structure efficiency. The present research aims to assess the efficiency of base isolation system for a 2D frame and to enhance the performance of structures that are subjected to seismic ground excitations and ground vibrations induced by blast. Two moments of resistant RC frames were studied and output of the isolator (Lead / Rubber Bearing) was observed to reduce structural responses. In SAP2000 non-linear dynamic analysis is conducted to compare normal and irregular moment-resistant frames and structural responses with and without passive control techniques. Isolators are constructed based on time of isolation. Reduction of structural responses is assessed by passive control techniques, and comparative analysis is performed. Mitigating systemic retaliation is affected by the implementation of passive control system.

1. Introduction:

Improvements are being found worldwide in the field of structural engineering. There are many different types of structures being designed depending upon requirements. This is important that these systems are safeguarded from any damage causing events. The structural failure calamities such as earthquakes and blast were a big concern. Base isolation technique are the most commonly used methods of structural enhancement under complex loads in recent years, and Indian codes have developed some guidelines for blast load calculations based on their results. Based on location of the event, there are two types of blasting effects on the structure, ground induced vibrations and above ground vibrations. Non-linear time history analysis is carried out to study the structural reactions under dynamic loads.

In considering its intensity under European regulations, Draganic and Vladimir [1]. Studied the effects of Blast loading on structures. Blast load measurements are obtained from Ngo et.al [2]. The mechanisms and their impact on the structure. In Omprakash Reddy et al.[3], efficiency of momentary building resistance under dynamic loadings is studied. Blast loading parameters such as peak ground accelerations are determined using study of Ranjan et al[4] for different soil properties. Ruiyang and Brain observe the efficiency of the base isolated structure and its behavior under seismic loading [5]. Kangda and Bakre research LRB (Lead Rubber Bearing) insulator parameters and their performance under dynamic loads [6]. The technique of base isolation and its efficiency is observed in Kangda and Bakre [7]. In Manchalwar and Bakre [8,9], the use of passive control device (X-plate damper) and its effectiveness in mitigating the structural responses are studied for seismic loading. Manchalwar and Bakre determine optimal position for enhancing damper performance in energy dissipation [12, 13, 14].

Blast and Seismic Loading Calculations

As observed from the study made by Kangda and Bakre [5] blast loadings considered in present study are taken as ground accelerations ($\ddot{x}_g$) for which the time (t) is taken as exponentially decaying function as mentioned in below equation 1

$$\ddot{x}_g(t)= \frac{-1}{td} ve^{-t/td}$$

Where v is the peak particle velocity and t_d is the arrival time.

Peak particle velocity is calculated from empirical formulae obtained from the study of Deepankar et al [4] as given in Eq. 2 below,

$$v = \frac{f_C^{-0.642} SD^{-1.463}}{\gamma_D}$$

Where SD ($m/kg^{1/2}$) is the scaled distance and is determined as the ratio of distance from charge point R (m) to the root of charged weight of dynamic loading Q (kg) , t_d= R/c where c is the propagation wave velocity (m/s) in soil, f_c and γ_D are the material properties of granite rock deposits in soil.

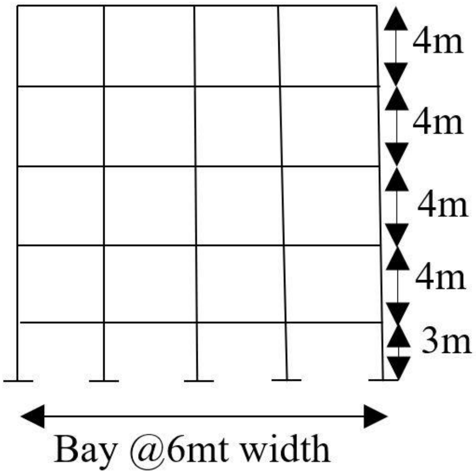
Seismic loadings considered of higher magnitude across the world namely imperial valley (magnitude 6.6, 1979), Loma earthquake, kern earthquake and Northridge earthquake (magnitude 6.7, 1994).

