The Seismic Response Of Fixed Base And Base Isolated Structures

Mr. Annasaheb Nimse [1], DR. Satish B. Allampallewar [2]
Department of Civil Engineering
[1] G.H. Raisoni College of Engineering and Management, Pune, Maharashtra.
[2]Professor, G.H. Raisoni College of Engineering and Management, Pune, Maharashtra.

Abstract- *From the beginning of ancient period, we know the Earthquake is the transfer mechanism which influences the seismic performance of the structural elements of building due to unnecessary and intense lateral displacements of the building. Due to the lack of space, there is a new trend to construct the multi storey building in the seismic area. For the construction of the multi storey buildings in the earthquake prone area required effective lateral load resisting mechanism which withstands against the seismic forces at the time of earthquake otherwise structure may be subjected to massive damage as well as collapse. After many experimental investigations it has shown that performance of the structure increased greatly because use of the base isolation system in the building configuration. Due to advancement in the construction industry and efforts of the various researchers, a number of base isolation systems like Lead rubber bearing, Friction pendulum system, New Zealand bearing, Ressilient bearimg are available. The choice of the particular isolated system depends on the two fundamental parameters like seismic zone and budget for the construction. In present work the comparative study is carried out for the fixed base structure and base isolated structute using Lead rubber braing. The parametric study is carried out with the help of parameters like fundamental natural time period, storey drift, storey displacement, storey stiffness, and base shear. The linear dynamic analysis is performed by response spectrum method using SAP2000 software and Experimental study of fixed and Base Isolated Structure is performed by using Shake Table.*

Keywords- Base isolaion, Lead Rubber Bearing, Response spectrum method, Shake Table.

I. INTRODUCTION

In recent years base isolation has become a progressively applied structural design technique for buildings and bridges in high seismicity regions. Many types of structures like residential, commercial, industrial and institutional have been built using this approach, and many others are in the planning and design phases. Most of the structures are constructed with the use of rubber and frictional pendulum bearings. Base isolation is the separation of the base or substructure from the superstructure. It is also called Seismic isolation.

During theoretical analysis, certain set of assumptions regarding idealization of the material; boundary conditions etc. are required to be made to simplify the analysis to simulate the field conditions. However, these are not always true representation of what is happening in practice or field. It is observed that well engineered structures are also subjected to distress during earthquake. This happens due to the limitations in the analysis due to certain simplified assumptions. Therefore, in order to investigate the realistic behavior and to identify the various causes of distress in the structure, experimental study needs to be carried out which always gives a valuable insight with respect to limitations of various assumptions made while carrying out theoretical analysis of structures and the physical behavior of the structure. Present experimental study aims to analyze the effect of base isolation on a building frames subjected to harmonic vibrations, on scale-down experimental steel model prepared using similitude laws. The theory of similitude includes a consideration of condition under which the behavior of two separate entities or systems (model and prototype) will be nearly similar. Similitude is a tool to establish the sufficient and necessary condition of similarity between models and prototype.

II. REASEARCH OBJECTIVES

To study the influence of the LRB base isolated system on the linear dynamic characteristics subjected to the lateral earthquake by performing response spectrum analysis in SAP 2000 and Experimental study on Shake Table .

III. SCOPE OF WORK

The present study focuses on the analytical and Experimental investigation of the influence of the base isolated system with fixed base on the seismic response of the structure subjected to a lateral seismic load.

1. Study of types of base isolators, their constituent elements.

2. The comparative study between base isolated structure and fixed base structure is carried out by Experimental and Analytical Study using Shake Table and SAP 2000.
3. The parametric analysis was carried out to study the linear dynamic characteristics considering different isolated systems used in the structure using Response spectrum method.
4. To design and study the effectiveness of lead rubber-bearing used as base isolation system.

IV. PROBLEM STATEMENT

The analytical and Experimental investigation of the influence of the LRB base isolated system on the seismic response of the structure subjected to a lateral seismic load. The comparative study between base isolated structures and fixed base structures is carried out using SAP 2000 and Shake table. The parametric analysis was carried out to study the linear dynamic characteristics considering LRB isolated system used in the structure using Response spectrum method. The following data is used for analysis:-

RC frame details:

- No. of stories: Four
- Floor to floor Height: 3.5 m
- Type of Building: Commercial
- Size of Beams: 230 X 400 mm
- Size of Columns: 300 X 450mm
- The thickness of Slab: 150mm

Seismic details:

