International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 08 | August 2019 www.irjet.net p-ISSN: 2395-0072

A Review Paper on Comparative Study of Fixed Base, Base Isolation & Damper System in RC Building

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Abstract – *Normal buildings are designed for 8-14% of the force total force experience. Therefore, design against earthquake effect is called as earthquake-resistant design and not earthquake-proof design. Earthquake design requires the structure to remain elastic or to undergo inelastic behavior, but wind design requires only elastic behavior in the entire range of displacement. In this review paper, we have studied the seismic behavior of RC building with base, with base isolation. Due to urbanization multi-story building with basement parking space and storage requirement seismic dissipating devices are being used for various types of structure and located in the basements which are difficult to maintain. Therefore, different types of dampers are used above the basement. Base isolation system is the passive control device which decouples the super structure from substructure resting ground motion by insinuating structural elements with low horizontal stiffness between the structure and foundation. The analysis and conclusion of research papers shows that base shear, time period, story drift, stiffness are increased, and storey displacement, damping ratio, overturning moment increases by the use of dampers and base isolation system. Base isolation shows the best result in hard soil and poor in loose soil. After comparing the results base isolation system is best for low to medium rise building and damper for high rise buildings.*

Key Words: **RC Buildings, Fixed base, Base isolation (LRB), Dampers, Fluid Viscous Dampers, Soil-Structure Interaction & Seismic Analysis**

1. INTRODUCTION

The development of fast urban infrastructures and the growth of people peoples getting economically poor to make their houses in the plain and urban areas. There will become the congestion of land and need of high rise buildings which must be safe from the seismic point of view to reduce the destruction from natural hazards. The knowledge of seismic and wind performance in modern building structures becomes an essential section in the design of frame structures. In high seismic zones, increasing the size of members of the building is not advantageous as it increases the weight of the building, covers the large spaces and so not economical design and safety means of structure.

Buildings are designed only for a fraction (8-14%) of the force that they would experience. Therefore, design against earthquake effect is called as earthquake-resistant design and not earthquake-proof design. Earthquake design requires the structure to remain elastic or to undergo inelastic behavior, but wind design requires only elastic behavior in the entire range of displacement. The loading imposed by earthquake shaking is displacement type and that by wind & all other hazards is of force type. Therefore wind requires only elastic behavior in the entire range of displacement, but in an earthquake, design building must be elastic or undergo inelastic behavior. Earthquake resistant design of the structure is the method of providing the special devices, methods of design that can resist the effect of ground motion and must be safe during the ground motion. For resisting the lateral forces acting due to seismic and wind load shear wall and bracing are provided in the building. However, it is not sufficient and economical for all types of structures. So the evolution of base isolation and dampers in the frame structures to reduce the horizontal movement of the upper story called energy dissipating device. The control strategy for seismic energy dissipating system is base isolation (tunned mass, liquid, liquid column dampers) energy dissipating devices such as VD, DED, FD is passive control device; active tendons, active TMDs & AMD are active control system and combination of the active and passive system are hybrid control systems. Analysis of building is done by various software like FEM, AASYS, ETABS, SAP2000, Staad Pro. Robot Structure etc. Dynamic analysis such as equivalent static analysis, response spectrum analysis, time history analysis, pushover analysis is essential to know the dynamic performance of structures. Among them, nonlinear time history analysis gives the best result and mostly used for research work.

1.1 Base Isolation System

Base isolation is one of the effective seismic energy dissipating devices used in earthquake-prone regions for designing of a new buildings as well as retrofitting of existing building structures. The base isolation system separates the superstructure from the base (foundation or substructure). It must be flexibility, damping, and to resist vertical or other service loads. Its first application was done in New Zealand in 1974, US application in 1984, Japanese application in 1985 but in India, it started in 2003. The main principle of base isolation is the separation of the building superstructure from the ground to place the base isolation system which reduces the chances of destruction due to seismic excitation. There are two types of base isolation i.e. sliding and elastomeric bearing systems are available. The sliding system dissipates the seismic force by providing sliding friction and limiting the transfer of shear in the upper story while elastomeric bearing eliminates horizontal earthquake force by providing a layer with low horizontal stiffness. Elastomeric bearings are three types viz, natural rubber bearing (NRB), lead rubber bearing (LRB), and high damping rubber (HDRB).

