Seismic Performance of Base Isolated Multi-Storey Building

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Abstract: During the last two decades considerable advances have been accomplished in the area of seismic protection of structures. These systems also known as earthquake-protection system consisting of passive, active, semi-active or hybrid devices and can considerably minimize the seismic effects on structures. The horizontal decoupling of the structure achieved through insertion of bearings at foundation level, transfers it in to lower frequency range and dissipates the energy through damping, the technique is known as base-isolation**.** The paper presents comparative study of performance of three types of base isolators namely High Damping Rubber bearing (HDRB), Low Damping Rubber bearing(LDRB) and Lead Rubber Bearing (LRB).A 8-storey building has been analysed using Response Spectrum Method. Dynamic analysis has been done using STAAD Pro software. Parameters like Base shear, Building displacement, frequency, storey drift and spectral acceleration are compared for isolated building and non isolated building.

Keywords: Base isolation, damping, energy dissipation, response spectrum, stiffness.

Introduction:

The base isolation technique is a seismic design approach in which, due to the insertion of a flexible layer between the foundation and the superstructure, the fundamental frequency of the system decreases to a value lower than the predominant energy containing frequencies of earthquake ground motion. In addition, the damping capacities provided by the isolation systems help dissipate the energy imparted during seismic activities.

Seismic base isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important building such as schools, hospitals, industrial structures, multi-storey buildings etc. In order to minimize inter storey drifts, in addition to reducing floor accelerations; the concept of base isolation is increasingly being adopted. Base isolation (BI) has also been referred to as passive control.

High Damping Rubber Bearing:

HDRB is one type of elastomeric bearing. This type of bearing consist of thin layers of high damping rubber and steel plates built in alternate layers as shown in Figure. Horizontal stiffness of the bearing is controlled by the low shear modulus of elastomer while steel plates provides high vertical stiffness as well as prevent bulging of rubber. High damping rubber bearing provides damping in the range of 10% to 20%.

Fig. 1 Typical High Damping Rubber Bearing

Low Damping Rubber Bearing:

Rubber bearings have two steel endplates and many thin steel shims interbedded with the rubber. The steel shims can provide the capability of the vertical stiffness but have no effect on the horizontal stiffness, which is dominated by the shear modulus of elastomer. The material in shear is quite linear up to shear strains above 100% with damping in the range of 2-3%. Using this device, it is also possible to manufacture isolators with no damping, which means that the isolators have exactly linear shear behavior**.**

Lead rubber bearing:

A lead-rubber bearing is formed of a lead plug force-fitted into a pre-formed hole in an elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads. When subjected to low lateral loads such as minor earthquake the lead-rubber bearing is stiff both laterally and vertically. The lateral stiffness results from the high elastic stiffness of the lead plug and the vertical rigidity. A major advantage of the lead-rubber bearing is that it combines the functions of rigidity at service load levels, flexibility at earthquake load levels and damping into a single compact unit.

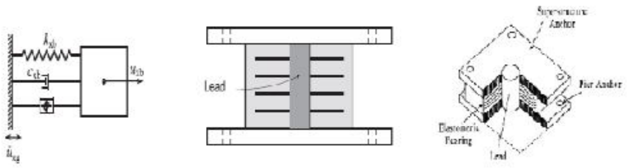

Fig. 2 Typical Lead Rubber Bearing

Modeling of a structure:

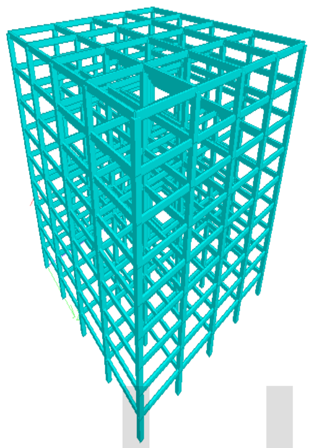

Fig. 3 A 3D Model of 8-storey office building

Fig. 3 shows mathematical model of 8-storey building prepared in STAAD Pro software. The building is an ordinary moment resisting frame, located in zone V with response reduction factor as 3. The building is resting on a medium soil.