- Type of Frame: RC building with SMRF
- Earthquake zone: Zone IV
- Type of soil: Medium [Type-II as per IS1893:2016]
- Importance factor: 1 [Table no. 8 IS1893:2016]
- Response reduction factor: 5
- Damping of structure: 5%
- Response spectra: As per IS1893:2016
- Time period: 0.075(H) 0.75 [MRF]

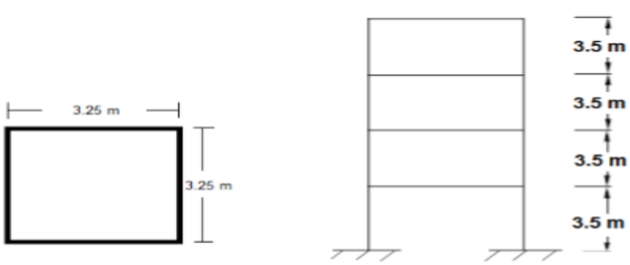

Figure 1: Plan and Elevation of the building with fixed base

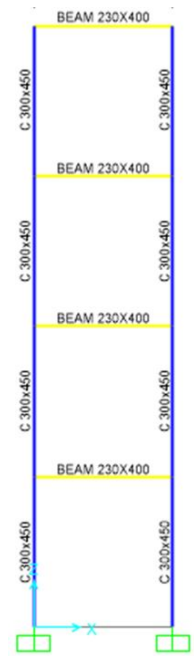

Figure 2: Elevation of the building with fixed base

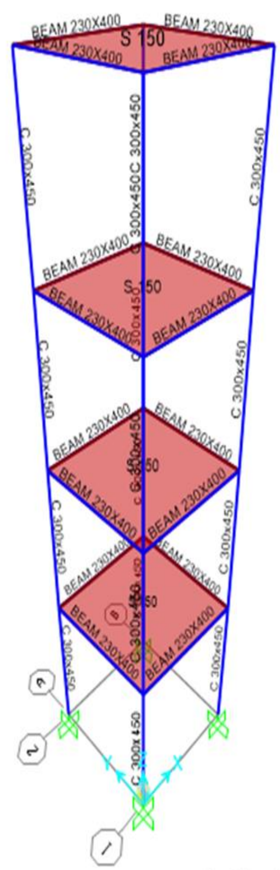

Figure 3: 3D view of building with fixed base

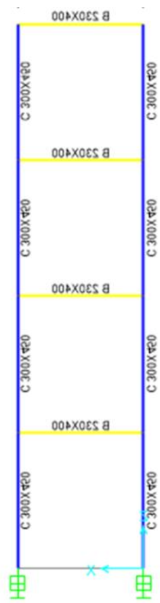

Figure 4: Elevation of the building with LRB

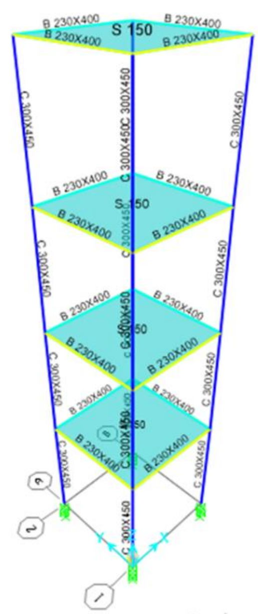

Figure 5: 3D view of building with LRB

V. ISOLATOR USED

Lead Rubber Bearing :

It 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. Top and bottom steel plates, thicker than the internal shims, are used to accommodate mounting hardware. The entire bearing is encased in cover rubber to provide environmental protection.

When subjected to low lateral loads (such as a minor earthquake, wind or traffic loads) 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 (which remains at all load levels) result from the steel-rubber construction of the bearing. The period shift effect characteristic of base isolation system developed due to a higher load levels the lead yields and the lateral stiffness of the bearing is significantly reduced. As the bearing is cycled at large displacements, such as during moderate and large earthquakes, the plastic deformation of the lead absorbs energy as hysteretic damping. The equivalent viscous damping produced by this hysteresis is a function of displacement and usually ranges from 15% to 35%.