Analytical model

Two moments of resistant RC frames, i.e. normal and irregular frames were considered from the Mondal.et.al [15] and subjected to considered loadings to test efficiency of base isolation. In Indian code IS 1893, irregular frame configuration is studied. For a time interval of t=0.0005, all seismic and blast loadings are called ground accelerations as blast activity occurs in a few milliseconds. Analysis of the nonlinear time history is carried out in SAP2000. These considered structures' structural behaviour against dynamic loadings is obtained and shown in table 1 and 2. The foundation insulation device is then introduced into the structure and comparative work is carried out on their performance under dynamic load

Base-Isolation System-Regular and Irregular Structure

Base isolation technique is one of the popular methods to reduce structural responses for dynamic loading. Base isolation reduces structural displacements and also dissipates the amount of energy incurred in the structure and also provides decoupling to the structure which reduces structural reactions for dynamic loading. In present work isolators are constructed according to the structural period of the structure i.e., Tb= 2Ts, Tb= 2.5Ts, and Tb= 3Ts where Tb is the period of isolation and Ts is the structural period and isolator properties are considered as shown in table no.3. The findings show the efficiency of the use of lead rubber bearing insulator in minimizing structure displacements for both normal and irregular buildings. It is observed that for considered column C1 percentage reduction in base shear is between 80 to 90 percent for both dynamic loads and also reduction in bending time is between 50 to 60 percent for blast loading and 20 to 60 percent for seismic loading in both regular and irregular structures as shown below.



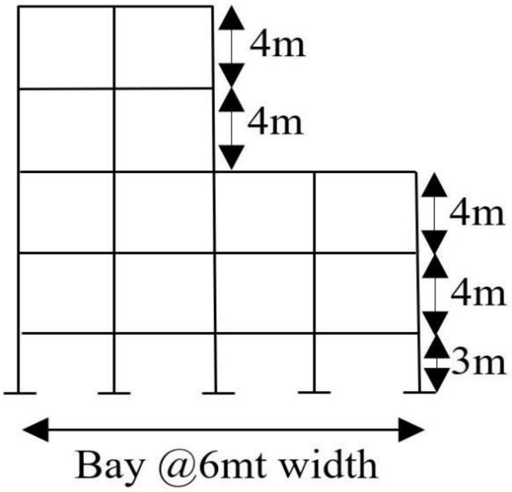


Table 1 Isolator properties for regular and irregular buildings (Tb = 3Ts)

Isolator properties	Regular Building					Irregular Building				
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 1	Column 2	Column 3	Column 4	Column 5
Effective Stiffness (K_{eff})	153.54	231.557	230.458	231.557	153.54	152.92	232.30	199.01	140.06	88.34
Yield stress (Q)	17.18	25.9	25.79	25.9	17.18	17.1	25.9	22.25	15.66	9.87
Post yield stiffness ratio (α)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 2 Peak responses of fixed-base regular building under dynamic loadings

Ground Excitation	Peak top Storey drift(mm)	Peak top Storey displacement(mm)	Peak top Storey absolute acceleration(m/s^2)	Peak maximum bending moment (kNm)	Peak maximum base shear(kN)
Blast1	5.45	42.384	22.34	9955.16	669.085
Blast2	10.661	82.85	43.68	19459.96	1307.09
Blast3	17.701	137.561	72.52	32310.6	2171.59
Blast4	23.813	185.058	97.56	43466.61	2921.38
Imperial Valley	4.782	50.984	8.05	8652.40	717.864
Kern	3.029	30.461	5.43	5596.566	475.927
Loma	1.862	19.046	3.46	3646.891	270.767
Northridge	21.322	195.504	47.28	45224.96	3354.37

