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Base Isolation: A Versatile Seismic Control Tool - A Review

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Abstract. Past study on earthquake prominently bring into notice that, earthquake protective structure isfalls notion. Only possible fact is to resistant vulnerable effects through control systems which limits the damage within permissible even under the greatest possible earthquake. There are many such systems available and serving the purpose from last two decade like passive, active and hybrid earthquake control systems. Passive control systems comprise base isolators, tuned mass damper etc. are most popular out of all. Base isolation is the most accepted member of the family due to its compatibility in hardware, applications, design codes and retrofit manuals. The most popular seismic isolation systems use elastomeric bearings which consist of rubber and steel plates with an energy dissipation mechanism. Common isolation systems in use today include elastomeric and sliding bearings with and without dampers or damping mechanisms. This review paper includes conceptual working principal, methodology, and types of available isolators. It also summarizes effect of different available isolator and their applicability on design parameters like storey drift, storey displacement, base shear and time period form literature. This study presents a comparative table of different parameters such as frequency, base shear, displacement, and story drift with and without base isolation from literature.

Keywords. Earthquake, Base isolation, LRB, FPS, HDRB

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1. Introduction

1.1 Earthquake

A disturbance that causes shaking of the earth's surface due to movement underground along a fault plane or from volcanic activity is called an earthquake [19]. The primary destructive effects of earthquakes are landslides, tsunamis, liquid fluorescence, and ground shaking. But the first and most obvious sign of earthquakes is ground shaking. Out of all the destructive effects of an earthquake, ground shaking has the most effect miles away from the epicentre, depending on magnitude. Ground waves generated by earthquakes are sudden and erratic in nature. This ground motion was transferred to the structure through the foundation resting on it.

During an earthquake, each structure oscillates with its natural frequency, depending on its stiffness, mass, and height. But the effect is violent if the frequency of the building matches the earthquake frequency and it is vulnerable to collapse due to ground motion. This issue can be mitigated by three measures, as shown in Figure 1.

1.2 Base Isolation

There are prominently three systems: passive, active, and hybrid earthquake control systems, which can control the effects of earthquakes within an acceptable level. But due to their compatibility with software, passive systems are perhaps the best known. Passive control systems, such as base isolators, tuned mass dampers, etc., have had a wide range of applications over the past few decades, such as seismic control, retrofitting, etc. [2].

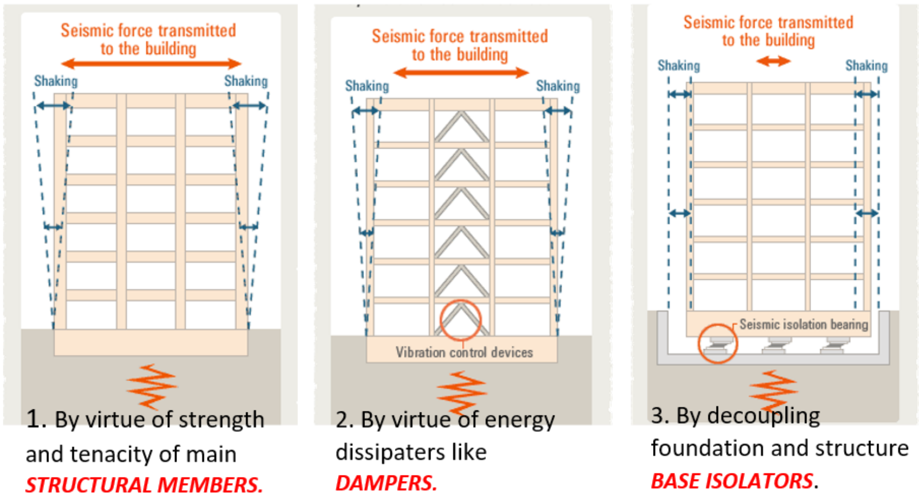

Figure 1. Seismic isolation design approach

Seismic base isolation design approach works on protecting structures against damage from earthquakes by limiting the earthquake attack, rather than resisting it [25].

The base isolation disassociates the direct interaction of superstructure from foundation in turn to the ground. This separation boosts fundamental period and reduce acceleration transfer to the structure during ground motion. Base isolators reduce the input of earthquake through Energy dissipation, shift period and support gravity load and acts rigidly rather than resonatingwith EQ.