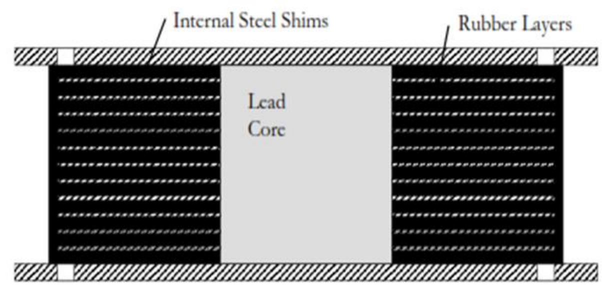

Figure 6: Lead rubber bearing section (A.B. M. Saiful Islam et.al)

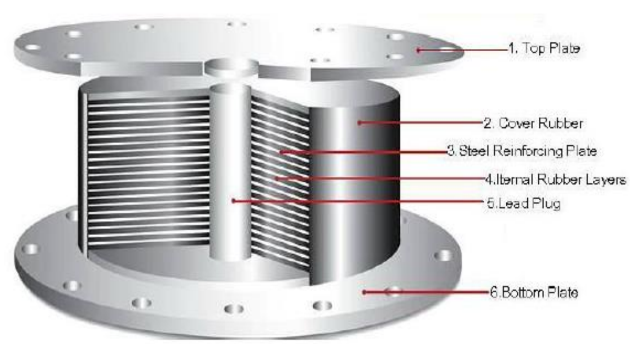

Figure 7: Components of the L R B (A.B. M. Saiful Islam et.al)

A major advantage of the LRB system is it combines the functions of rigidity at service load levels, flexibility at earthquake load levels and damping into a single compact unit. These properties make the lead-rubber bearing the most common type of isolator used where high levels of damping are required (in high seismic zones) or for structures where rigidity under services loads is important (for example, bridges). As for HDR bearings, the elastomeric bearing formulas are also applicable for the design of LRBs.

Table 1: Parameters of the LRB system

Parameters in U_1 Direction	
Linear Effective Stiffness	376025.5 KN/m
Effective Damping	0.05
Parameters in U_2 and U_3 Direction	
Linear Effective Stiffness	752.051 KN/m
Effective Damping	0.15
Non Linear Effective Stiffness	5686.6621 KN/m
Yield Strength	156.9144 KN
Post Yield Stiffness Ratio	0.1

VI. METHOD OF ANALYSIS

To know the linear dynamic behaviour of the different framing system response spectrum method is used in SAP 2000.

Response spectrum method:

To know the topmost response of the building during the earthquake is obtained from the response spectrum method. This method gives earthquake response spectrum based on the type of soil condition. This method provides an approximate response but it is very beneficial for the structural design aspect. This method reflects the distribution of the forces up to the elastic range efficiently and also shows the effect of the higher modes of vibration. This method is applicable for the regular and irregular building without any height restrictions.

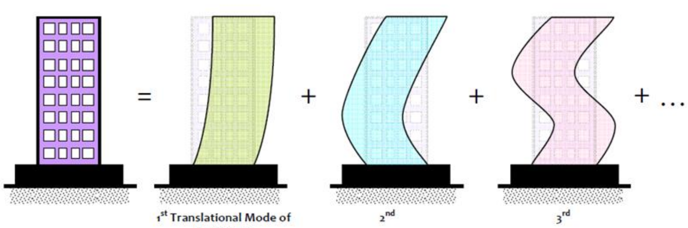

Figure 8: Idealisation of Response spectrum method

Shake table:

Shake Table is a most appropriate experimental set up for the prediction of seismic behavior of various civil engineering structures. Structural models are directly subjected to dynamic excitations resembling those expected to be encountered in a real time earthquake event. It is possible to realistically simulate the effect of seismic forces on the test structures on Shake Table. The full dynamic loading property makes Shake Table testing an effective tool in the research field. There are two significant challenges for adopting the Shake Table technique, firstly, dynamic similitude scaling requirements, and secondly, the control of table motions to ensure the reproduction of target accelerations. Shake Tables are capable of producing motion in only one horizontal direction (uniaxial), in one horizontal and the vertical direction (biaxial) or in both horizontal direction and the vertical direction (triaxial) simultaneously. Triaxial Tables are the most realistic but are more expensive. Therefore, much of the research is been consequently done on Uniaxial or Biaxial Tables. Uniaxial Shake Tables are ideal for performing seismic simulation, soil liquefaction and vibration tests on models as well as for engineering qualification of components and assemblies for earthquake and vibration resistance. Modern tables typically consist of a rectangular platform that is driven in up to six degrees of freedom (DOF) by servo- hydraulic or other types of actuators.

