Journal of Science Engineering Technology and Management Science
Volume 02, Issue 08, August 2025 *ISSN: 3049-0952*
www.jsetms.com *DOI:10.63590/jsetms.2025.v02.i08.307-312*

PASSIVE VIBRATION CONTROL OF FRAMED STRUCTURES BY BASE ISOLATION METHOD USING LEAD RUBBER BEARING

V.Srinivas (Asst. Prof) [1]. Mamidala shivakumar. M Tech[2]
Siddhartha Institute of Technology & Sciences (SITS) Narapally village, Peerzadiguda, Hyderabad, Telangana 500088

To Cite this Article
V.Srinivas, Mamidala shivakumar, "Passive Vibration Control Of Framed Structures By Base Isolation Method Using Lead Rubber Bearing", Journal of Science Engineering Technology and Management Science, Vol. 02, Issue 08, August 2025,pp: 307-312, DOI: http://doi.org/10.63590/jsetms.2025.v02.i08.pp307-312
Submitted: 10-07-2025 *Accepted: 14-08-2025* *Published: 20-08-2025*

ABSTRACT
In recent years considerable attention has been paid to research and development of structural control devices with particular emphasis on mitigation of wind and seismic response of buildings. Many vibration-control measures like passive, active, semi-active and hybrid vibration control methods have been developed. Passive vibration control keeps the building to remain essentially elastic during large earthquakes and has fundamental frequency lower than both its fixed base frequency and the dominant frequencies of ground motion. Base isolation is a passive vibration control system.Free vibration and forced vibration analysis was carried out on the framed structure by the use of computer program SAP 2000 v12.0.0 and validating the same experimentally. The results of the free vibration analysis like time period, frequency, mode shape and modal mass participating ratios of the framed structure were found out. From modal analysis the first mode time period of fixed base building is found to be 0.56 sec whereas the first mode period of isolated building is found to be 3.11s (approximately 6 times the fixed-base period!). This value is away from the dominant spectral period range of design earthquake. Forced vibration analysis (non-linear time history analysis) was done to determine the response of framed structures and to find out the vibration control efficiency of framed structures using lead rubber bearing. Isolation bearings in this study are modelled by a bilinear model. Under favorable conditions, the isolation system reduces the interstorey drift in the superstructure by a factor of at least two and sometimes by a factor of at least five. Acceleration responses are also reduced in the structure by an amount of 55-75% although the amount of reduction depends upon the force deflection characteristic of the isolators. A better performance of the isolated structure with respect to the fixed base structure is also observed in floor displacements, base shear (75- 85% reduction), floor acceleration relative to the ground(less acceleration imparted on each floor and their magnitude is approximately same in each floor), roof displacement. Introduction of horizontal flexibility at the base helps in proper energy dissipation at the base level thus reducing the seismic demand of the super structure to be considered during design.

***Keywords**: Passive vibration control, Time history analysis, interstorey drift, yielded stiffness, Design basis earthquake.*

INTRODUCTION

1.1 Background

For seismic design of building structures, the traditional method, *i.e*., strengthening the stiffness, strength, and ductility of the structures, has been in common use for a long time. Therefore, the dimensions of structural members and the consumption of material are expected to be increased, which leads to higher cost of the buildings as well as larger seismic responses due to larger stiffness of the structures. Thus, the efficiency of the traditional method is constrained. To overcome these disadvantages associated with the traditional method, many vibration-control measures, called structural control, have been studied and remarkable advances in this respect have been made over recent years. Structural Control is a diverse field of study. Structural Control is the one of the areas of current research aims to reduce structural vibrations during loading such as earthquakes and strong winds.In terms of different vibration absorption methods, structural control can be classified into active control, passive control, hybrid control, semi-active control and so on (Appendix-VI). The passive control is more studied and applied to the existing buildings than the others. Base isolation is a passive vibration control system that does not require any external power source for its operation and utilizes the motion of the structure to develop the control forces. Performance of base isolated buildings in different parts of the world during earthquakes in the recent past established that the base isolation technology is a viable alternative to conventional earthquake-resistant design of medium-rise buildings. The application of this technology may keep the building to remain essentially elastic and thus ensure safety during large earthquakes. Since a base-isolated structure has fundamental frequency lower than both its fixed base frequency and the dominant frequencies of ground motion, the first mode of vibration of isolated structure involves deformation only in the isolation system whereas superstructure remains almost rigid. In this way, the isolation becomes an attractive approach where protection of expensive sensitive equipments and internal non-structural components is needed. It was of interest to check the difference between the responses of a fixed-base building frame and the isolated-base building frame under seismic loading. This was the primary motivation of the present study.

