iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4696

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Seismic Performance of Building with Base Isolation, Damper and Braced System

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Abstract: The Need for taller structure in construction and real estate industry is increasing all over the world. These structures are flexible and constructed as light as possible, which have low value of damping, makes them vulnerable to unwanted vibration. This vibration creates problem to serviceability requirement of the structure and also reduce structural integrity with possibilities of failure. In this study reinforce concrete structures are taken for seismic performance evaluation. This RC building is modeled with different structural control system such as base isolator, damper and bracing with use of commercial computer software. After that various ground motion data is applied to the building model to evaluate structural response. Non-linear time history analysis is carried out for building model with each control system and the result of seismic response of each of control system is compared with other control system. Time history analysis results shows that building with cross bracing shows lesser displacement and lesser drift than building with FVD and building with LRB.
Keywords: Seismic performance, structural response control system, lead rubber bearing base isolation, fluid viscous damper, cross bracing, time history analysis

I. INTRODUCTION

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. 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. 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.

Viscous dampers are hydraulic devices that dissipate the kinetic energy of seismic events and cushion the impact between structures. They are versatile and can be designed to allow free movement as well as controlled damping of a structure to protect from wind load, thermal motion or seismic events. The development of bracing made the construction of the skyscraper possible. Bracings are strong in compression. Bracing with their surrounding frames has to be considered for increase in lateral load resisting capacity of structure. When bracings are placed in Steel frame it behaves as diagonal compression strut and transmits compression force to another joint. Variations in the column stiffness can influence the mode of failure and lateral stiffness of the bracing.

II. STRUCTURAL MODELING

This section presents the information for model development of R.C. frame building with LRB, FVD and cross bracing in ETABS. Here, each control system is modeled for different stories building such as 4 stories building, 6-stories building, 8-stories building, 10- stories building, 12-stories building, 14-stories building, 16- stories building, 18 stories building, 20 stories building, 22 stories building, 24 stories building, 26 stories building, 28 stories building, 30 stories building. The response of R.C frame building in the form of Story Displacement, story drift and time period were calculated. The method of analysis used is time history analysis and EL CENTRO earthquake data used for dynamic time history analysis.

Table 1: Building design data

Story Height	3000 mm
No. of Bays in X-Direction	4
No. of Bays in Y-Direction	4
Bay Width in X-Direction	5000 mm
Bay Width in Y-Direction	5000 mm
Column Size	560×560 mm^2 (4 to 10 story building), 790×790 mm^2 (12 to 20 story building) , 950×950 mm^2 (22 to 30 story building)
Beam Size	230 * 450 mm^2
Slab Thickness	120 mm
External wall thickness	230 mm
Internal wall thickness	115 mm
Number of story	4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30
*f*ck (Characteristic Strength of Concrete)	25 N/mm^2
fy (Yeild Strength of Steel)	415 N/mm^2

Table 2: building site earthquake data

Type of Soil (as per IS 1893:2002)	Rocky or hard strata (type-1)
Seismic Zone (as per IS 1893:2002)	IV (Z = 0.24)
Importance Factor (as per IS 1893:2002)	1
Response Reduction Factor (as per IS 1893:2002)	5

Table 3: building loading data

Terrace slab live load	1.5kN/m^2
Typical storey slab live load	3kN/m^2
Typical storey slab dad load	1kN/m^2
Frame load on external beam	11.73 kN/m
Frame load on internal beam	5.85 kN/m
Parapet load	5.75 kN/m

The properties of the Viscous Damper are considered as provided by the manufacturing company Taylor Device Inc.,
Damping coefficient: 770kN-s/m, Velocity exponent: 0.3
The section for mounting brace is considered as $200 \times 200 \times 10$ mm hollow square section. The value of stiffness is calculated as 214960.699 KN/m.
In this study ISMB 200 used for group-A buildings (4 story building to 10 story building), ISMB 225 used for group-B buildings (12 story building to 20 story building), ISMB 250 used for group-C building (22 story building to 30 story building) section is used as cross brace member. Bracings are provided at each exterior corner bay of reinforce concrete building.

TABLE 4: properties of LRB

Design variable	4 Story	6 Story	8 Story	10 Story	12 Story	14 Story	16 Story
Vertical Stiffness (K_v)	457686.7	457686.7	771650.6	771650.6	771650.6	957481.0	957481.0
Effective Horizontal stiffness (K_{eff})	670.93	1019.68	1367.67	1722.00	2072.23	2419.30	2754.44
Elastic Stiffness (K_r)	4508.86	6852.55	9191.14	11572.31	13925.96	16258.36	18510.62
Yield Strength (KN)	22.13	33.64	45.11	56.80	68.36	79.80	90.86

Design variable	18 Story	20 Story	22 Story	24 Story	26 Story	28 Story	30 Story
Vertical Stiffness (K_v)	1162477.	1162477	1386607	1386607	1629847.7	1629847.7	1629847.73
Effective Horizontl stiffness (K_{eff})	3084.97	3408.37	3725.29	4035.58	4339.83	4640.12	4936.38
Elastic Stiffness (K_r)	20731.86	22905.20	25035.01	27120.29	29164.89	31182.93	33173.92
Yield Strength (KN)	101.76	112.43	122.89	133.12	143.16	153.06	162.84