Figure 9: Shake Table for Experimental Study

Table 2: Specifications of shake table

Sr.No.	Particulars	
1	Motion	Horizontal
2	Table size	400 X 400 mm
3	Capacity	30 kg
4	Operating frequency	0-25 Hz
5	Frequency Control	+/- 5%
6	Amplitude	0-10 mm
7	Accelerometers	Dual axis 2 g, 100 Hz-4nos
8	Rotating table diameter	390 mm

Experimental Setup on Shake Table:

An experimental study is carried out in order to validate the fundamental natural frequency of a model. The scaled down steel model explained in section 4.3 is used for the study. The laboratory set up is developed for fixed base condition without tuned liquid damper. There are 4 numbers of accelerometers used to acquire the data. Accelerometer no. 1 is at bottom of Shake Table (Actuator), no. 2 and 3 are at slab level and accelerometer no. 4 is at roof level of scale down model. These 4 accelerometers are connected to data acquisition system which convert the analogue signals to digital signals. To show the digital signals data acquisition system connected to the laptop. Kampana software is used to get the results of experiment. The experimental setup and placements of accelerometers are shown in Figure.

Figure 10: Experimental setup on a shake table for fixed base

Figure 11: Experimental setup on a shake table for Base Isolated Structure

Response of structure with and without base isolation:

Response of structure is found out by measuring the displacements and accelerations at the storey level of a model subjected to harmonic loading with and without base isolation. The following table shows the experimental data used for the measuring the responses.

Table 3:External frequency applied during shake table test

Base type	External Frequency
Fixed base	1.3, 1.6, 1.9, 2.2, 2.5, 2.8, 3.1, 3.4, 3.7, 4.0, 4.3, 4.6, 4.9, 5.2, 5.5, 5.8, 6.1, 6.4, 6.7, 7.0, 7.3, 7.6, 7.9, 8.2
LRB	1.3, 1.6, 1.9, 2.2, 2.5, 2.8, 3.1, 3.4, 3.7, 4.0, 4.3, 4.6, 4.9, 5.2, 5.5, 5.8, 6.1, 6.4, 6.7, 7.0, 7.3, 7.6, 7.9, 8.2, 8.5, 8.8, 9.1, 9.4, 9.7, 10.0, 10.3

The effect of base isolation is measured by comparing the responses of a model with and without isolator. A model is subjected to the different excitation frequencies to measure the responses

VII. RESULTS AND DISCUSSION

The results obtained from the response spectrum method for the framing system for moment resisting frame system SAP 2000 and Shake Table are as follows.

STOREY DISPLACEMENT BY ANALYTICAL METHOD :

Table 4: Store Displacement by Analytical Method

Frequency (Hz)	Displacement (mm)	
Base Type	Fixed base	LRB
5.38	25.47	12.54
7.42	28.94	14.11

.

STOREY DISPLACEMENT BY EXPERIMENTAL METHOD :

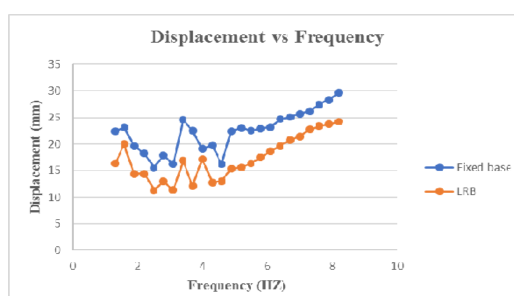

Figure 12: Displacement results from the experimental study

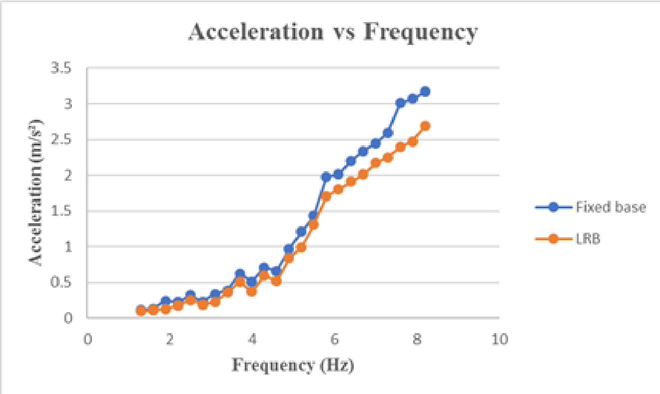

Figure 13:Acceleration results from the experimental study

Inference from the experimental and analytical study:

From the analytical study using SAP 2000 software and experimental study using shake table test for four storied structure, it is inferred that the base isolated structures show good seismic response than the fixed base structure. As shown in following table.