Table 3 Peak responses of fixed-base irregular building under dynamic loadings

Ground Excitation	Peak top Storey drift(mm)	Peak top Storey displacement(mm)	Peak top Storey absolute acceleration(m/s^2)	Peak maximum base shear (kN)	Peak maximum bending moment (kNm)
Blast1	4.678	36.694	28.87	646.475	7971.72
Blast2	9.144	71.72	56.43	1263.702	15582..79
Blast3	15.182	119.094	93.70	2098.207	25873.13
Blast4	20.424	160.215	126.05	2822	34806.44
Imperial Valley	4.745	34.048	10.83	498.429	5970.80
Kern	3.07	23.007	6.47	325.786	3956.77
Loma	3.017	18.886	6.71	279.447	3492.62
Northridge	24.669	167.297	56.82	2645.515	32161.5

Table 4 Performance of base-isolated regular building under dynamic loadings

Ground Excitation	T_b= 2T_S		T_b= 2.5T_S		T_b= 3T_S	
	Reduced maximum base shear (%)	Reduced maximum bending moment(%)	Reduced maximum base shear (%)	Reduced maximum bending moment(%)	Reduced maximum base shear (%)	Reduced maximum bending moment(%)
Blast1	86.33	43.63	86.16	48.02	86.3	51.45
Blast2	94.79	58.59	94.08	64.16	93.5	67.3
Blast3	96.14	63.60	97	69.58	97.07	73.2
Blast4	95.53	65.16	96.8	71.31	97.57	75.3
Imperial Valley	85.58	56.54	85.78	60.822	86.34	57.499
Kern	77.12	26.42	78.14	35.02	82.47	45.71
Loma	75.03	24.204	79.67	20.69	84.59	45.72
Northridge	78.16	59.64	84	70.13	88.44	75.8

Table 5 Performance of base-isolated irregular building under dynamic loadings

Ground Excitation	T_b= 2T_S		T_b= 2.5T_S		T_b= 3T_S	
	Reduced maximum base shear (%)	Reduced maximum bending moment (%)	Reduced maximum base shear (%)	Reduced maximum bending moment (%)	Reduced maximum base shear (%)	Reduced maximum bending moment (%)
Blast1	87.05	43.50	88.68	47.83	87.07	51.43
Blast2	95.17	58.78	94.41	63.71	93.89	67.26
Blast3	96.38	63.13	97.19	69.37	97.28	73.08
Blast4	95.75	64.85	97.04	70.90	97.71	75.06
Imperial Valley	75.85	37.61	76.26	43.66	77.18	38.74
Kern	66.5	20.03	75.90	34.75	74.22	46.61
Loma	70.63	21.2	67.93	21.85	81.60	20.26
Northridge	72.63	48.86	79.966	61.98	85.52	69.23

Table 6 Percentage of energy dissipated by the passive system installed in regular buildings

Passive System	Blast 1	Blast 2	Blast 3	Blast 4	Imperial Valley	Loma	Kern	Northridge
LRB(T_b=2T_s)	69.83	72.88	66.04	63.98	49.88	57.14	28.07	52.48
LRB(T_b=2.5T_s)	65.86	73.44	70.45	65.85	49.65	43.41	17.07	59.12
LRB(T_b=3T_s)	60.46	72.99	71.81	67.80	47.47	23.23	30.34	60.46

Table 7 Percentage of energy dissipated by the passive system installed in irregular buildings

Passive System	Blast 1	Blast 2	Blast 3	Blast 4	Imperial Valley	Loma	Kern	Northridge
LRB(T_b=2T_s)	70.14	72.87	65.95	64.08	50.38	58.08	29.06	52.33
LRB(T_b=2.5T_s)	65.84	73.49	69.67	64.87	49.88	43.27	17.29	57.01
LRB(T_b=3T_s)	60.93	73.10	71.79	67.71	47.82	24.11	30.82	60.40

