ISSN: 0975-5662, October, 2016www.ijrct.org

T.Sandeep,INDIA / International Journal of Research and Computational Technology, Vol.8 Issue.2 page: 01-09

# Study of Base Isolated Structure and Analysis of Base Isolated Frame

**#T.SandeepKumar**,M.Tech, Civil Engg, email:thati.sandeep7@gmail.com
**#Rajesh Goud**, Asso.Professor, [1]Department of Civil Engineering
# Progressive Engineering College, Hyderabad, India

***Abstract**: For seismic design of building structures, the conventional method, i.e., strengthening the stiffness, strength, and ductility of the structures, has been commonly used 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 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. 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 equipment 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.*

Keywords: Seismic Design, Isolated Structure, Isolated Frame.

## INTRODUCTION

The Earthquakes affect buildings in several ways. Thus, providing isolators is one of the remedy to safeguard the structure against severe earthquake. Also, the secondary structures are strategically very important structure as they have vital uses in activities connected to public life. As we have seen in past earthquakes that there was devastating damage to life and structure. So safety is a must for them. There have been a number of reports on damage to structures in past earthquakes which have demonstrated the seismic vulnerability of structure and the damage. The major reason for the damage is that there is a loss of support under its foundations, failure structural member etc. A building may also be affected by earthquake motion excites the structure due to which various floors acts as independent to the structure wall motion while another part of the structure which moves in unison with the rigid frame wall. Also, if the flexibility of the frame wall is considered then the part of the impulsive mass moves independently while remaining accelerates back and forth with frame wall as rigid mass. The accelerating structure and rigid masses, induces substantial pressures onthe wall of RC frame which in turn generates lateral pressures (i.e. base shear) and overturning moment. The failure occurs also as the RC structure buckles due to axial compression, toppling of the frame structure, failure of floors, failure if roof and uplift of the anchorage system.

"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. The first base isolated systems actually constructed in the world are the Fudo Bank Buildings in Himeji and Simonoseki, Japan designed by R. Oka. After the world War-II, the U.S took a leading part of Earthquake Engineering. Garevski A et al. [2] The primary school "Pestalozzi" in Skopje, built in 1969, is the first building in the world for which natural rubber isolators were used for its protection against strong earthquakes. The first base isolated building in the United States is the Foothill Communities of Law And Justice Centre completed in 1985 having four stories high with a full basement and sub-basement for isolation system which consists of 98 isolators of multilayered natural rubber bearings reinforced with steel plates. The Superstructure of the building has a Structural Steel frame stiffened by braced frames in some Bays. In India, base isolation technique was first demonstrated after the 1993 Killari (Maharashtra) Earthquake [EERI, 1999]. Two single storey buildings (one school building and another shopping complex building) in newly relocated Killari town were built with rubber base isolators resting on hard ground. Both were brick masonry buildings with concrete roof. After the 2001 Bhuj (Gujarat) earthquake, the four-storeyBhuj Hospital building was built with base isolation technique [4]. The Base isolation system has been introduced in some books of dynamic Engineering and the number of scholars has been increasing in the world.

## 1.0 LITERATURE REVIEW

The studies presented for literature review are categorized as:

- Nonlinear dynamic Analysis of framed structure.

ISSN: 0975-5662, October, 2016www.ijrct.org

T.Sandeep,INDIA / International Journal of Research and Computational Technology,
Vol.8 Issue.2 page: 01-09

- Relative performance of Fixed-base and Base-isolated concrete frames.
- Base Isolated Structures subjected to near-fault earthquakes
- Effect of Superstructure Stiffening on base isolation.

## 1.2 Nonlinear dynamic Analysis of framed structure

Constantinou et al. [3] described in this paper an analytical model and an algorithm to analyze multiple buildings on a common isolation system and the results are used to demonstrate the importance of analyzing the combined system as against analyzing individual buildings. Jain and Thakkar [4] explored the idea of superstructure stiffening is to enhance the effectiveness of base isolation for 10 to 20 storeys range of buildings. The superstructure stiffening may result in reduced fixed base period and such buildings, if base isolated may develop smaller seismic response. Jangid and Kulkarni [5] made a comparison in this study of the seismic response of a multi-storey base-isolated building by idealizing the superstructure as rigid and flexible. The top floor acceleration and bearing displacement of the system are plotted.