Table 5: Combine results obtained from analytical and experimental study for Displacment:

Base type	Displacement (mm)		
	Frequency (Hz)	Analytical study	Experimental study
Fixed base	5.38	25.47	22.72
LRB	7.42	14.11	16
Fixed base	8.2	30.28	29.58
LRB	8.2	21.41	24.70

VIII. CONCLUSION

a. From the Experimental Study using Shake Table the displacement and Acceleration of the Base Isolated Structure are much less than the fixed Base structure.

b. The Base Isolated Structure is more stable for External frequency applied during Shake Table Test as compared to fixed Base Structure.

c. The base shear is much greater in moment resisting frame system than composite frame system then followed by shear wall system for all models in both x and y-direction.

.

d. Storey displacement, Storey acceleration, base shear and drifts are reduced considerably in case of the base isolated structure than the fixed base structure for symmetrical and unsymmetrical building in both directions. In all the case storey displacement and drifts are within permissible limit as per codal provision of IS1893:2016.

e. Finally it is concluded that base isolation system is significantly effective to protect the structures against moderate as well as strong earthquake ground motion.

ACKNOWLEDGEMENT

I am greatly thankful to Dr. S.B. Allamapllewar Professor of the Civil Engineering department, G H Raisoni College of Engineering and Management Pune., who has been a great source of inspiration and helped in easy and quick access of facilities throughout the course, also appreciate the assistance provided by our college and our Structural engineering department for carrying out our research work with great ease. We also extend my heartfelt thanks to Dr. K. K. Paliwal, Director of G H Raisoni College of Engineering and Management Pune, for having given the infrastructure for successful completion of the thesis.

REFERENCES

[1] Gomase O.P, Bakre S.V, "Performance of Non-Linear Elastomeric Base-Isolated Building Structure", International Journal of Civil and Structural Engineering Volume 2, No 1, 2011.

[2] A. B. M. Saiful Islam, Mohammed Jameel And Mohd Zamin Jumaat, A. B. M. Saiful Islam, Mohammed Jameel And Mohd Zamin Jumaat "Seismic Isolation in Buildings to be a Practical reality behaviour of structure and Installation technique"Journal Of Engineering And Technology Research Vol. 3(4), Pp. 99-117, April 2011.

[3] Ajay Sharma, And R.S. Jangid, "Behaviour of Base-Isolated Structures With High Initial Isolator Stiffness", World Academy of Science, Engineering and Technology 50 2009.

[4] R.S. Jangid, "Optimum Friction Pendulum System for Near-Fault Motions", Engineering Structures 27 (2005) 349–359.

[5] Fabio Mazza, Alfonso Vulcano, "Base-Isolation Techniques For The Seismic Protection Of RC Framed Structures Subjected To Near-Fault Ground Motions",

13th World Conference On Earthquake Engineering, Vancouver, B.C., Canada August 1-6, 2004, Paper No. 2935.

[6] P. Bhasker Rao, R. S. Jangid, "Experimental Study Of Base Isolated Structures", IEST Journal Of Earthquake Technology", Paper No. 408, Vol. 38, No. 1,March 2001, Pp. 1-15.

[7] Arati Pokhrel1, A , Jianchun Li, B. Yancheng Li, C. Nicos Maksis , D. Yang Yu , "Comparative Studies Of Base Isolation Systems Featured With Lead Rubber Bearings And Friction Pendulum Bearings", Applied Mechanics And Materials, ISSN: 1662-7482, Vol. 846, Pp 114-119.

[8] Ms. Minal Ashok Somwanshi, Mrs. Rina N. Pantawane, "Seismic Analysis of Fixed Based and Base Isolated Building Structures", International Journal Of Multidisciplinary And Current Research ISSN: 2321-3124.

[9] Susan Paul, Dr. T. Sundararajan, Prof. Basil Sabu, "Seismic Performance And Economic Feasibility Of Structures By Optimal Positioning Of Combined Base Isolation Systems", International Research Journal Of Engineering And Technology (Irjet) Volume: 04 Issue: 04 | Apr -2017.

[10] Luigi Petti, Fabrizio Polichetti, Bruno Palazzo, "Analysis Of Seismic Performance Of Fps Base Isolated Structures Subjected To Near Fault Events, International Journal Of Engineering And Technology (IJET) Vol. 5 No 6 Dec 2013-Jan 2014

[11] R.S. Jangid, "Optimum Friction Pendulum System for Near-Fault Motions", Engineering Structures 27 (2005) 349–359.

[12] Susan Paul, Dr. T. Sundararajan, Prof. Basil Sabu, "Seismic Performance And Economic Feasibility Of Structures By Optimal Positioning Of Combined Base Isolation Systems", International Research Journal Of Engineering And Technology (Irjet) Volume: 04 Issue: 04 | Apr -2017.

[13] Harry Harris, Gajanan Sabnis, Structural Modelling and Experimental Techniques.