Description of Building:

A eight-storey reinforced concrete office building is located on a medium soil

Storey height : 3m
Size of beams : 0.23m x 0.5m
Size of columns : 0.5m x 0.5m
Thickness of wall : 0.15m
Thickness of slab : 0.15m
Dead load : 8 KN/m
Live load : 2.5 KN/m^2
Density of concrete : 25 KN/m^3
Modulus of elasticity : 25000 N/mm^2
fck : 25 N/mm^2
fy : 415 N/mm^2
Span width in X – direction : 6m (4–bay)
Span width in Z – direction : 6.5m (4–bay)

By a static analysis using the software (STADDPro program) the loads are computed for all the columns at their base, where the bearings are to be installed. The maximum load on column is 4745 KN. The weight of structure is 10072.6 KN. The maximum relative displacement is 114mm.

TABLE I - DETAILS OF BEARING

Sr. No.	Dimensions of Bearing	HDRB	LDRB	LRB
1	Diameter of Bearing	500mm	600mm	740mm
2	Thickness of individual rubber layer	12mm	15mm	17mm
3	Numbers of rubber layer	21	17	38
4	Thickness of individual steel plates	2mm	2mm	2mm
5	Numbers of steel plates	20	16	37
6	Thickness of top and bottom steel plates	25mm	25mm	25mm
7	Total height of bearing	342mm	337mm	770mm
8	Diameter of lead core	-	-	100mm

Table I shows dimensions of bearing which are calculated on the basis of required stiffness. Time period is assumed to be 2 sec.

Stiffness of HDRB : 809KN/m
Stiffness of LDRB : 780KN/m
Stiffness of LRB : 445KN/m

Comparative study with and without base isolator:

TABLE II
FREQUENCY OF BUILDING WITH AND WITHOUT ISOLATOR

Mode	Frequency(Cycles/sec)			
	With Fixed Base	With HDRB	With LDRB	With LRB
1	0.926	0.561	0.509	0.407
2	0.957	0.766	0.761	0.696
3	1.075	0.926	0.926	0.926
4	1.335	1.254	1.254	1.249
5	1.691	1.431	1.428	1.391
6	1.754	1.754	1.754	1.754

Table II shows values of frequencies for their respective modes that are obtained by dynamic analysis of structure by response spectrum method for building with fixed base and building isolated with different isolators.

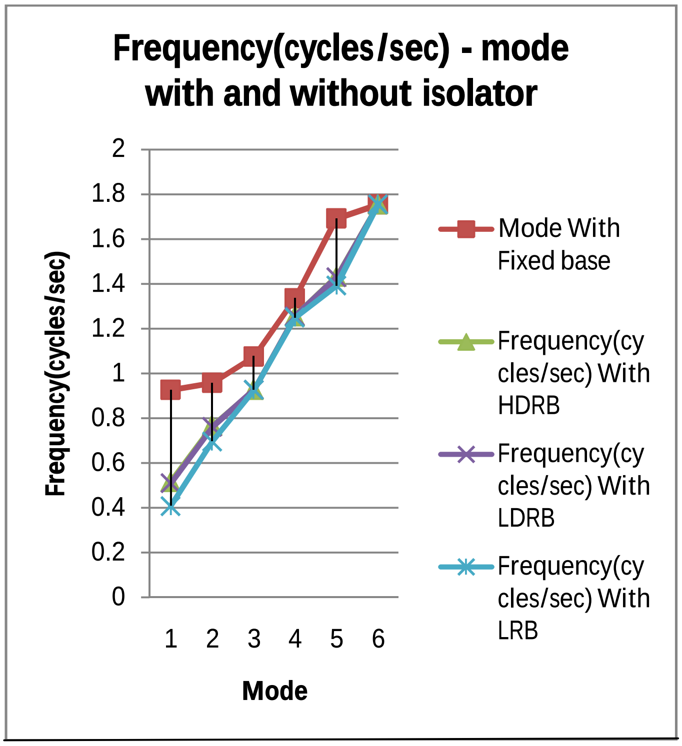

Fig. 4 Comparative graph of Frequency-mode no.

Fig. 4 shows Frequency (cycles/sec)-mode shape graph. It is seen that frequency has reduced due to insertion of base isolators in a building.