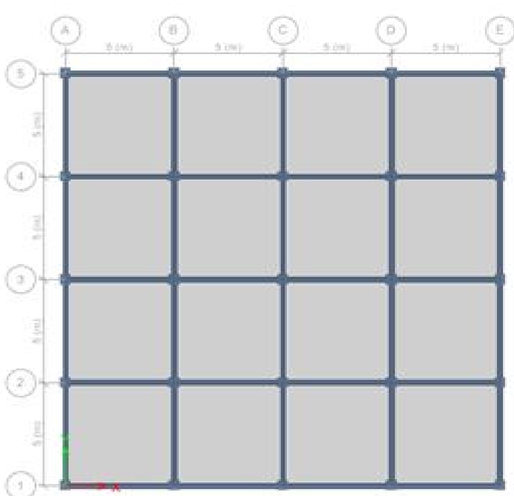

Fig.1: Plan view of building

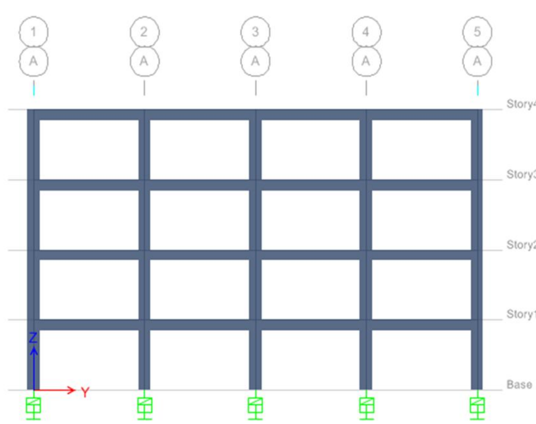

Fig.2: isometric view of building with LRB

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

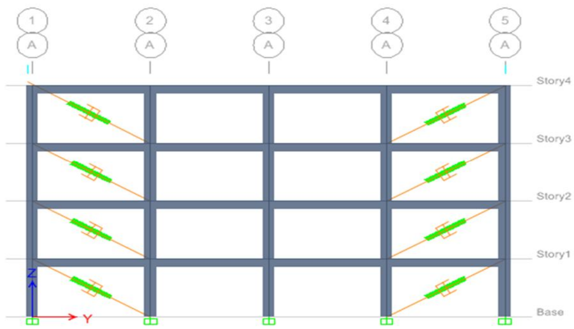

Fig.3: isometric view of building with FVD

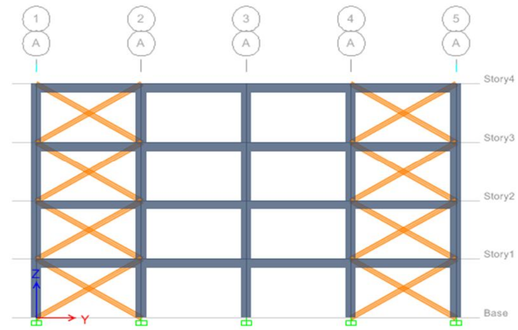

Fig.4: isometric view of building with X bracing

III. ANALYSIS RESULTS

A. Time period

From graph it is shown that maximum time period of building is found at 30 story building. The maximum time period of building with LRB, with FVD, with bracing is respectively 6.181sec,5.250sec,3.776sec

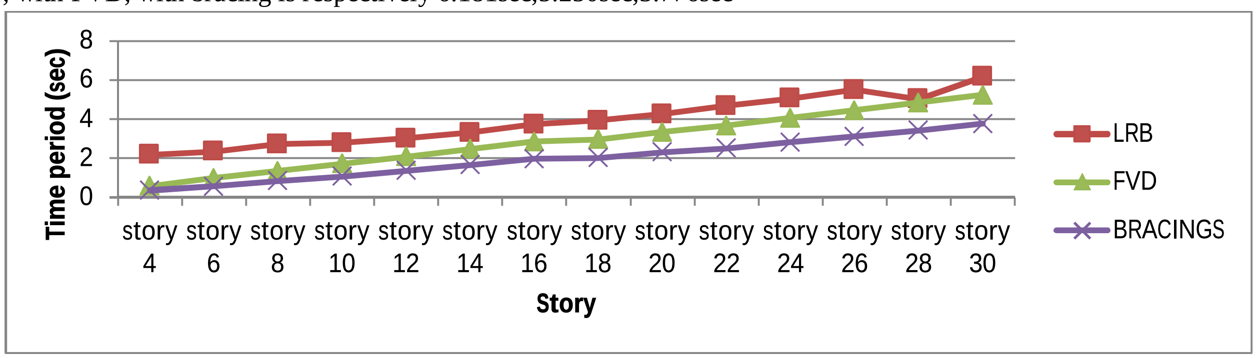

Fig.5: building time period comparison

B. Building Story Displacement

From building story displacement table it is shown that maximum story displacement of building is found at 30 story building. The maximum story displacement of building with LRB, with FVD, with bracing is respectively 63.2 mm, 46.4 mm, 30 mm.