Base isolators impart superstructure a frequency much lower than its natural frequencyand ground motion frequency due to its low horizontal stiffness. The first ground motion mode deforms isolated system only and superstructure remains intact and rigid. The higher modes formed after first modes are large and susceptible to produce deformation but they act orthogonal to first mode hence cannot directly transfer to superstructure. Likewise Base isolators work through dynamics of systems.

The major benefit is obtained from the period shift and the secondary benefit is obtained from the further available damping in the isolation layer. Use of base isolation not only increases fundamental period 1.5–3 times but also increases damping to more than 15% [8].

1.3 Time History Analysis

There has two distinct approaches used to investigate the seismic response of a base-isolated structure, first linearized response spectrum analysis techniques while second nonlinear time history analysis. The nonlinear time history analysis technique can simulate and record the actual performance of a building under a design time history record and widely used in the design of building structures.

Time history analysis approach yields different acceptable criteria for various design parameters like, base shear, storey displacement, storey drift. Time history analysis forecast the structural response more accurately than the response spectrum analysis [25].

2. Literature Review on Types of Isolators

Use of base isolators has a long history of many decades since it was used in the elementary school in Skopje, Yugoslavia by rubber isolation system to protect school from earthquake [9]. Though extensive work is carried out on working principal, types of isolators, this reviewarticle included following base isolators for research works

Majorly Seismic isolation techniques have been categorized based on their mechanism however it mainly consists of,

1. Isolation Units as basic component that performs of decoupling effect and
2. Isolation Components- connection units between the isolation units.

2.1 Elastomeric bearings

Elastomer is Multilayer isolation bearings uses natural rubber, neoprene rubber, butyl rubber and nitrile rubber. The alternate layer of natural or synthetic rubber sandwiched the steel reinforced plates forms elastomeric bearing under vulcanization [10]. Both materials serve specific purpose, Steel shims can support high vertical loads without bulging of rubber layers and rubber provides flexibility together provides stable support for structures. This sandwiched Multilayer construction provides better vertical rigidity for supporting a building over rather than single layer rubber pads. Elastomers are very stiff to carry the vertical load of the structurealong with horizontal flexibility to move in lateral direction under strong ground motion. These bearings have a widely used in RCC structures like buildings and bridges.

The most common elastomers are:

2.1.1 Natural rubber bearing (NRB): This bearing uses Natural Rubber layers as a flexible material along with alternatelyplaced thin steel shims packed between to steel endplates. This assembly shows linear shear variation up to shear strains above100% and damping in the range of 2-3% [10].

2.1.2 High damping rubber bearings (HDRB): This is same as that of natural rubber bearing with improved damping ranging from 8% to 15% compared to natural rubber of 2% damping by adding carbon black or resin. The additional damping is produced by modifying the compounding of the rubber and altering the cross-link density of the molecules [7] This additive alteration in the material shows nonlinear behavior at shear strains less than 20% [19].

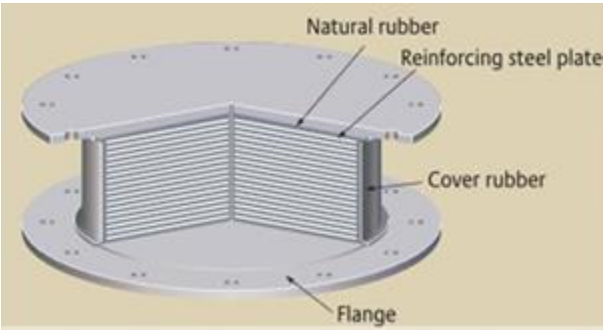

Figure 2. Natural rubber bearing

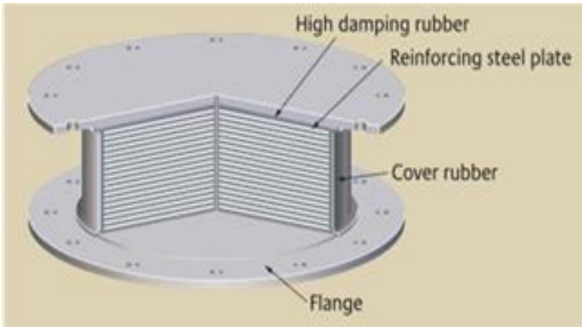

Figure 3. High damping rubber bearing

2.1.3 Lead Rubber Bearing (LRB): A lead-rubber bearing as shown in Fig C is another type of elastomer formed by using a lead plug fitted at the centre of an elastomeric bearing in a pre-formed hole. This central Lead core provides extra stiffness and appropriate damping to the isolators system. [18]. Also this Lead core impart elastic restoring force to the rubber layers which bring back the building to the original position [19] Additional encasing provided externally protects this assembly from environmental hazards.