Base isolation system is advantageous in RC buildings due to following reasons it reduces the floor acceleration and inter-story drift, no or fewer damages of structures, better protection of secondary system, prediction of response is more reliable and economical, improve safety of structures, enhance the performance of structure under seismic load, reducing the cost of structure, etc. Major applications are bridge bearings, important and high rise buildings, enhance the response of historic structures & isolation in the machinery field.

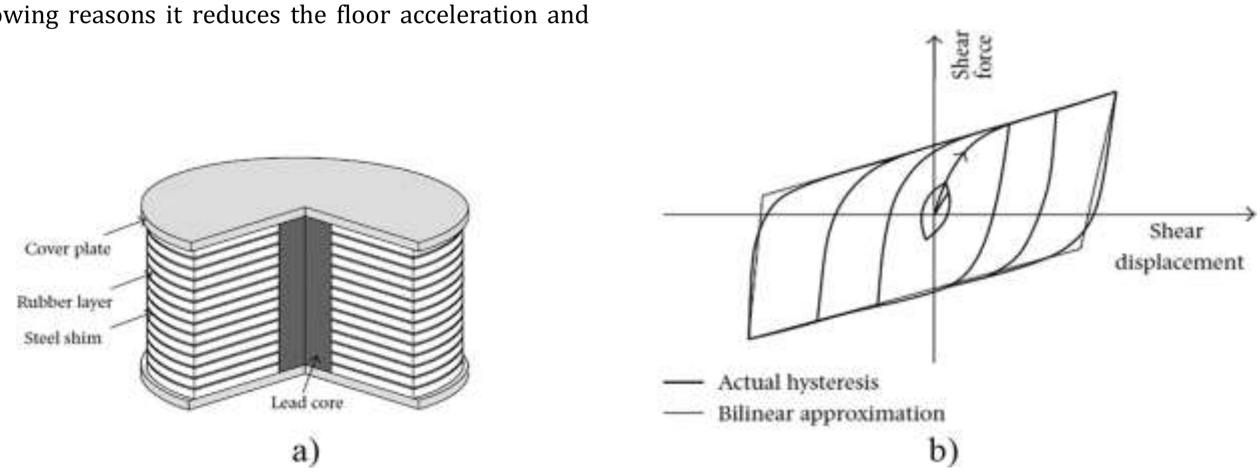

Fig -1: Schematic representation and hysteretic behavior of the lead-plug bearing

1.2 Damper System

Damping is the phenomenon that makes the structure to decay in the amplitude of motion gradually using energy dissipation through the various mechanism. Viscous elastic dampers were initially used in the military and aerospace industry but at present, it is the most widely used damper system all over the world both in new or existing buildings. FVD type dampers consist of a piston head with orifices contained in the cylinder filled with visco-elastic material (silicone or oil). When the damper is subjected compressive force the incompressible fluid volume decreased as a result of piston area movement which causes restoring force. This force is prevented by accumulator which works by collecting a volume of fluid displaced by piston rod and storing in the makeup area. Fluids come out due to the vacuum created as rod retreats. Previous studies show that it is the ideal energy dissipating device due to efficient energy dissipations, high reliability, and cost-effectiveness. Generally, visco-elastic dampers are used as horizontal dampers above the basement level. Types of modern dampers are Metallic Yielding Dampers, Visco Elastic Dampers, Friction Dampers, Tuned Mass Dampers, Tuned Liquid Dampers & Active Tuned Mass Dampers.

Energy equations of damping system are

For structural systems vibrating in elastic range;

$$E_I(t) = E_K(t) + E_s(t) + E_D(t) \quad (1)$$

For structural system vibrating in inelastic range;

$$E_I = E_K(t) + E_S(t) + E_H(t) \quad (2)$$

$E_I(t)$ = Input energy by ground excitation to the structural system

$E_K(t)$ = Kinetic energy of the vibrating structural system

$E_S(t)$ - Strain Energy of the vibrating structural system

$E_D(t)$ = Damping energy dissipated by the structural system

$E_H(t)$ = Hysteretic energy dissipated within the structural system

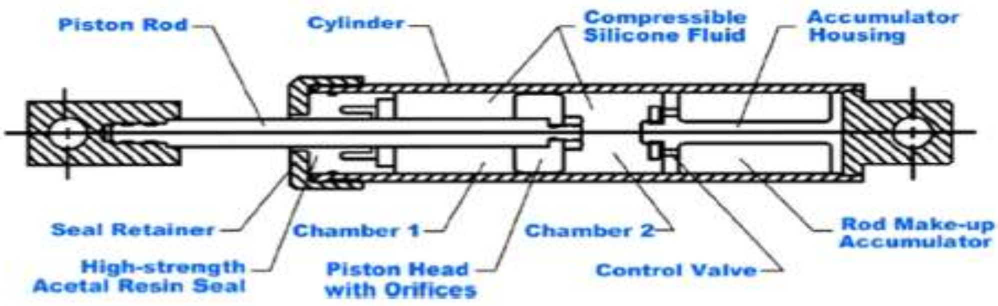

Fig -2: Fluid Viscous Dampers

2. LITERATURE REVIEW

Literature reviews are written by studying the research papers published in the journals, textbooks and review papers of the RC buildings with dampers and base isolators in a different plan, structural configurations of regular as well as irregular buildings:

Vijay et al. (2015), study the response of viscoelastic dampers on the G+10 storey RC hospital building having plan 55m x 61.8m and vertically irregular located at Delhi. Foundation is a raft slab, the horizontal structural system is a flat slab and shear walls for lateral load resisting system. Modeling and analysis are done in ETABS by response spectrum analysis method according to IS codes. The optimization of dampers is done by placing it at different locations to find the maximum damping ratio. The result shows that damping ratio increase by 2%, 14 - 19% reduction in inter-story drift, roof displacement and 5% decrease in overturning moment by providing dampers. It facilitates the idea of the design of shear wall without increasing the wall thickness.

Sumana et al. (2016), study the comparative analysis of 6, 8 & 10 storey OMRF building having 4 bays with 4m each both in X and Y direction & 3.3m storey height in sloping (25˚, 30˚ & 35˚) ground having one brick thick exterior infill wall according to IS 1893:2002 for seismic zone II & IV. They had made three types of model viz. base isolation at the foundation, above the foundation and in between the columns to know the stability of LRB isolated buildings by analyzing based on the dynamic linear seismic analysis in SAP2000. Comparison was made for a fixed base and isolated base, base isolation at a different level and base isolation between different storey buildings. They show the conclusion that an isolated base increases displacement 2.02, 2.32 & 2.61 times than fixed base in 25˚, 30˚ & 35˚ slope which causes increase ground slope decrease storey drift. 25˚ to 35˚ ground slope decrease base shear by 55% and so avoid the provision of the shear wall, bracing and ductile detailing of beam-column joints. The isolated base increase time period by 2.65 times than fixed base and also acceleration. Base isolation at foundation and other places shows no significant change in the result, it also decreases the axial force and bending moment. Thus base isolation (LRB) is suitable at the foundation level.

Thriveni et al. (2016), study the comparative seismic behavior of 64.7m X 17.12m irregular G+7 storey with 3m storey height and 1.5m bottom height. The analysis was done by equivalent static and response spectrum analysis method in ETABS according to IS 1893:2002 for seismic zone II and IV. The result shows that model with base isolator has higher displacement and storey drift than fixed base and shear wall model but the shear wall has maximum base shear & stiffness than fixed base and base isolator respectively. The time period is increased by 31% in base isolator than the fixed base.

Anwar et al. (2016), study the soil structure interaction of base-isolated system for seismic performance of structures resting on different types of soli (limestone, stiff clay, and loose sand) on 18 & 14 storey both symmetric and asymmetric plan RC building. Nonlinear analysis of 6 models with a fixed base, 6 models considered of soil-structure interaction and 6 models are with base isolation system for comparing the seismic parameters: base shear, storey displacement, and torsion in SAP2000. They find the resulting structure resting on medium and soft soil is more significant than on hard soil. Base isolation system is best suited for hard soil. Also, base shear, storey displacement, and torsion are reduced. The base isolated structure with soil-structure interaction reduces torsion by 81% on limestone, 76% on stiff clay, and 75% on loose sand.

Pathan (2017), study the control of seismic force **on** 193.6 m^2, 13 storey C type building for the seismic parameters; storey stiffness, storey displacement, base shear, time period providing dampers and shear wall according to IS 1893:2002. After analysis, they concluded that displacement and storey drift decreases but base shear & stiffness is increased by the use of friction dampers.

Polat (2017), study the seismic behavior and soil interaction of 3 storeys 21.60 x 14.35m floor plan with 3m storey height frame shear wall concrete building by changing the beam, column and slab sizes. The analysis was done by equivalent static and time history analysis method according to the 1999 Marmara earthquake recorded at Duzce meteorology station data. The results concluded that base isolation is made on the time history analysis method. Natural period increases by 8 to 16 times more in a base isolation system than fixed-base buildings. Bending capacity in all columns and shear wall is inadequate. Base isolation system is the alternative solution to construct more secure structures in settlement density regions.