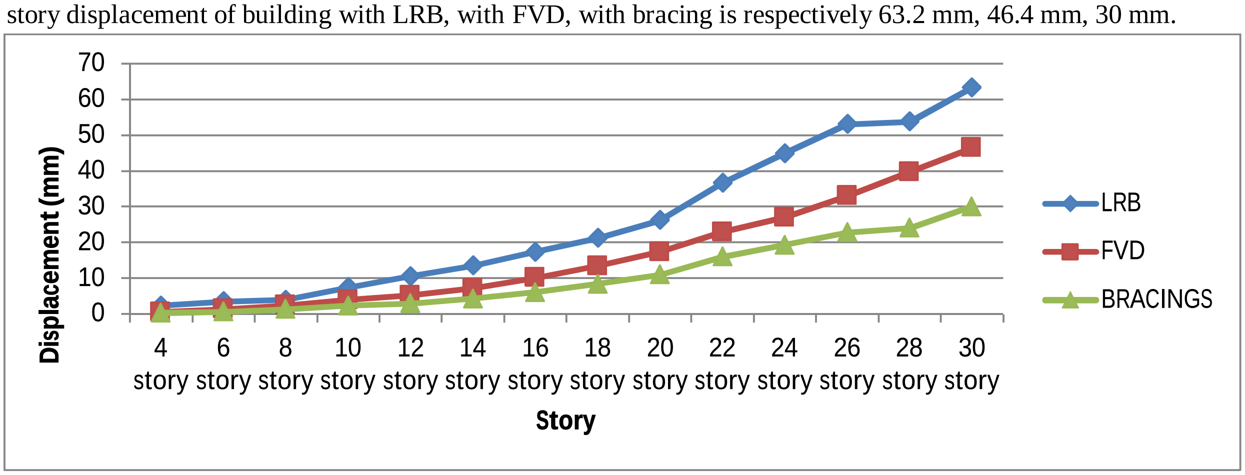

Fig.6: building story displacement comparison

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C. Story Drift

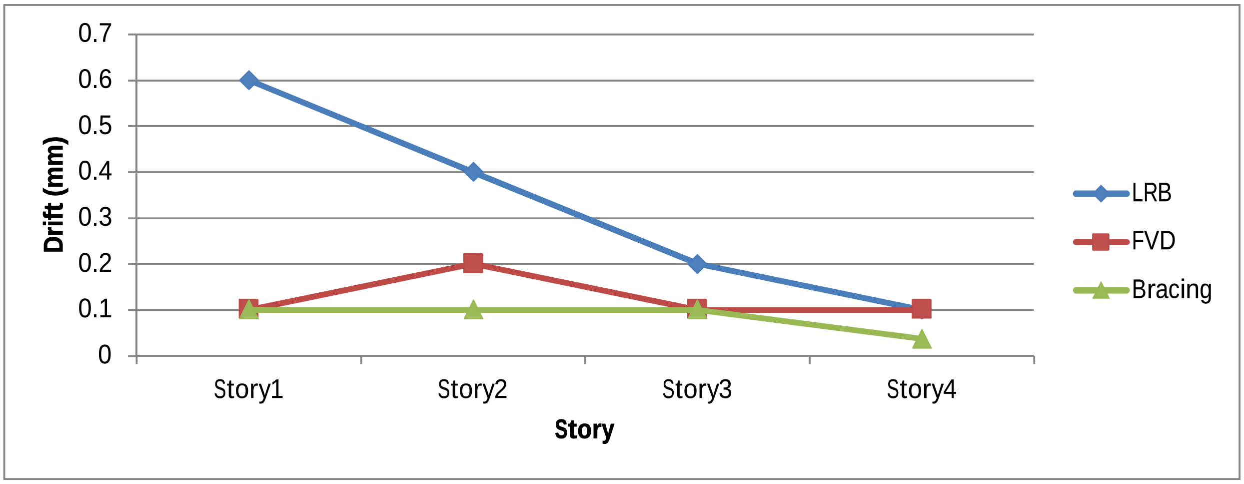


Fig.7: 4 story building drift comparison