LITERATURE REVIEW

2.1Introduction: - Thus the modal analysis of framed Structure is of great technical importance for understanding the behaviour of the framed Structure under applied dynamic loading. The study of response analysis methodology (Experimental or Analytical) of a base isolated framed structure with a fixed base otherwise similar framed structure is essential to conclude the effectiveness of base isolation using rubber bearing.

"Earthquake proof structures" generally mean the structures which resist the earthquake and save and maintain their functions. The key points for their design includes select good ground for the site, make them light, make them strong, make them ductile, shift the natural period of the structures from the predominant period of earthquake motion, heighten the damping capacity.Izumi Masanory [1] studied on the remained literature, the first base isolated structure was proposed by Kawai in 1981 after the Nobi Earthquake (M=8.0) on journal of Architecture and building Science. His structure has rollers at its foundation mat of logs put on several steps by lengthwise and crosswise manually. After the San Francisco Earthquake (M=7.8) an English doctor J.A. Calantarients patented a construction by putting a talc between the foundations in 1909.

RESULT AND DISCUSSION

Modal Analysis of a Benchmark Problem

Modal analysis of a typical building structure frame is done to determine the dynamic parametres like natural frequency, time period, modal participating mass ratios and their corresponding mode shapes. Typical building structure frame (Fig. 10) made of reinforced concrete has four floors and composed of columns 3.0m height and of cross section 30×50 cm^2 with $I = 3.1\times10^{-3} m^4$, and beams with span of 4.5m, cross-section 24x55 cm^2, and inertia I

$= 3.5\times10^{-3} m^4$. The first natural frequency of the building is 2.3Hz.

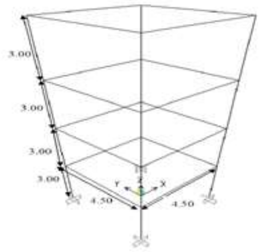

Fig. 10. Structural model of Building (from SAP window)

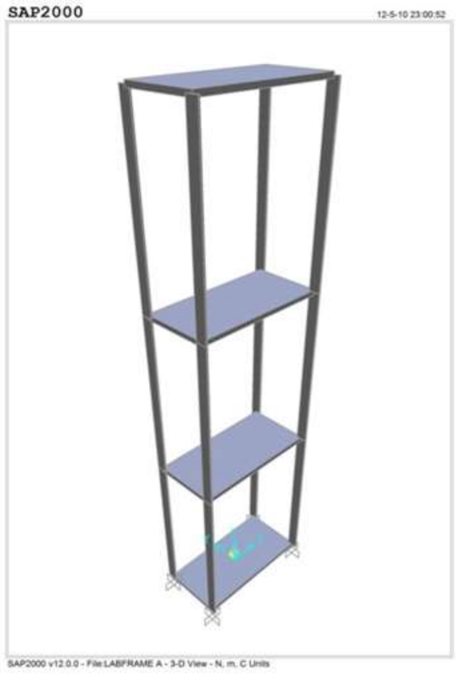

Fig. 11. Computational model of the Aluminium frame

Properties of the aluminum frame

- 3 storeys 1 bay 1 bay aluminum frame available in Structural Engineering laboratory, NIT Rourkela.
- Plan dimension of the building is 0.303m 0.148m with a storey height of 0.4 m.