## 1.3 Relative performance of Fixed-base and Base-isolated concrete frames

Shenton and Lin [6] compared the performance of code designed fixed-base and base-isolated concrete frames in a quantitative manner. Time-history analyses were conducted. Bezerra and Carneiro [7] presented a paper which deals with numerical evaluation of the efficiency of anti-vibration mechanisms applied to typical frame structures under earthquake. The building structure is modelled by finite elements, an anti-vibration mechanism is placed at the building base with special finite element, and an artificial earthquake equivalent to El Centro is generated and applied at the building base. The behaviour of the frame, with and without anti-vibration mechanisms, is compared. Providakis [8] carried out nonlinear time history analyses using a commercial structural analysis software package to study the influence of isolation damping on base and superstructure drift. Aiken et al. [9] documented in their paper the seismic behaviour of four seismically isolated buildings from their recorded response for earthquakes producing various amplitudes and durations of shaking. It considers the responses of multiple buildings to multiple earthquakes.



## 1.4 Base Isolated Structures subjected to near-fault earthquakes:

Mazza and Vulcano [10] studied the nonlinear seismic response of base-isolated framed buildings subjected to near-fault earthquakes to analyze the effects of supplemental damping at the level of the isolation system, commonly adopted to avoid overly large isolators. Aiken et al. [11] described the results of a study of an existing seismically isolated building in Southern California which are located near San Andreas Fault, San Jacinto fault and south frontal fault zone. Analysis result for three levels of earthquake was presented and recommendations are made.

## 1.5 Effect of Superstructure Stiffening on Base Isolation:

Jain and Thakkar [12] explored the idea of superstructure stiffening is to enhance the effectiveness of base isolation for 10 to 20 storeys range of buildings. The superstructure stiffening may result in reduced fixed base period and such buildings, if base isolation may develop smaller seismic response. Jangid and Kulkarni [13] made a comparison of the seismic response of a multi-storey base-isolated building by idealizing the superstructure as rigid and flexible with the corresponding response under rigid superstructure conditions to study the influence of superstructure flexibility under various isolation system parameters (i.e. isolation period, damping, yield strength of the elastomeric bearings and friction coefficient of sliding systems).

## 2.0 MATHEMATICAL FORMULATION

The greatest interest in structural engineering is the deformation of the system, or displacement u(t) of the mass relative to the moving ground, to which the internal forces are linearly related.

Knowing the total displacement u(t) and acceleration of a structure during an earthquake adequate step can be taken to prevent its failure during earthquake. After equating the acceleration and displacement of a structure, the cause of damage to several buildings during earthquake is reduced.

The frame modeling is based on the approach used in the computer program SAP2000 14. SAP2000 14 is object based software, meaning that the models are created using members that represent the physical reality. This idealizes the system into a lumped mass and a mass less supporting system.

The RC structure was first equated without the Based Isolator and its natural frequency was calculated w.r.t. time. Dynamic characteristics of the structure such as natural frequencies and mode shapes are also obtained using SAP2000 14.
The structure was then modeled with Base Isolator placed in it. And its acceleration and displacement are found.



## 2.1 MODAL ANALYSIS:

Modal analysis is the study of the dynamic properties of structures under vibration excitation. In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate. A normal mode of an oscillating system is a pattern of motion in which all parts of the system move sinusoidal with the same frequency and with a fixed phase relation.

### 2.1.1 Time-History Analysis:

Time history analysis of the frame was carried out to determine the response of the frame under a given dynamic loading. Time history analysis is the most natural and intuitive approach. The response history is divided into time increments Kt and the structure is subjected to a sequence of individual time-independent force pulses Kf (t). The nonlinear response is thus approximated by series of piecewise linear systems.

Here time history records of Northridge Earthquake, Century City (17/01/1994) data recorded at LACC NORTH is used for the time history analysis. The Northridge earthquake was a massive earthquake that occurred on January 17, 1994 in Reseda, a neighborhood in the city of Los Angeles, California, lasting for about 10–20 seconds. The earthquake had a "strong" moment magnitude of

6.7, but the ground acceleration was one of the highest ever instrumentally recorded.