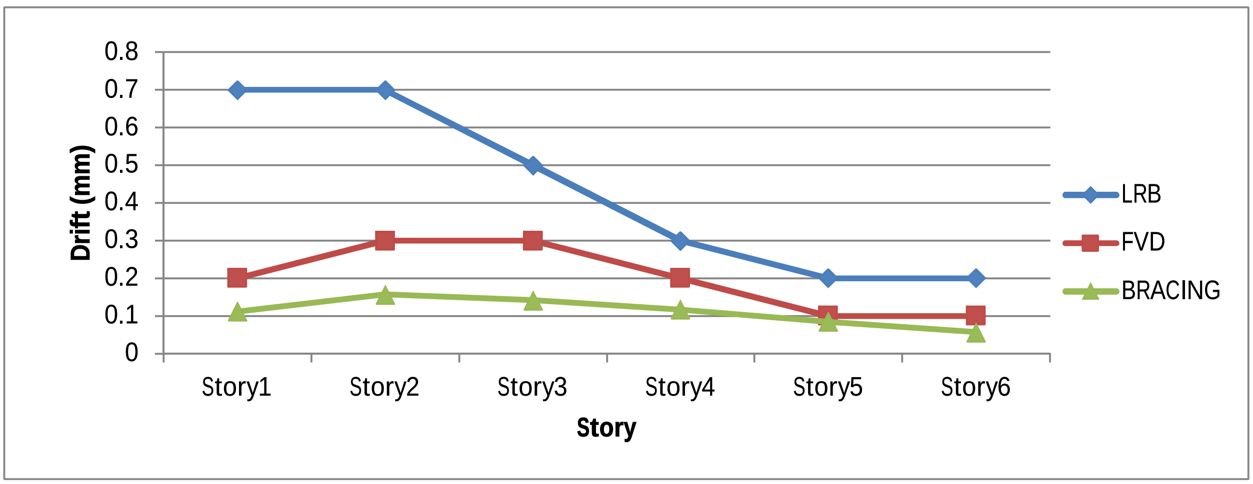


Fig.8: 6 story building drift comparison

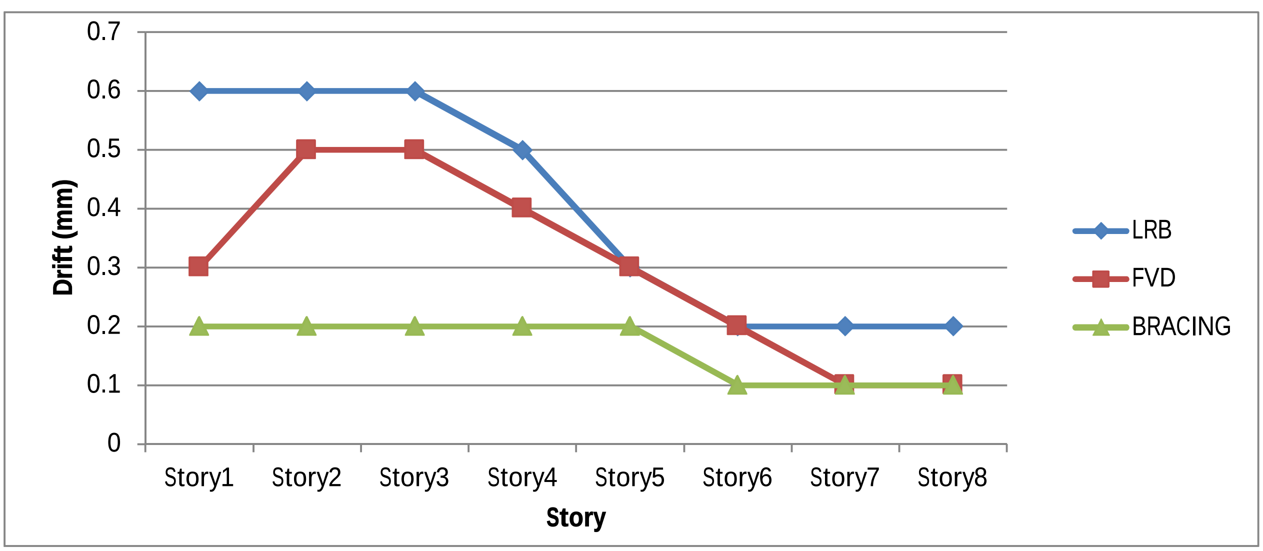


Fig.9: 8 story building drift comparison

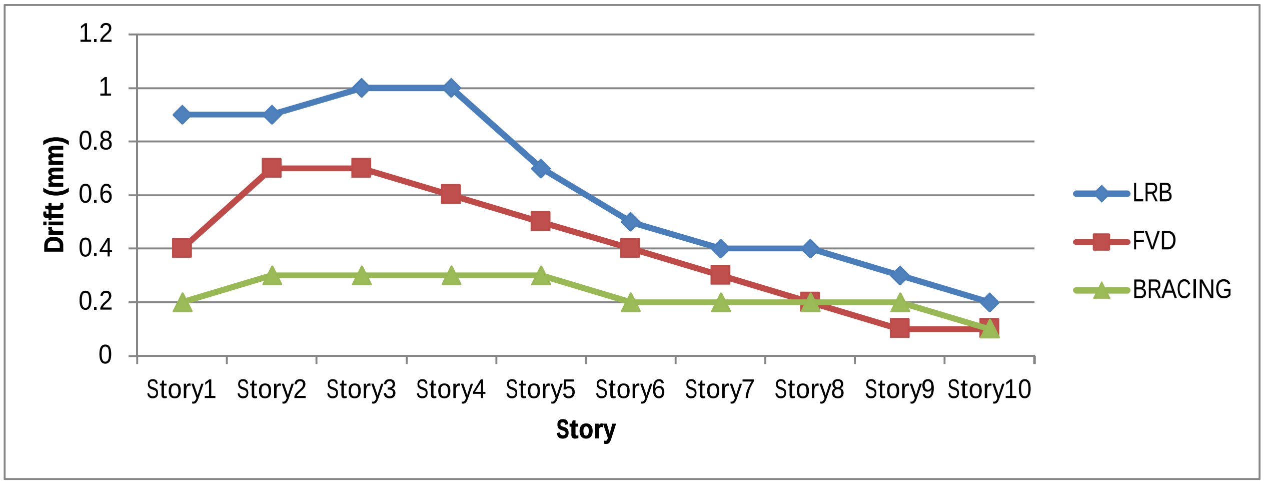
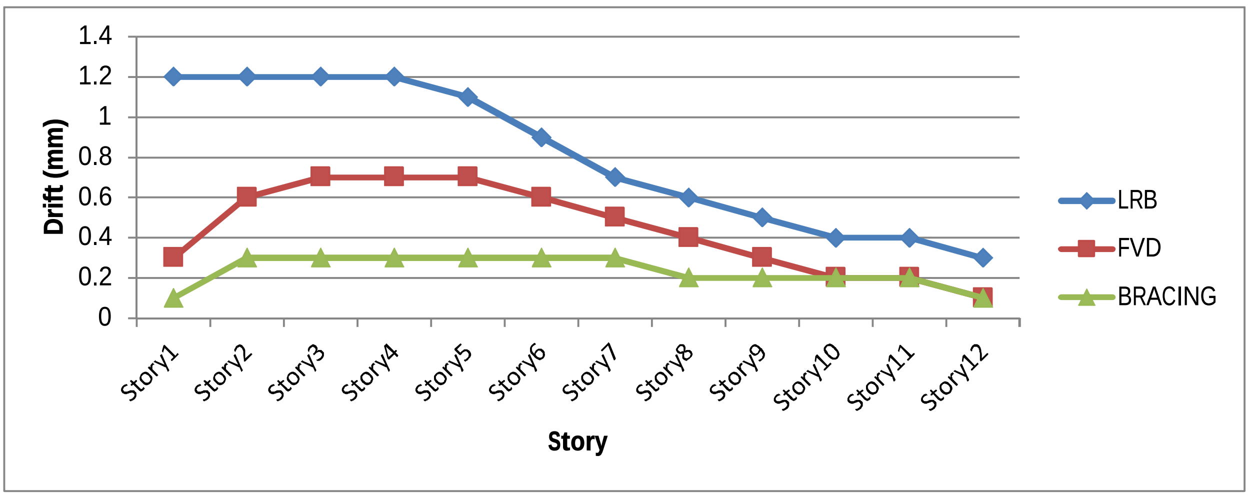