Another Fibre Reinforced Elastomeric Bearings (FREB) uses fibres instead of steel sheets, which makes FREB light in weight and cost effective [1].

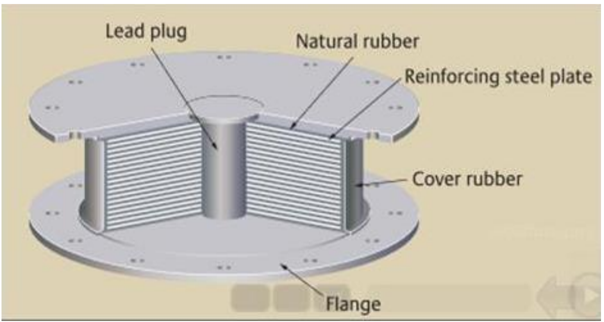

Figure 4. Lead rubber bearing

2.2 Friction Pendulum Sliding (FPS) Bearing

FPS Bearing the pendulum system comprises a spherical globe that is placed in between two steel concave curved surfaces separated by Teflon layer. The friction pendulum system (FPS) is durable and stable seismic isolation techniques [18] FPS works on very simple combine mechanism of Sliding action & pendular motion.

An articulated concave curved steel frictional sliding plates separated by a Teflon layer tends to move on a spherical pendulum along its surface. Friction between the slider and the spherical surface produces damping in the isolators

In built restoring force due to the pendular motion along the perfectly spherical surface deviceis able to recentre itself and can dissipate a large quantity of energy through the sliding on a curved surface [13].

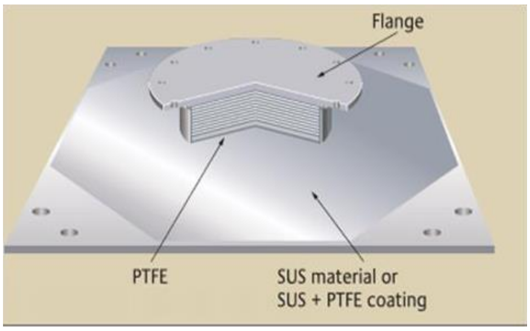

Figure 5. Flat plate sliding bearing

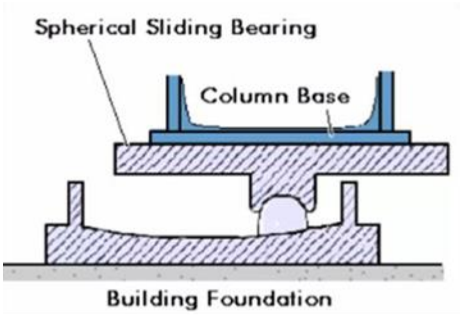

Figure 6. Friction pendulum bearing

3. Literature Review on Base Isolation

Buckle, I. G. (2000) explained that seismic isolation is a design strategy that is based on the premise that it is both possible and feasible to uncouple a structure from the ground and thus protect it from the damaging effects of earthquake ground motions [2].

Anjali Palheriya et al. (2022) used a G+10-story building with the same floor plan, with six bays having the same lengths of 3.5m along the longitudinal and transverse directions. This building is designed as per IS Code 1893 (Part-1):2002 to be seismic-resistant. The study analysed design parameters like frequency, base shear, displacement, and story drift in fixed and base-isolated modes. This study indicates that the damage caused to the base-isolated structure is less as compared to the fixed base structure, and less damage allows immediate occupation of the building [17].

Rakshith K. J. et al. (2017) studied a RCC G+14 structure modelled using ETABS 2016 software. LRB and HDRB are used for base isolation. The paper studied the performance of fixed and base-isolated structures against two different time histories, El-Centro and Bhuj. The models are analysed for various dynamic factors governing the earthquake response like base shear, story acceleration, story drift, column, and beam forces between the fixed base condition and the base isolated condition against a two-time history and are compared [18].

The study concludes that

- The base isolation allows additional displacement of the building and reduces base shear, story drift, and story acceleration over fixed
- HDRB gives better performance against base shear compared to LRB and fixed
- The analysis results of the study strongly recommended a high-damping rubber isolator as compared to a lead rubber bearing isolator.