# 3.0 RESULTS AND DISCUSSION

## MODAL ANALYSIS OF A RC FRAME

Modal analysis of a typical building structure frame is done to determine the dynamic parameters like natural frequency, time period, modal participating mass ratios and their corresponding mode shapes. Typical building structure frame made of reinforced concrete has ten floors (figure 1) and composed of columns 3.0 m 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. From the modal analysis time period, frequencies are noted for modes with considerable mass participation. These are the important modes of consideration. The first natural frequency of the building was calculated in Hz.

From the modal analysis time period, frequencies are noted for modes with considerable mass participation. These are the important modes of consideration. The first natural frequency of the building was also calculated in SAP2000 in Hz (table 1).

TABLE 1

TIME PERIOD AND FREQUENCY OF THE BUILDING FOR FIRST THREE MODES

| MODE | TIME PERIOD (second) | FREQUENCY (hertz) |
|---|---|---|
| 1 | 0.762349 | 1.3117 |
| 2 | 0.744952 | 1.3424 |
| 3 | 0.604138 | 1.6553 |



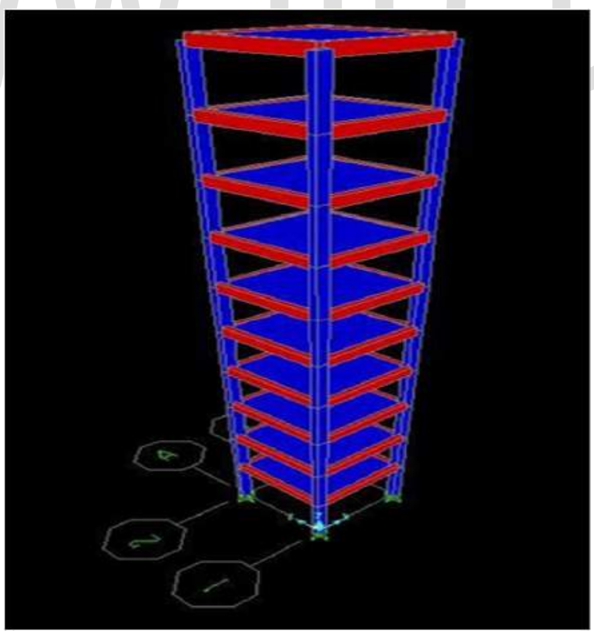

Figure 1: Structural model of building from SAP window

## 3.1 TIME-HISTORY ANALYSIS OF THE FRAME:

The response (i.e. Displacement, Velocity, and Acceleration) of the steel frame subjected to a selected earthquake ground motion was found out by non-linear time history analysis using SAP 2000 v12.0.0. The selected earthquake ground motion is Northridge Earthquake record. (Northridge earthquake, January 17, 1994, Reseda, a neighbourhood in the city of Los Angeles, California, USA).

## 3.2 RESPONSE OF THE FRAME
## Displacement

Displacement of the frame subjected to time history analysis is recorded in each node in both X-direction and Y-direction. No displacement is recorded at the base since the base is in the fixed condition. It is to be noted that that maximum displacement is achieved at all the nodes at the same time i.e. at 6.44 sec. Storey displacement are calculated. It is clear from the result that storey drift is more in the first storey which goes on decreasing in successive upper storeys. Displacement of the frame in each node in Y-direction is found to be very less as compared to the displacement of the frame in the X-direction when it is subjected to time history force.

## 3.3 Velocity
Velocity of the frame subjected to time history analysis is recorded in each node in both X-direction and Y-direction. No velocity is recorded at the base since the base is in the fixed condition. The result indicates that storey velocity is more in the lower storey and it goes on decreasing in the successive upper storeys.

## 3.4 Acceleration
Acceleration of the frame subjected to time history analysis is recorded in each node of the frame. No acceleration is recorded at the base since the base is in the fixed condition. From the result it is clear that storey acceleration is more in the lower storey and it goes on decreasing in the successive upper storeys.

## Result
Modal analysis of the fixed base steel frame is done to determine its natural frequency and mode shape followed by its time-history analysis using time history record of Northridge earthquake (January 17, 1994 in Reseda, a neighbourhood in the city of Los Angeles, California, USA) at an interval of .02 sec for 60 sec. duration to determine the response of the frame under dynamic loading.