TABLE III
SPECTRAL ACCLERATION OF BUILDING WITH AND WITHOUT ISOLATOR

Mode	Spectral Acceleration			
	With Fixed base	With HDRB	With LDRB	With LRB
1	1.2598	0.7013	0.6918	0.5530
2	1.3018	1.0414	1.0350	0.9463
3	1.4620	1.2598	1.2598	1.2598
4	1.8154	1.7060	1.7054	1.6980
5	2.2995	1.9464	1.9425	1.8915
6	2.3849	2.3849	2.3849	2.3849

Table III shows spectral acceleration values in different modes. Values shows that acceleration reduces in fundamental modes by providing base isolators.

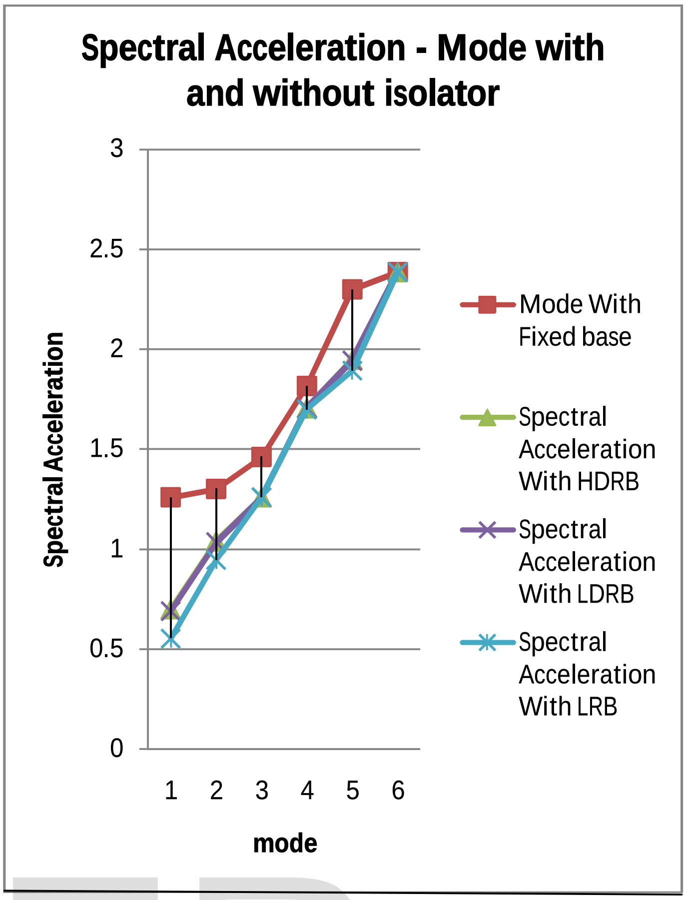

Fig. 5 Mode-spectral acceleration graph

Fig. 5 shows mode-spectral acceleration graph of building with fixed base and with base isolators.

TABLE IV
PEAK STOREY SHEAR OF BUILDING WITH AND WITHOUT ISOLATOR

Floor	Peak Storey Shear(KN)			
	With Fixed base	With HDRB	With LDRB	With LRB
10	156.04	74.05	72.86	56.12
9	305.89	147.24	144.89	111.84
8	445.54	219.00	215.56	166.88
7	570.81	288.73	284.27	220.96
6	677.86	355.80	350.44	273.78
5	763.42	419.62	413.49	325.04
4	825.05	479.65	472.92	374.48
3	861.51	535.51	528.34	421.90
2	874.61	587.26	579.81	467.32
1	874.61	587.26	579.81	467.32

Table IV shows Peak storey shear values for isolated and non isolated building. Base shear is an important parameter to be extracted in response spectrum method.