Zou, X. K., et al. (2004) compared the overall cost of an isolated structure and proved that an isolated structure is economical since a well-designed base isolation system results in a small and slender structural member due to a reduction in forces. Much research has been conducted on the design optimisation of either the base isolation or the superstructure separately. But the most cost-efficient design results only if both the base isolation and the superstructure are simultaneously considered. This study provides an effective numerical optimisation technique called the Optimality Criteria Method for the performance-based design of base-isolated concrete building structures under time-history loading. The numerical study concludes that the integrated optimal design methodology will provide a powerful computer-based technique to automate and optimise the seismic drift performance of base-isolated concrete building structures and minimise the total construction cost of a base-isolated building structure subject to the inter-story drift constraints of the base-isolated superstructure and the effective stiffness constraints of the base isolation system [26].

Wani, R. A., et al. (2020) provided a glance at base isolation techniques, bearings, and the material behaviour of elastomers. It also compared the various modes of failure, major design methods, and standard practice throughout the world, with pros and cons. This paper provides a better understanding of the design of base isolators. For the study, modelling of G+6 buildings with fixed bases and bases isolated with lead rubber bearings is considered using SAP 2000 along with various standard codes. The study concluded that LRB is effective in reducing the earthquake response of the structure to story displacement, base shear, and storey drift by 10%, 65%, and 30%–40%, respectively [24].

Reddy, M. R. et al. (2017) carried out a comparative study on multi-storeyed RC frame buildings with low rise (G+5) and high rise (G+17) under fixed base and base isolation. The lead rubber bearing (LRB) and friction pendulum system are designed as per UBC97 and ASCE07 codes, and the same was used for the analysis of the base isolation system. The results obtained from the analysis were time period and base shear [19].

The results conclude that the LRB and FPS isolators hold good for high- and low-rise structures. The time period is stretched, and base shear in both X and Y directions is reduced as compared to a fixed base. To reduce the earthquake response of structures, FPS performs better than LRB.

Dhawade, S. M. (2014) studied the (G+14) storied frame structure modelled with base isolation using the ETAB software to compare the seismic effect of a fixed base structure with respect to an isolated structure. A high-damping rubber bearing (HDRB) is used as an isolator. The study shows that due to HDRB, there is a decrease in lateral loads and accelerations of the stories and, therefore, in inertia forces. The reduction in story overturning moment and story shear results in a rigid and stiffer superstructure above the isolation plane. In short, the study recommends the use of a base-isolated structure in the earthquake-prone area rather than a fixed base [5].

Table 1. Result for design parameters

Seismic parameter		RC G+5 Structure			RC G+17 Structure		
		Fixed base	LRB	FPS	Fixed base	LRB	FPS
Time period(Sec.)		0.934	2.545	2.860	1.887	3.059	4.05
Base Shear(kN)	Max.	3219.00	948.00	885.00	5389.69	4809.00	1801.00
	Min.	642.00	154.00	207.00	655.559	280.55	251.00

Shameena Khannavar et al. (2016) shed light on the performance of horizontal and vertical irregularities in framed structures in a seismic zone. In the present study, modeling and analysis of a 10-story RC building using two vertical irregular and two plan irregular models are considered. The analysis is done by the equivalent static and response spectrum methods. The ETAB 15 version was first on a fixed base and the second on an isolated base lead rubber bearing (LRB), designed as per UBC 97, which was used as the base isolation system. The results obtained from the analysis were summarised below:

The study results obtained emphasized the use of the response spectrum method as compared to the equivalent static method. Horizontal irregularity works better than vertical when used as a base-isolated building in a higher seismic zone area [20].

Jain, S. K., et al. (2004) aimed at finding the suitability and influence of filled rubber bearings as a base for the isolation of bearing parameters. Though natural rubber bearings are widely used due to their very low stiffness and energy dissipating capacity, they result in unacceptably high displacements at isolation level. The researcher tried to mitigate this issue by supplementing the damper with certain chemicals mixed in a suitable amount with the natural rubber. The compound it forms is called filled rubber bearing (FRB). Further, for the case study, five earthquakes recorded at different sites in India are considered and isolated with this newly formed FRB isolator. The study concluded that filled rubber bearings provide displacement within an acceptable limit and a proven effective isolation system against ground motions with high dominant frequencies. These filled rubbers can be used efficiently in the manufacture of isolation bearings [12].