Fig.10: 10 story building drift comparison



Figu.11: 12 story building drift comparison

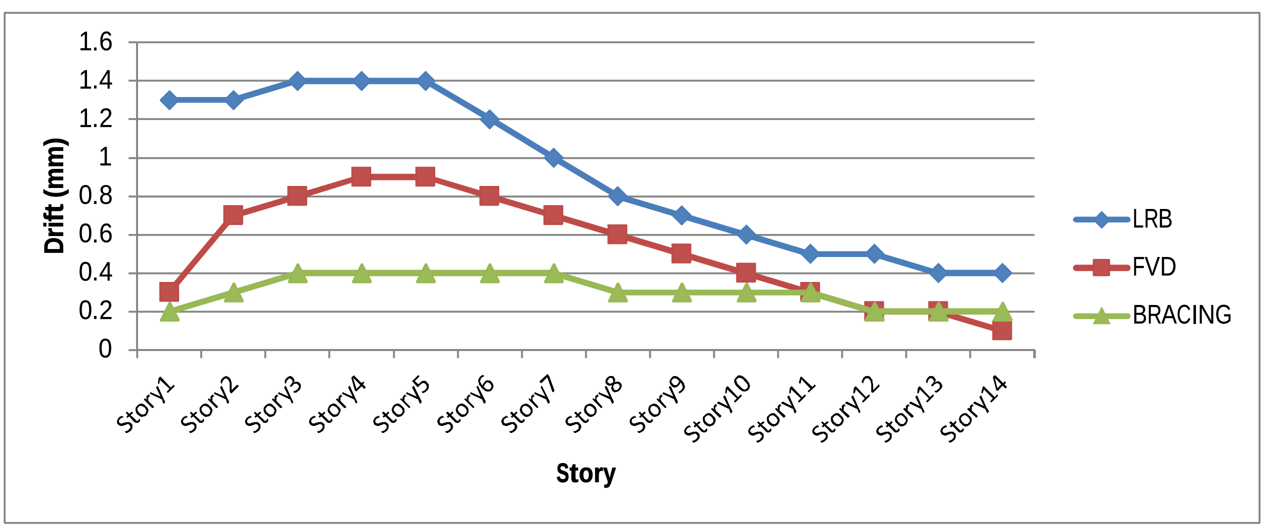


Fig.12: 14 story building drift comparison

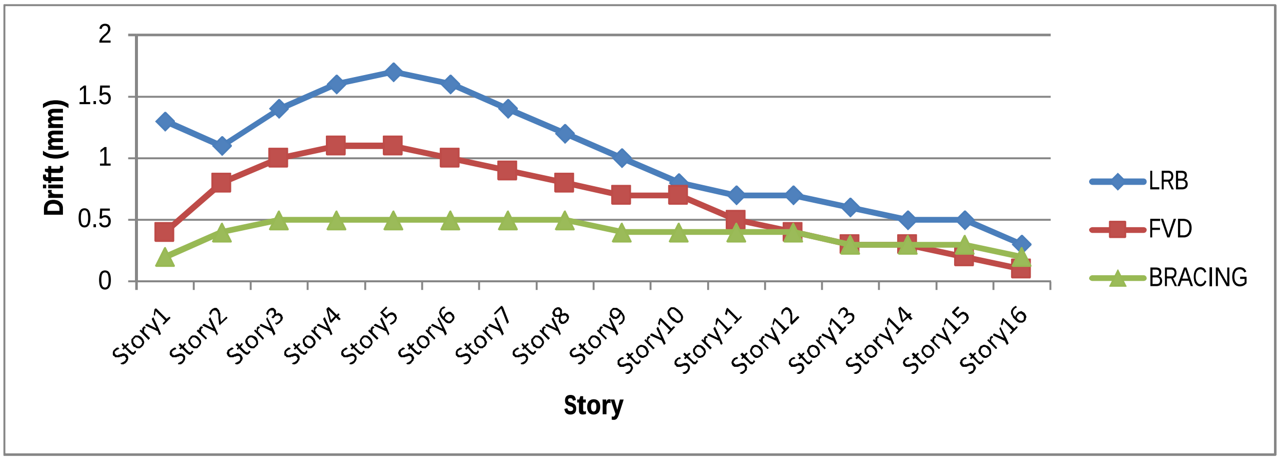


Fig.13: 16 story building drift comparison

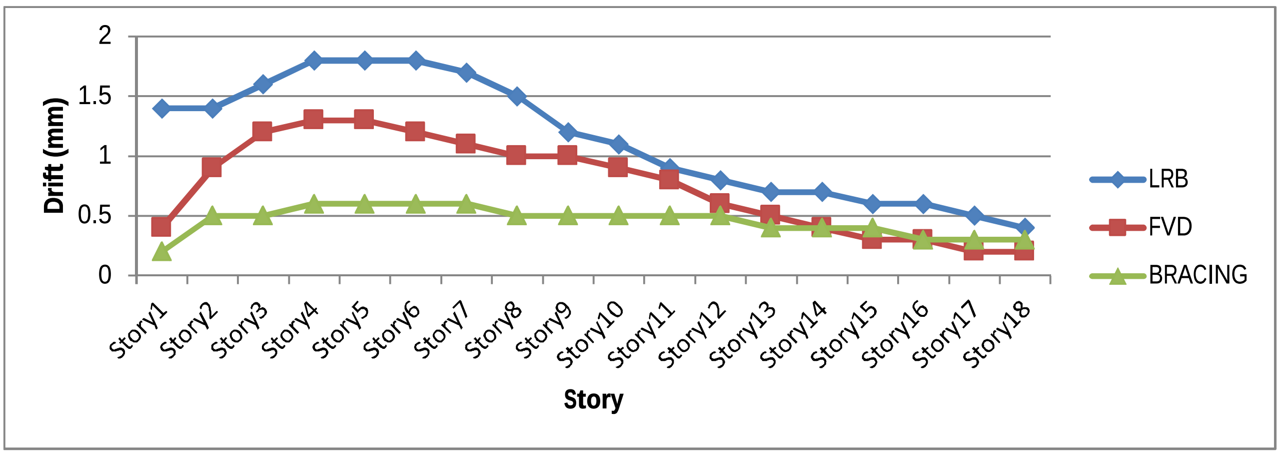


Fig.17: 18 story building drift comparison

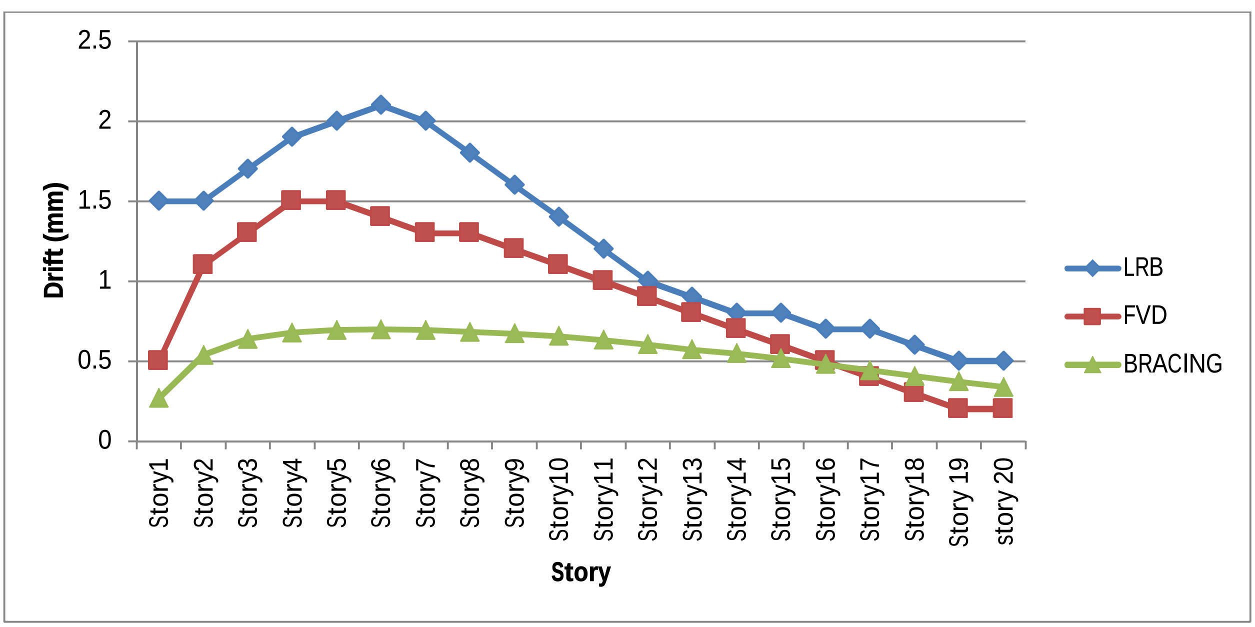


Fig.18: 20 story building drift comparison

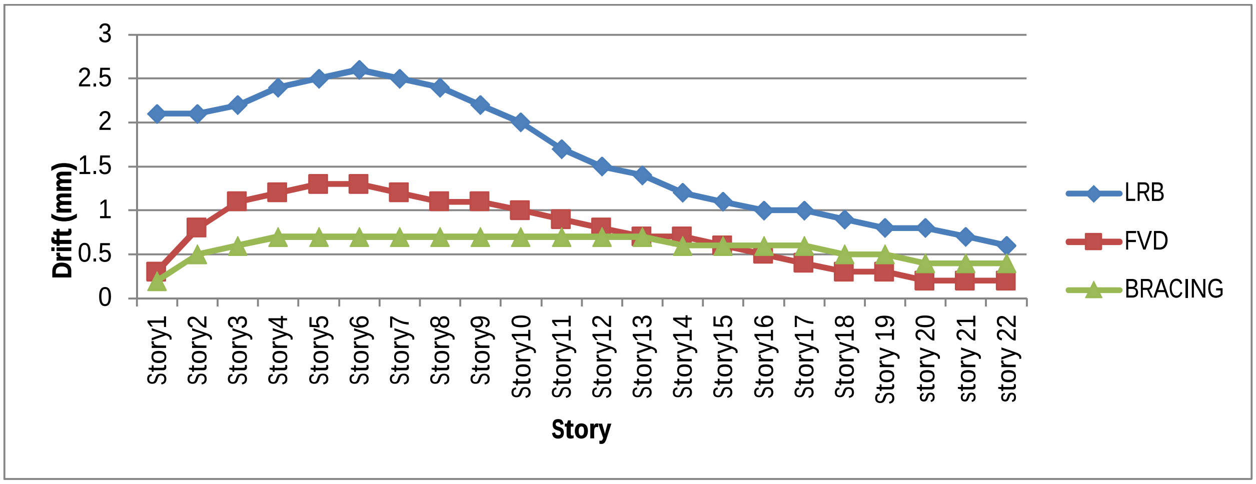


Fig.19: 22 story building drift comparison

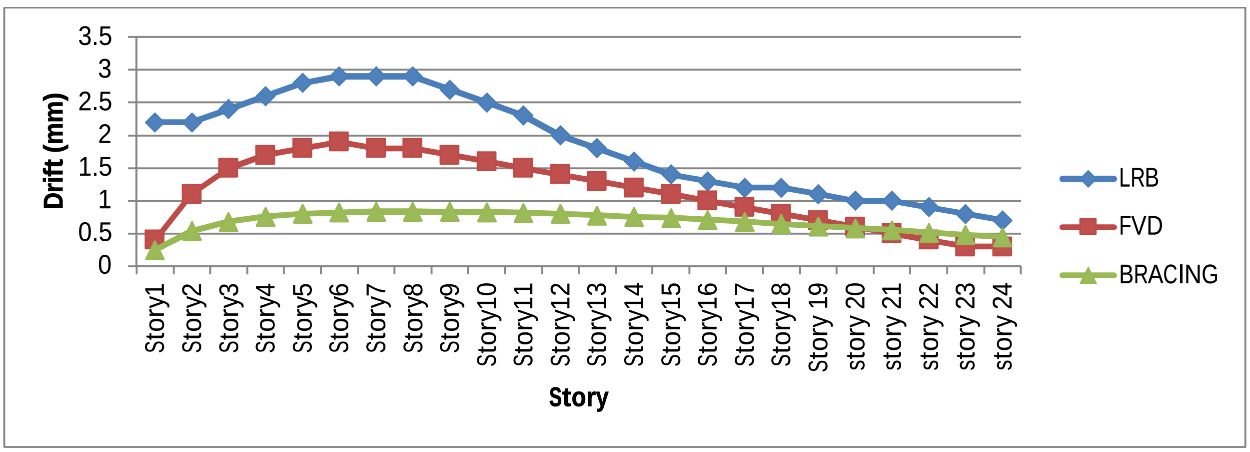


Fig.20: 24 story building drift comparison