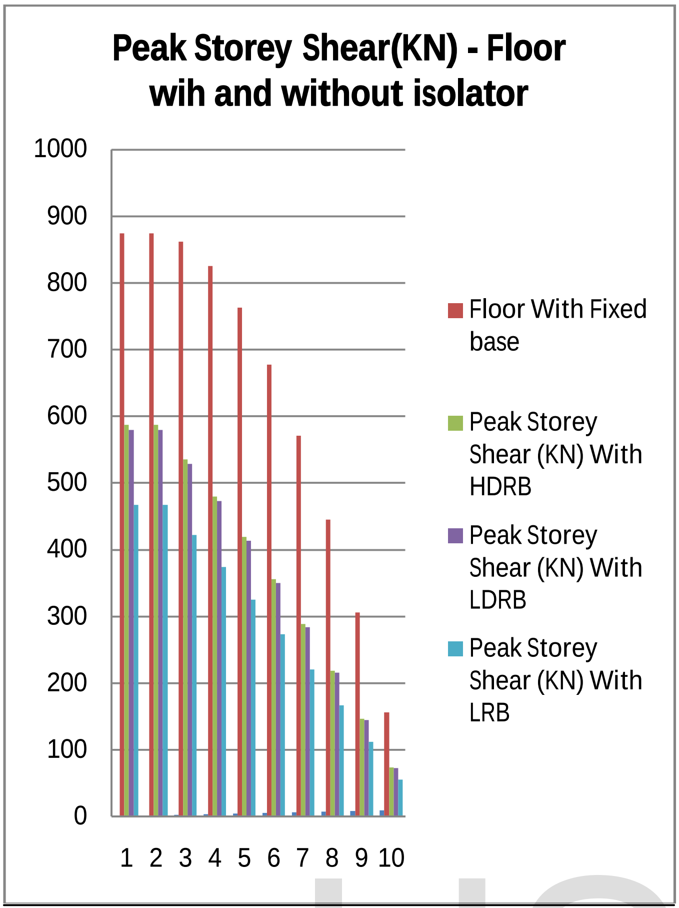

Fig. 6 Floor No.-Peak storey Shear Graph

Fig. 6 shows values of peak storey shear at different floors for isolated and non isolated building. It is seen that base shear is maximum at the base.

TABLE V
AVERAGE DISPLACEMENT OF BUILDING WITH AND WITHOUT ISOLATOR

Floor	Avg. Displacement(cm)			
	With Fixed base	With HDRB	With LDRB	With LRB
1	0	9.6759	10.0363	17.5907
2	0.4896	10.1483	10.5078	18.0601
3	1.3698	10.9559	11.3147	18.8587
4	2.3125	11.7742	12.1320	19.6622
5	3.2114	12.5155	12.8720	20.3850
6	4.0180	13.1517	13.5067	21.0013
7	4.7020	13.6721	14.0257	21.5025
8	5.2417	14.0724	14.4248	21.8865
9	5.6243	14.3518	14.7033	22.1541
10	5.8571	14.5204	14.8714	22.3156

Table V shows comparative values of avg. displacement with different base isolators and without isolators. It can be seen that displacement has increased after provision of base isolator.

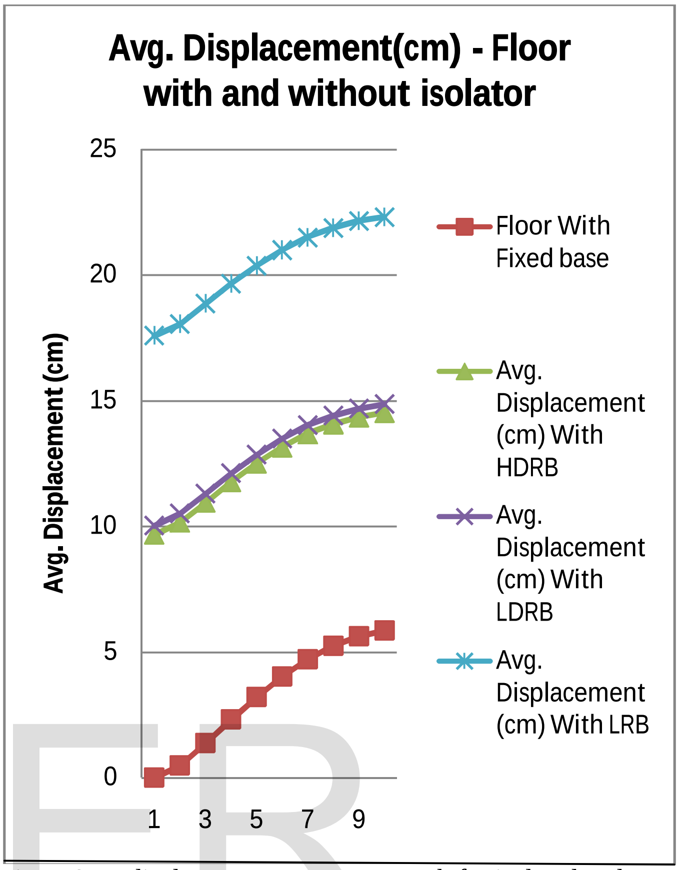

Fig. 7 Avg. displacement-srotey no. graph for isolated and non isolated building

Fig. 7 shows values of dispacement at different storey for isolated and non isolated building. Displacement increases with the height of building.