  Typical floor plan of the building is given in Fig. 12.

- Columns are of rectangular size (2.5cm 0.3cm) directly supporting the slabs.
- Slabs having plan dimension 303mm 148mm and thickness 11mm. Shake table test:

Fig. 15. Experimental set up for the Shake table test.

SUMMARY AND CONCLUSION

SUMMARY

The investigation of dynamic properties of the framed structure, nonlinear response of framed structure under dynamic loading and effectiveness of base isolation of structure under dynamic loading are done and following conclusions achieved. This chapter first presents the modal analysis results of the benchmark problem. Then it discusses the free vibration analysis and time history analysis results of moment frame with fixed and isolated base subjected to Northridge Earthquake ground motion. The results show that the base isolation reduces the responses (displacement, velocity, acceleration, and inter-storey drift) drastically. Also, base isolation reduces the stiffness and thereby increases the fundamental period of the building to bring it out of the maximum spectral response region. Therefore it can be concluded from the results presented here that base isolation is very effective seismic control measures.

CONCLUSION

Modal analysis study: From the modal analysis study natural frequency and the mode shape of the framed structure is obtained. The determination of mode shape is essential to analyse the behaviour of the structure under applied dynamic loading. From the modal analysis of the Aluminium frame natural frequency, mode shapes and corresponding modal participating mass ratios are obtained. The mode shapes for which modal partiapting mass ratios are maximum taken into consideration. SAP 2000 is very effective tool to validate the results obtained experimentally. From the modal analysis first mode time period of fixed base building is found to be 0.56 sec whereas the first mode period of isolated building is found to be 3.11s (approximately 6 times the fixed-base period!). This value is away from the dominant spectral period range of design earthquake. Similar Shift was also observed in the higher modes, which shows the effectiveness of base isolation.

Time history analysis study: By conducting the nonlinear time history analysis it was shown that base isolation increases the flexibility at the base of the structure (Figs. 19 and 20), which helps in energy dissipation due to the horizontal component of the earthquake and hence superstructure's seismic demand drastically reduced as compared to the conventional fixed base structure. The lead core present at the centre increases the energy absorption capacity of the isolator (Fig. 3). The area of each cyclic loop represents the energy dissipated per cycle (Fig. 21). Here floor displacement and roof displacement response curves of the isolated structure are plotted which are equivalent and it indicates the rigidity of the superstructure above the isolator (Fig. 22). Base isolation reduces the base shear by 75-85% (Fig. 23) and reduces the velocity, acceleration response by 55-75% (Figs. 25 and 26). It also reduces interstory drift as compared to the conventional fixed base structure. It reduces the force imparted on the structure at each floor (Fig. 29) and the force imparted is equivalent at each floor as compared to the fixed base structure.

FUTURE SCOPE OF STUDY:

The vibration control technology is developing and its application is spreading in various fields of engineering structures. Factories, hospitals and residential houses will be protected from environmental vibration. It is evident that this technology will be progressed and become more important in the coming century.

In the present study natural frequency, mode shape, modal mass participating ratios of the structural model and nonlinear time history analysis was carried out to determine the behaviour of the structure under dynamic loading. Effectiveness of base isolation was studied by considering bilinear model of the LRB and modelling the same and superstructure by SAP 2000. The future scope of the present study can be extending as follows:

- Introduction of analysis software such as ETABS, SAP 2000 and LARSA help in explicit modelling of isolators which exhibit mildly nonlinear behaviour during dynamic loading.
- More research in earthquake time history records will help to study the behaviour of the structural model under a given loading.
- With recent advancement in material technology, more study can be focussed on material qualities used in isolators like their strength, durability, high vertical stiffness, low horizontal stiffness and high energy dissipating capacity.
- Development in testing methodology of the isolator to predict more accurate behaviour of the isolator under a given loading is of prime importance which needs a considerable attention in future.