Baruwala et al. (2018), study the seismic response of 4 x 4 with 5m bay width in both x and direction from 4 to 30 storey RC Building providing EL CENTRO earthquake data for time history analysis in ETABS. Models are prepared with cross bracing, LRB base isolation and fluid viscous damper. Data for damper is taken for Taylor Device Inc. having damping coefficient: 770 kN-s/m, velocity exponent: 0.3, bracings are made with different ISMB sections at each exterior corner bay of RC building. Analysis results show maximum time period for 30 story buildings is 6.181sec, 5.250sec, and 3.776sec in building with LRB, with FVD, with bracing respectively. Similarly, maximum story displacement is 63.2mm, 46.4mm, 30mm respectively. They concluded the result from analysis as maximum time period with base isolation in 4 story building are 83.47% & 71.34% than with bracing & with FVD respectively. Similarly, the minimum time period with base isolation in 30 storey building is 38.90% & 15.06% than with bracing & with FVD respectively. 30 storey building with bracing shows 52.53% lesser displacement than LRB and 35.24% than FVD. LRB shows maximum drift and bracing shows minimum drift in low rise building while in high rise (more than 14 storey) building FVD shows maximum and bracing shows minimum drift.

Sonawane et al. (2018), study the effect of base isolation in 15 storey regular, irregular and vertical irregular RC building by providing LRB isolator at the foundation. The analysis was carried out according to UBC 97 code for rubber bearing and Bhuj earthquake data for time history analysis in ETABS. The shows that the time period in the base-isolated building of regular building was 27% more than the fixed base. For Plan irregular building it was 27% & 28% in Y and X-direction. Similarly, in vertical irregular building, it was 30% & 36% in X and Y direction. The base shear for the fixed base of the regular, irregular and vertical irregular building was decreased by 27%, 31% & 35% respectively. There was zero displacements at the foundation in the fixed base and some displacement occurs in base-isolated buildings.

Kumar (2018), study the comparative seismic response of 5, 8, 12 & 15 storey with 19.80m x 6.78m plan sizes RC building with and without base isolators and viscous dampers for seismic zone V. The building fixed at base was subjected to EI Centro 1940 North-South Component ground motion data and parameters like roof displacement, base shear and time period were performed by time history analysis in ETABS. The result shows that maximum time period for 15 storey building with and without base isolator is 1.56 sec & 7.02 sec and with dampers, it is 0.6589 sec. Maximum lateral roof displacement in 15 storey building with the bare frame, base-isolated and viscous dampers are 24.26mm, 28.6mm & 8.895mm respectively. Similarly, base shear in 15 storey building with bare frame structure, base-isolated structure and with dampers are 9214kN, 336.10kN & 5787kN respectively.

Patowary & Marsono (2018), in this research 40 story hypothetical moment resisting the building of regular configuration keeping the constant column size providing viscous dampers at the different storey above the basement. Gravity loads are taken according to Eurocode 1 EN1991-1:2002 and seismic data from the Sabah earthquake [05/June/2015] with the PGA of 0.126g. Dynamic analysis is done by time history analysis with 5% damping in ETABS. Dampers decrease flexibility and hence time period make stiffer, maximum storey displacement occurs at one-third height of the building. The best result is found at the one eight height of the building.

3. CONCLUSIONS

1. Optimum design of shear wall and other structures by placing the dampers strategically which facilitate the increase of 0.5% of floor area.
2. Optimum results are found by providing the dampers in the outer periphery above the basement level.
3. The base isolator provided at the base is better than other places because it doesn't show any significant change result.
4. Increased ground slope decreased storey drift.
5. The base isolation system facilitates the economic design of the structure.
6. Seismic performance of the base-isolated building is better than the fixed base in irregular buildings.
7. Better bending capacity was found in the base-isolated building than fixed base and shear wall system even in the region of settled density near the fault line.
8. LRB will be suitable for low rise building and FVD for medium to high rise building for seismic energy dissipating device.
9. LRB system gives maximum time sifting than with FVD & bracing.
10. For plan regular, irregular and vertical irregular the building with base isolation shows higher base shear, time period and lateral displacement than the fixed base. Therefore, Base Isolation system is the solution for seismic energy dissipating device.

11. Base isolation system is more effective in reducing base shear than with viscous fluid dampers.

12. Horizontal dampers are economical and easy for installation than the base isolation system and become the alternative solution of the base isolation system.

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