TABLE VI
STOREY DRIFT OF BUILDING WITH AND WITHOUT ISOLATOR

Floor	Storey Drift(cm)			
	With Fixed base	With HDRB	With LDRB	With LRB
1	0	0	0	0
2	0.4896	0.4471	0.4716	0.4694
3	0.8802	0.8075	0.8096	0.7985
4	0.9428	0.8183	0.8172	0.8035
5	0.8988	0.7414	0.7400	0.7229
6	0.8066	0.6362	0.6347	0.6163
7	0.6840	0.5204	0.5190	0.5012
8	0.5397	0.4003	0.3991	0.3840
9	0.3827	0.2794	0.2785	0.2676
10	0.2328	0.1686	0.1681	0.1615

Table VI shows values of storey drift at different storey. It is seen that storey drift is maximum at 9m height.

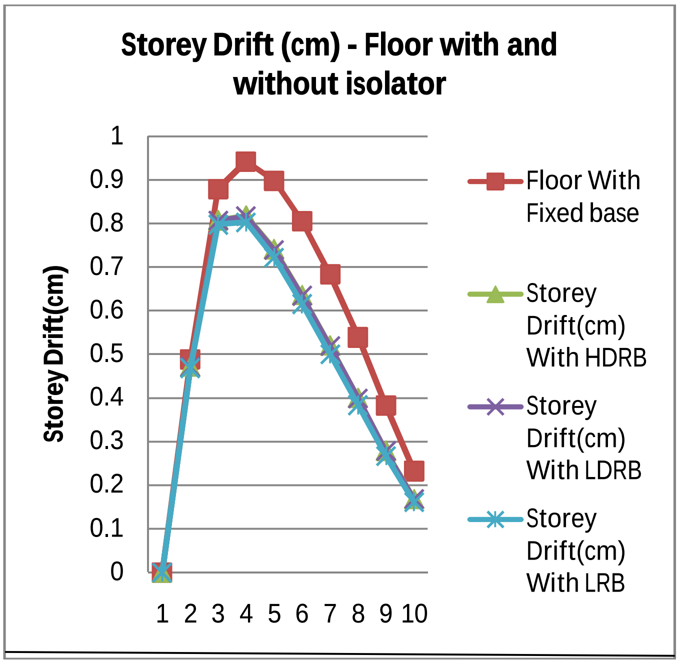

Fig. 8 Comparative graph of storey drift for isolated and non isolated building

Fig. 8 shows variation of storey drift at different storey level. Storey drift has reduced in isolated building as compared to non isolated building

Conclusion:

Dynamic Response Spectrum Analysis is carried out for 8-storey office building. The structure is analysed with fixed base and with different base isolator. Comparative study of different parameters like frequency, spectral acceleration, base shear, displacement and storey drift is carried out without provision of isolator and with provision of different base isolators. From the summary of results, it can be concluded that:

1) Frequency has reduced in base isolated building as compared to the fixed base building. Fundamental mode is more effective in seismic analysis. Frequency is minimum in LRB structure in fundamental mode as compared to HDRB and LDRB.
2) Acceleration has reduced when isolators are provided. LRB structure gives least acceleration compared to other two types of isolators.
3) The base shear reduces considerably in base isolated structure. There is 47% reduction in base shear when structure is isolated with LRB as compared to the fixed base building. The reduction in base shear are 33% and 34% respectively when structure is isolated with HDRB and LDRB as compared to the fixed base structure.
4) Displacement has increased in all three isolators compared to the non isolated structure. The Avg. displacement is maximum in Lead Rubber Bearing as compared to HDRB and LDRB.
5) Storey drift has reduced considerably by provision of isolator. The reduction in storey drift at 9m height are 13%,13% and 15% respectively for HDRB, LDRB and LRB structures as compared to the non isolated structure.
6) It can be concluded that performance of isolated building is better compared to the non isolated building.
7) Performance of Lead Rubber Bearing is better compared to the High Damping Rubber Bearing and Low Damping Rubber Bearing.

References:

[1] A. Calabrese, G. Serino, S. Strano and M. Terzo(2013), " Investigation of the Seismic Performances of an FRBs Base Isolated Steel Frame through Hybrid Testing," *Proceedings of the World Congress on Engineering 2013*, Vol III, WCE 2013, July 3 - 5, 2013, London, U.K.