A boom of base isolation study in Japan will be over soon, but more steady study and research will be continued for aiming earthquake free structures.

REFERENCES

1. Izumi Masanory. Base Isolation and passive Seismic response control, Proceedings of Ninth World Conference on Earthquake Engineering, VIII, (1988): pp. 385-396
2. Garevski A Mihail. Analysis of 3-D vibrations of the Base Isolated School Building "Pestalozzi" by analytical and experimental approach, Proceedings of Ninth World Conference on Earthquake Engineering, 12 (2000): pp. 1-8.
4. Murty C.V.R.. Earthquake Tips-Learning Earthquake Design and Construction, Kanpur, National Information Centre for Earthquake Engineering, 2009
5. Constantinou M. C. *et al.* Non-linear dynamic analysis of multiple building base isolated structures, Computers and Structures, 50, (1994): pp. 47-57
6. Jain S K and Thakkar S K. Effect of Superstructure Stiffening in Base Isolated Tall Buildings, IE (I) Journal.CV, 85, (2004): pp. 142-148
7. Jangid R. S. and Kulkarni Jeevan A.. Rigid body response of base-isolated structures, Journal of Structural Control, 9, (2002): pp. 171–188
8. Naharajaiah Satish and Sun Xiahong. Seismic Performance of base Isolated Buildings in the 1994 Northridge Earthquake, Eleventh World Conference on Earthquake Engineering, 598, (1996): pp. 1-8
9. Hang *et al.* Multifunctional vibration-absorption RC mega frame structures and their seismic responses, Earthquake Engineering and Structural Dynamics , 29, (2000): pp. 1239-1248
10. Mazza Fabio and Vulcano Alfonso. Base-Isolation techniques for the seismic protection of RC Framed Structures subjected to near-fault ground motions, 13th World Conference on Earthquake Engineering, 2935, (2004): pp. 1-14
11. Palazzo B. and Petti L. Reduction factors for Base Bsolated structures, Computers & structures, 60, (1996): pp. 94S-956.
12. Dutta T.K and Jangid R.S. Seismic Reliability of Base Isolated Building Frames, Eleventh World Conference on Earthquake Engineering, 491, (1996): pp. 1-8
13. Mei C. In-plane Vibrations of Classical Planar Frame Structures – an Exact Wave- based Analytical Solution, Journal of Vibration and Control, 16(9), (2010): pp. 1265– 1285
14. Nagarajaiah Et Al. Nonlinear Dynamic Analysis Of 3-D Base- Isolated Structures, Journal Of Structural Engineering, 117, (1991): pp. 2035-2054
15. Deb Sajal Kanti. Seismic base isolation – An overview, Current Science, 87, (2004): pp. 1426-1430
16. Kitagawa Yoshikazu et al. Experimental Study on Base Isolation Building using Lead Rubber Bearing

through vibration tests, Ninth World Conference on Earthquake Engineering, V, (1988): pp. 711-716

17. Shenton H. W. and Lin A. N. Relative performance of Fixed-base and Base-isolated concrete frames, Journal of Structural Engineering, 119, (1993),: pp. 2952-2968
18. Luciano M. Bezerra and Rodolfo C. Carneiro. A Numerical Evaluation of Anti- Vibration Mechanisms Applied to Frame Structures Under Earthquake, 17th International Conference on Structural Mechanics in Reactor Technology (SMIRT 17), 13-2, (2003): pp. 1-8
19. Kang Beom-Soo *et al*. Dynamic response characteristics of seismic isolation systems for building structures, Journal of Mechanical Science and Technology, 23 (2009): pp. 2179-2192
20. Ibrahim R.A. Recent advances in nonlinear passive vibration isolators, Journal of Sound and Vibration, 314 (2008): pp. 371–452