Structural responses for base isolated structures such as decrease in percentage of storey drifts, decrease in top storey displacements and accelerations as per loads for different time devices are compared and are plotted for both regular and irregular structures in figures 1, 2 and 3 as shown below. It is observed that the efficiency of storey drift isolators is between 30% to 90% for regular frames and, as for irregular frames, the isolators considered have shown greater efficiency as storey drift reductions have increased to and above 90%. Reductions in top-storey displacements and accelerations for various isolators are also between 70 percent and 90 percent as seen for both regular and irregular structure. This study also includes the comparison of force displacement for different isolators; with the less shear force resulting in maximum energy dissipation can be observed for both regular and irregular buildings in case of blast loading as shown in figures 4 and 5 below. The study also includes the observation of the amount of hysteretic energy dissipated by various isolators used in figures 6 and 7 for both structures. The isolator with Tb= 3Ts is proved to be more effective for both normal and irregular sets, as observed from results obtained.

The hysteretic energy is evaluated using the concept of energy-conversion equation proposed by Uang and Bertero [16] and given by Equation 1, where Ei is the absolute input energy, EK is the absolute kinetic energy; it is the elastic energy of recoverable strain; the non-negative damping energy is expressed by E.

$$E_i= E_K+ E_s+ E_\xi+ E_h$$

$$Eh = \int_0^t Fbxdt - \frac{(Fb)2}{2kb}$$

$$Ed = \frac{100Eh}{Ei}$$

The irrecoverable hysteretic energy (Eh) is measured using an Eq.3 where Fb is the restore force produced in the isolating device and kb is the rigidity of the isolating device. Equation 4 also gets the percent dissipated energy (Ed) by the vibration management technique. It is also found that in the case of seismic excitations an increase in the isolation time reduces the dissipated energy along with the input energy**.**

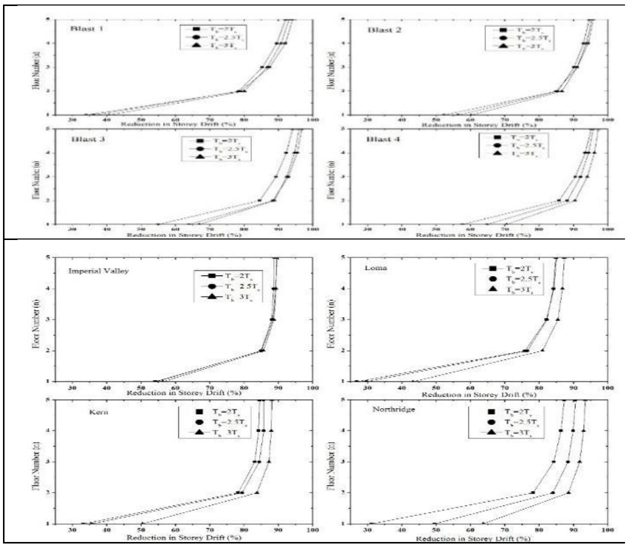


Fig 1 Reduction in Storey Drift (%) in base-isolated regular building under dynamic excitations.

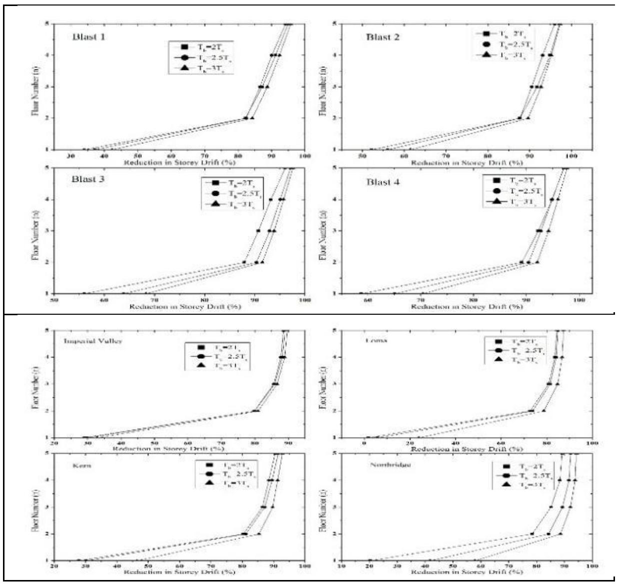


Fig.2 Reduction in storey Drift (%) in base-isolated irregular building under dynamic excitations.