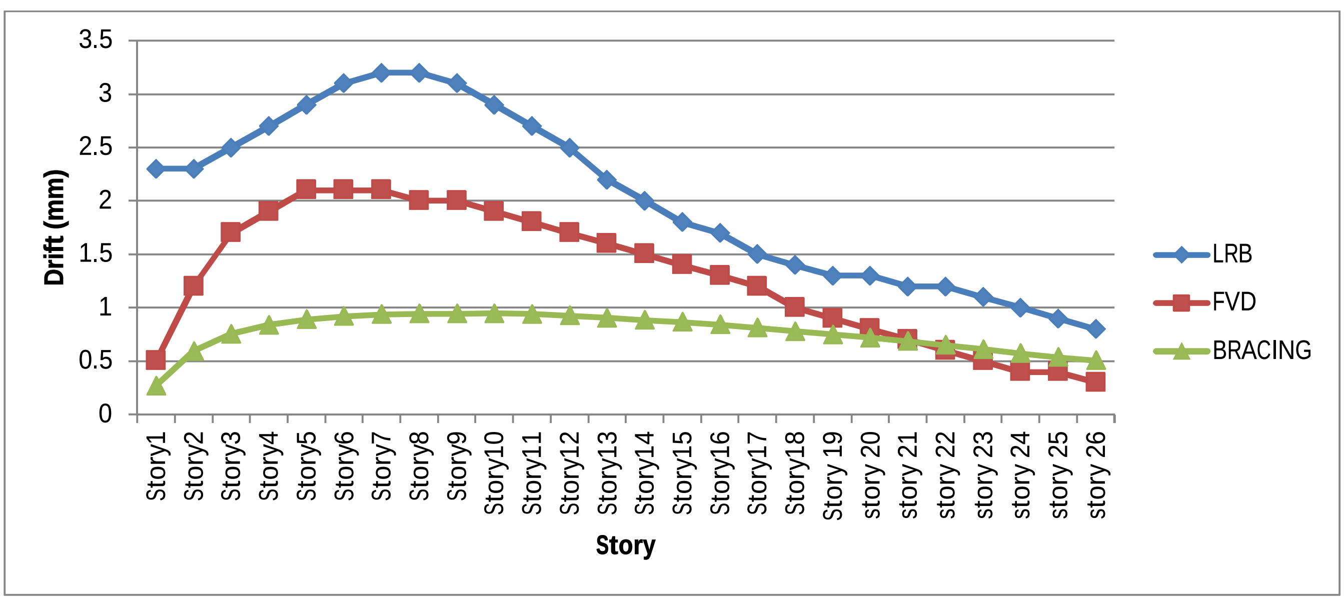


Fig.21: 26 story building drift comparison

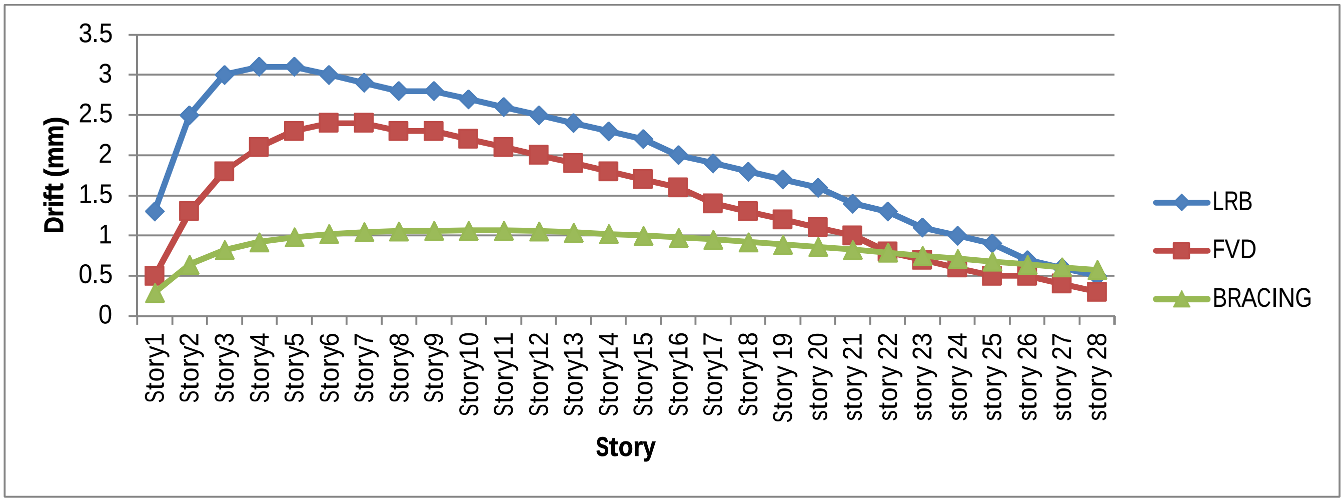


Fig.22: 28 story building drift comparison

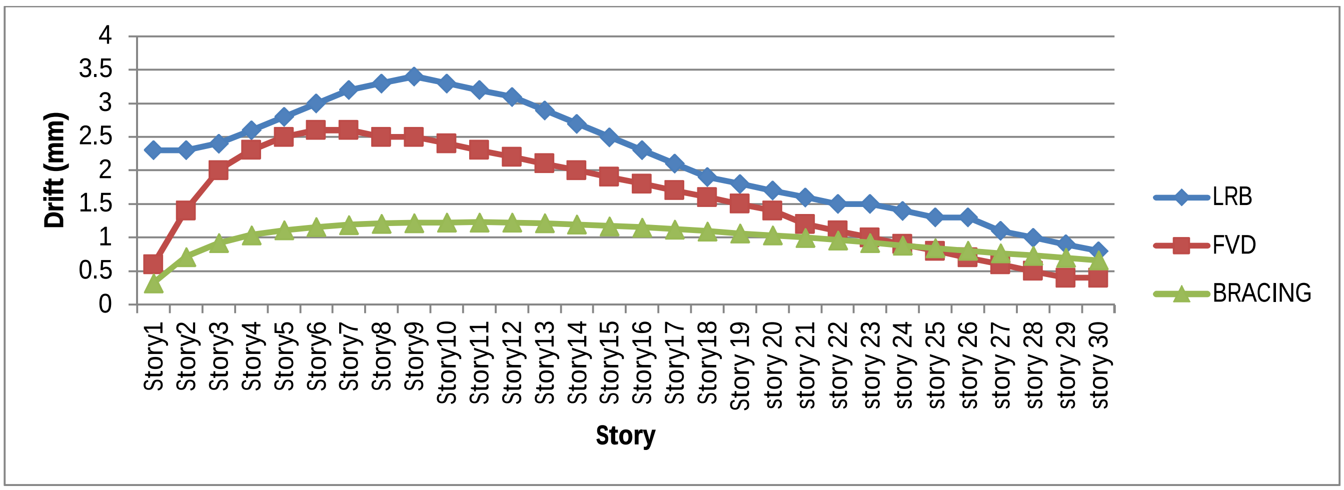


Fig.23: 30 story building drift comparison

IV. CONCLUSION

A. From analytical studies it is concluded that maximum time shifting can be achieved building with LRB isolators when compared to FVD and bracing.

B. The maximum time period achieved for 4 stories building with base isolation is of 83.47% more when compared to 4 stories building with bracing and 71.34% more when compared 4 stories building with FVD.

C. The minimum time period achieved for 30 stories building with base isolation of 38.90% more when compared to 30 stories building with bracing and 15.06% more when compared 4 stories building with FVD.

D. The higher the time period; the higher will be flexibility of building and higher flexibility provides more seismic wave energy dissipating capacity to the building.

E. As the height of building increase the displacement is increase. All building with control system shows maximum displacement at 30 stories building.

F. At 30 stories building bracing system show 52.53% lesser displacement than LRB isolators and it also shows 35.24% lesser displacement than FVD.

G. Building with FVD shows lesser displacement of building in Y direction when compared to displacement of building in X direction.

H. The drift difference in varies stories with building with bracing is lesser and at some stories drift are same which shows all stories moves at same level when lateral force act on it.

I. LRB isolator shows maximum drift while bracing shows minimum drift but in high rise building above 14 story maximum drift control by FVD is more than bracing.

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