Sekar and PL Kadappan (2015) carried out an assessment to assess the effect of different terrain conditions, viz., plain and sloping grounds, on the seismic response of structures. The ten different buildings of ascending height resting on plain and sloping terrain are modelled using STAAD Pro software. These models are located in seismic zones II, III, IV, and V as per the Indian standard code. The response spectrum method of dynamic analysis has been performed using STAAD Pro software for all the simulated building models with and without seismic base isolators. The dynamic response parameters such as inter-storey drift, base shear, storey displacement, and fundamental period were tested for all the simulated models. The earthquake analysis of building models for all seismic zones and terrain conditions has been carried out with and without seismic base isolators. The output showcases that structures behave satisfactorily for a given base condition and terrain nature with respect to all earthquake parameters, and base shear, storey displacement, and storey drift increase as the seismic zone level increases. Furthermore, the results recommended the introduction of a seismic base isolation system at the base of the building, as it makes the structure behave like a rigid structure [23].

Pokhrel, A. et al. (2016) aimed to access the seismic response of the five-story SMRF structure with a fixed base and an isolated base. The response of this building to four different time histories like Kobe, Northridge, El Centro, and Hachinohe earthquakes was simulated for study and evaluated on the basis of storey acceleration, base shear, and inter-storey drift under LRB and FPS isolators are considered isolation systems. Both isolation systems serve the purpose of decoupling the base, and great improvement is seen in the seismic performance of structures in a controlled environment. Lead rubber bearings undergo reductions in elastic base shear and inter-storey drift for most of the benchmark earthquakes, especially at the first floor. The base-isolated structure remains within the limiting drift ratio of 0.5% for almost all ground motion histories and elastic linear analysis [16].

Chandak, N. R. (2013) deals with the effects of regularity and irregularity on the structural form of reinforced concrete (RC) structures under uncontrolled and controlled conditions with base isolators. The main motive of this study is to compare the Standard Code IS 1893-2002 (Part-I) and Euro Code 8 Response Spectrum Method for Dynamic Analysis, used for analysis of structure with two base isolators, i.e., rubber bearing (RB) and friction isolator (FPS). To evaluate the seismic response of the buildings, elastic analysis is performed using the computer programme SAP2000 [4].

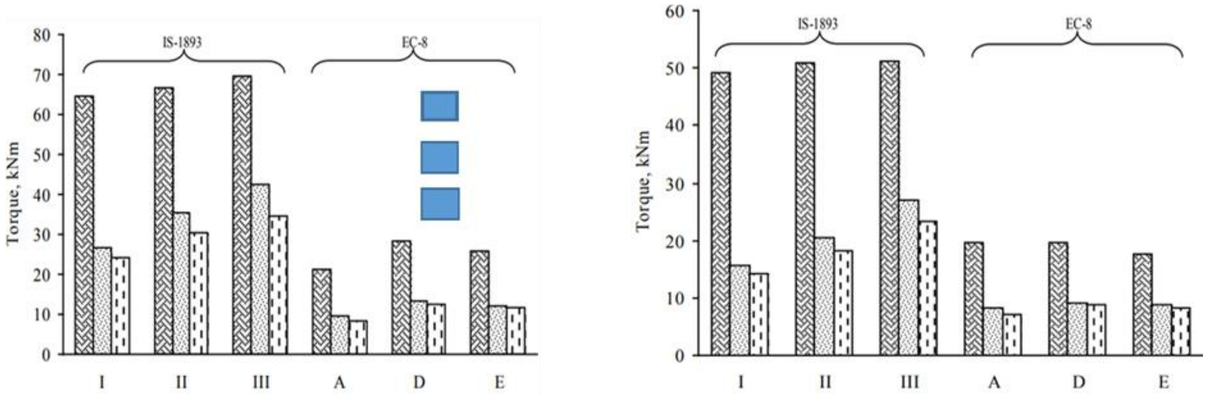

Figure 7. Comparison for base shear and torsion for IS & EC-8 for 6 UB

The research summarises that,

- Time period increased and other parametric response is reduce due to base isolation as compare with fixed base for both regular and irregular structural form.
- FPS performs better as compared to LRB.
- IS code yields higher results over Euro code in terms of design parameters like base shear, Storey drift for both regular and irregular structural form with or without isolators.