[2] A. Dusi, M. Mezzi, K. Fuller, "The Largest Base-Isolation Priject in the World", *The 14th World Conference on Earthquake Engineering*, October 12-17, 2008, China.

[3] A.B.M.Saiful Islam, M. Jameel, Syed Ishtiaq Ahmad, Mohd Zamin Jummat(2011), "Study on Corollary of Seismic Base Isolation System on Buildings with Soft Storey", *International Journal of Physical Sciences*, Vol.6(11),pp. 2654-2661, 4 June, 2011

[4] Chauhan Kalpesh M. and Dr. B.J.Shah(2013), "Excel Spreadsheet for Design of Lead Rubber Bearing uses for Seismic Isolation of Bridges", *International Journal of Advanced Engineering Research and Studies*, Vol.II , Issue III, April-June 2013/60-62

[5] Dimitrios Konstantinidis, James M. Kelly and Nicos Makris," Experimental Investigation on the Seismic Response of Bridge Bearings".

[6] Evany Nithya S., Dr. Rajesh Prasanna P, "Moment Resisting Frame with Rubber Base Isolation for Development of Earthquake Resisting Structures, *International Journal of Modern Engineering Research*, Vol. 2, Issue 4, July-August 2012 pp-2431-2433.

[7] Ganga Warrier,Balamonica K., Sathish Kumar K and Dhanalakshmi(2015), "Study on Laminated Rubber Bearing base isolators for Seismic Protection of Structures", *International Journal of Research in Engineering and Technology*, Volume : 04, Issue : 02,Feb.- 2015.

[8] Harshita. R, A. Soundarya, Krishnareddygari Prathima, Y. Guruprasad(2014), "Seismic Analysis of Symmetric RC Frame Using Response Spectrum Method and Time History Method", *International Journal of Scientific Research and Education*, Volume 2, Issue 3, March 2014, pp 483-499.

[9] J.C. Ramallo, E.A Johnson, AM. ASCE and B.F. Spencer Jr. M. ASCE, "Smart Base Isolation Systems", *Journal of Engineering Mechanics*, October 2002.

[10] Julie S, Sajeeb R, "Performance of Base Isolators and Tuned Mass Damprs in Vibration Control of a Multistoried Building", *IOSR Journal of Mechanical and Civil Engineering*, ISSN 2278-1684 Vol. 2, Issue 6 (Sep-Oct 2012) PP 01-07.

[11] K S Sable, J S Khose and V P Kulkarni(2012), "Comparison of Different Bearing Types Performance in Multistoried Building ," *International Journal of Engineering and Innovative Technology (IJEIT)* Volume 1, Issue 4, April 2012.

[12] Katsumi Karita, Shigeru Aoki, Yuji Nakanishi, Kazutoshi Tominaga, Mitsuo Kanazawa, "Experimental Study of Base

Isolation System for Small Equipmens and its Evaluation", *Internaional Journal of Engineering Research and Applications(IJERA)* ISSN: 2248-962, Vol. 3, Issue 3, May-June 2013, pp. 166-173 166 page

[13] R.S. Jangid, "Performance of Base Isolation Systems for Asymmetric Building Subject to Random Excitation", 1993.

[14] S. Etedali, M.R. Sohrabi, "Torsional Strengthening of Base Isolated Asymmetric Structures by Increasing the Flexible Edge Stiffness of Isolation System", *International Journal of Civil and Environmental Engineering*, Vol. 11, N0: 02.

[15] S.J Patil, G.R. Reddy,"State Of Art Review-Base Isolation System for Structures", *International Journal of Engineering Technology and Advanced Engineering*, ISSN 2250-2459, Vol. 2, Issue 7, July 2012.

[16] Sarvesh K. Jain, Shashi K. Thakkar, "Application of Base Isolation for Flexible Buildings", *13th World Conference on Earthquake Enginnering*, August 1-6, 2004 Paper No 1924.

[17] Syed Ahmed Kabeer and Sanjeev Kumar K.S(2014) , "Comparison of Two Similar Buildings with and without Base Isolation", *International Journal of Advanced Research, Ideas and Innovations in Technology*, Volume I, Issue I, Oct- 2014.