Regular Base-Isolated Building	Irregular Base-Isolated Building

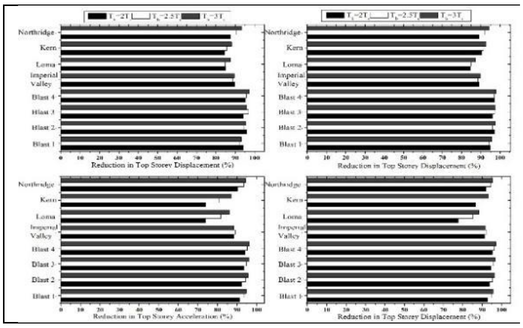


Fig 3 Performance of base-isolated buildings under dynamic excitation.

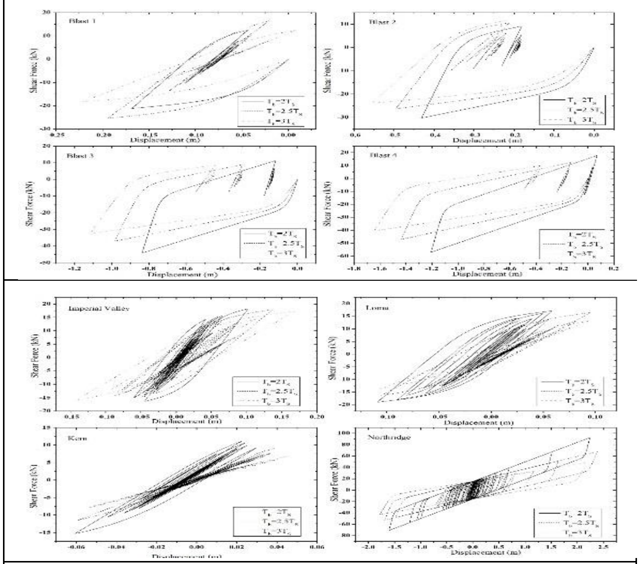


Fig 4 Force displacement behaviour of lead/rubber isolators under selected ground excitations (regular building).

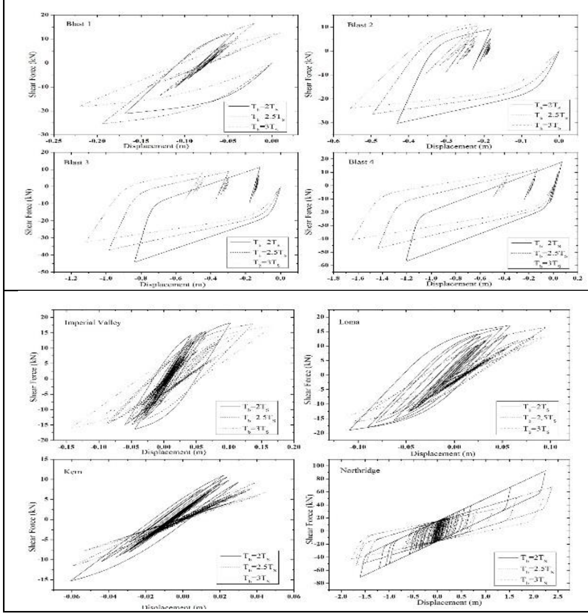


Fig 5 Force displacement behaviour of lead/rubber isolators under selected ground excitations (regular building).