It was concluded that the responses (displacement, inter-storey drift, velocity, acceleration) of the structure is more in lower storey as compared to the upper storeys. Maximum displacement is achieved at all the nodes at the same time i.e. at 6.44 sec. Story drift is more in lower storeys and it goes on **decreasing in the successive upper storeys.**
For dynamic loading design of building structures, we have to consider the dynamic loading response demand and go for the methods like strengthening the stiffness, strength, and ductility of the structures which 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.

Base isolation decreases the dynamic loading response demand of the structure to a certain extent as compared to its bare frame by absorbing and dissipating the energy imparted on the structure due to dynamic loading (figures 3 and 4).

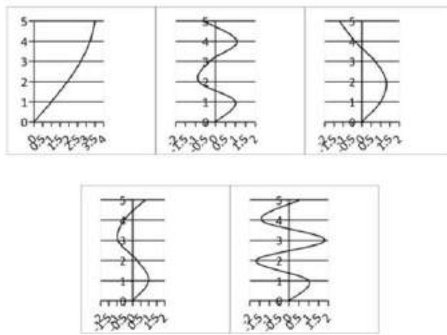

Figure 2: Mode Shape without base isolator and with fixed base



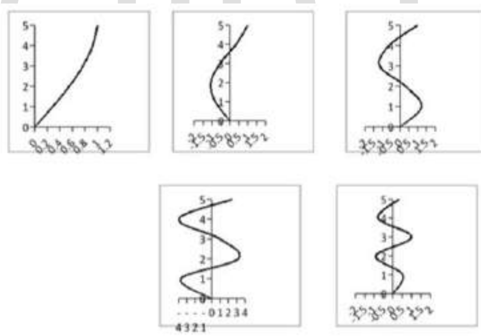

Figure 3: Mode Shape with base isolator

## 4.0 CONCLUSION

The investigation of dynamic properties of the framed structure under dynamic loading and effectiveness of base isolation of structure under dynamic loading are done and following conclusions achieved. This paper first presents the modal analysis results and then it discusses the time history analysis results of 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 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.

## 5.0 REFERENCES

[1] I. Masanory, “Base Isolation and passive Seismic response control, ” Proceedings of Ninth World Conference on Earthquake Engineering, VIII, (1988): pp. 385-396

[2] G. 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.

[3] M. C. Constantinou et al. “Non-linear dynamic analysis of multiple building base isolated structures, ” Computers and Structures, 50, (1994): pp. 47-57

[4] S. K. Jain and S. K. Thakkar, “Effect of Superstructure Stiffening in Base Isolated Tall Buildings, ” IE (I) Journal.CV, 85, (2004): pp. 142-148

[5] R. S. Jangid and J. A. Kulkarni, “Rigid body response of base-isolated structures, ” Journal of Structural Control, 9, (2002): pp. 171–188

[6] H. W. Shenton and A. N. Lin “Relative performance of Fixed-base and Base-isolated concrete frames, ” Journal of Structural Engineering, 119, (1993),: pp. 2952-2968

[7] L. M. Bezerra and R. C. Carneiro. “A Numerical Evaluation of AntiVibration Mechanisms Applied to Frame Structures Under Earthquake, ” 17th International Conference on Structural Mechanics in Reactor Technology (SMIRT 17), 13-2, (2003): pp. 1-8

[8] C.P. Providakis “Effect of LRB isolators and supplemental viscous dampers on seismic isolated buildings under near-fault excitations, ” 30 (2008) : pp. 1187–1198Aiken Ian D. Observed behaviour of Seismically Isolated buildings, Journal of Structural Engineering, 125 (1999): pp. 955-964.

[9] M. Fabio and V. Alfonso. “Nonlinear Response of RC Framed Buildings with Isolation and Supplemental Damping at the Base Subjected to Near-Fault Earthquakes, ” Journal of Earthquake Engineering,, 13(2009): pp. 690–715

[10] I.D. Aiken et al. “Performance considerations for isolation systems in the region of high seismicity, ” Proceedings, ATC-17-1, Seminar on seismic isolation, passive energy 69 dissipation and active control, applied technology Council, San Francisco, California, 17-1 (1991): pp. 1-12

[11] S K. Jain and S. K. Thakkar “Effect of Superstructure Stiffening in Base Isolated Tall Buildings, ” IE (I) Journal.CV, 85 (2004): pp. 142–148

[12] R. S.Jangid and J. A. Kulkarni “Rigid body response of base-isolated structures, ” Journal of Structural Control, 9 (2002): pp. 171–188