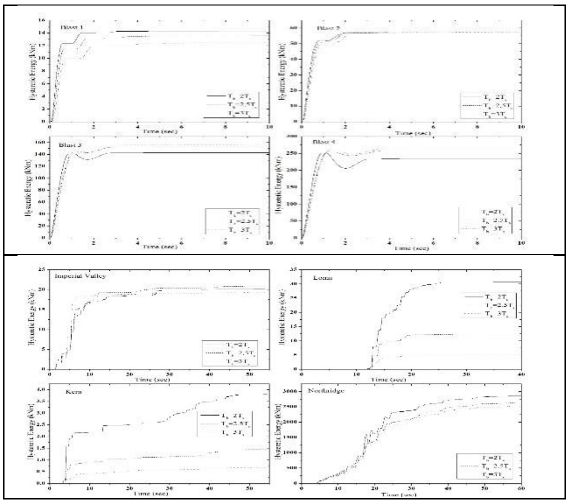


Fig 6 Energy dissipated by base isolation system in mitigating structural responses under selected excitations (regular building).

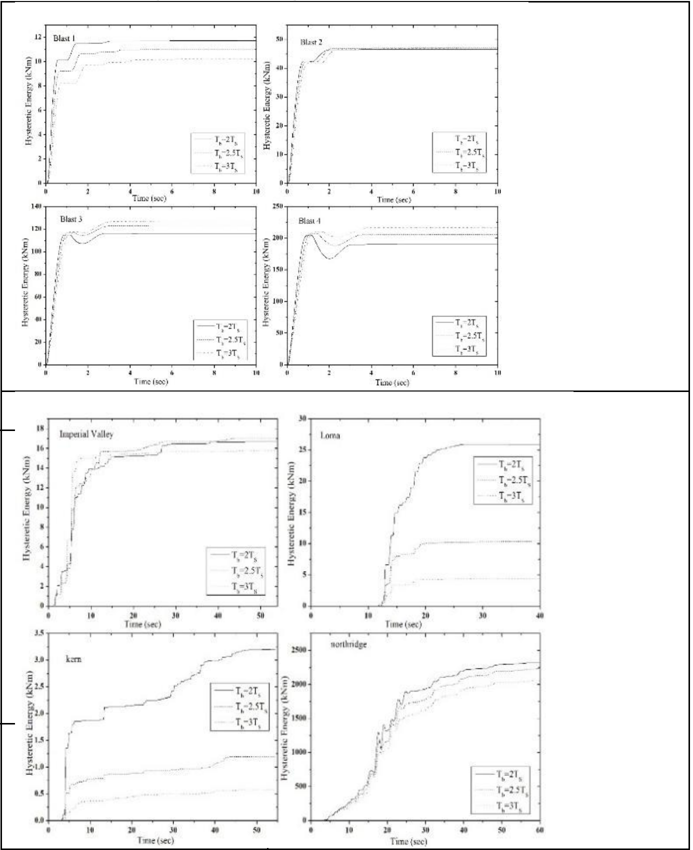


Fig 7 Energy dissipated by base isolation system in mitigating structural responses under selected excitations (regular building)

Conclusion

This research evaluates the performance of passive control techniques, i.e., base insulation system (e.g., LRB) and viscous fluid damper (FVD's). RC frames of G+4 are considered and subject to dynamic loadings with regular and irregular conditions. As ground accelerations and seismic loading used are collected from the database, blast loading on frame is considered to be exponential decaying function. Isolator is planned as per isolation period i.e. Tb= 2Ts, Tb= 2.5Ts, and Tb= 3Ts where Tb is the isolation duration and Ts is the structural duration for improving its performance and the results obtained are compared to frames fitted with a damper and the following conclusions are obtained. LRB isolators used for various periods of isolation have been shown to be efficient in dissipating the structural responses and it is found that isolators are more efficient for irregular frame than normal frame. Isolator with Tb= 3Ts isolation time has maximum percentage in structural response reduction.

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