Sonawane, O., et al. (2018) showed that structural irregularities cause non- uniform load distribution in various members of a building and susceptible to damage. Hencethis study catches attention towards this parameter of Seismic performance. Paper provides literature review for base isolation and a brief on various structural irregularity and in detail analysis of four different type model in fixed base and base isolated pattern for specific Time history of earthquake. A comparison of following earthquake parameters with and without baseisolation is presented in following Table2. Result concludes that, base isolation is efficient to counterbalance the structural irregularity of structure and gives better performance [22].

Hatami, F. et al. (2015) studied soil structure interaction with the base isolation system. An actual ten-story base isolator structure designed in compliance with IBC-2009 was modelled. Three different soil strata available around the building premises were also simulated to predict the effects of soil on the structure. Loma Preita and North Ridge time history analysis are used for the all-three-soil structure model. The different seismic parameters like time period, base shear, etc. are found on isolated buildings with each soil model. The result showed that the effect remains unchanged if the underlay strata is hard or stiff, but if soft or medium strata exist, the response gets affected. It also concludes that time is a function of soil type. Furthermore, the study emphasized that the soil-structure interaction (SSI) is important in earthquake design and should be taken care of [8].

Table 2. Compile result for design parameters

Symbol	Model Type	Base Shear X-dir	Base Shear Y-dir	Time period X-dir	Time period Y-dir
		Decrease		Increase	
1A 1B	Regular Building fixed base Regular Building isolated base	44%	27%	27%	27%
2A 2B	Plan irregular Building fixed base Plan irregular isolated base	45%	31%	28%	27%
3A 3B	Vertical irregular Building fixed base Vertical irregular Building isolated base	60%	35%	36%	30%

Mazza, F., et al. (2016) evaluated the static and seismic stability of a retrofitted residential six-story SMRF structure built in 1955. All structural members and their materials are examined by means of conventional and NDT techniques. The Italian (NTC08) and European (Eurocode 8) codes applied for nonlinear static analysis under gravity loads are carried out. Three-dimensional fiber model of the original fixed base structure (FB) to check the chord rotation at member level and shear strength at sections and joints Furthermore, to make FB sustain a safe gravity load, it is reinforced with carbon fiber reinforced polymer (CFRP) wrapping. To check the seismic vulnerability of structures, two models are simulated. First fixed base with a hybrid system of elastomeric HDRB and friction steel flat plate sliding bearings FTP, and another fixed base with a hybrid system (HDRB+FLP+CFRP) [15].

CFRP improves the flexural and shear capacities of beams and columns by wrapping beams and columns with these composite materials. Nonlinear seismic analysis is carried out to check the efficacy of both hybrid combinations and conclude that

- Due to CFRP, the original structure performs satisfactorily against gravity.
- FB+CFRP performs better in controlling the shear performance of beams and columns than FB.

A hybrid system (HDRB+FLP+ CFRP) results in better control of certain limit states as compared to individual FB or FB+ CFRP.

Sheikhi, J., et al. (2020) investigated the efficacy of natural rubber bearings (NRB) reinforced with dampers. Primarily, the properties of steel ring dampers (SRD) are assessed separately. These rings are provided in two patterns: continuous steel ring dampers and separate steel ring dampers. The steel ring has a different diameter-to-thickness ratio (D/t) but identical length (L) and is embedded between the top and bottom plates along the periphery of the NRB. ANSYS software was applied for modelling, meshing, and analysis of NRB. The various design parameters such as Hz. stiffness, energy dissipation, and viscous damping are calculated for three models: HDRB, NRB+SRD, and shape memory alloy (SMA)-lead core rubber bearing (SMA+LRB) [21]. Results obtained are compared with the HDRB and the analysis concluded with,

- Due flexural behaviour of the ring, energy get dissipated
- NRB+SRD serve the purpose of energy dissipation more reliably than SMA+LRB
- HDRB Steel rings form an interface between structure and substructure.
- This added dampers impart initial and ultimate stiffness and energy dissipation throughdamping.

3. Summary

The above literature study strongly recommended the use of base isolation in regions of the high seismic zone over fixed base structures, as the damage is minimised and allows immediate occupancy of the structure. The base isolator is the best tool used for the retrofitting of almost all types of structures. In different studies, different isolators performed better, which indicates that the performance of base isolation is not constant and is a function of structural form (regular or irregular), height of the building, and soil-structure interaction. The review work recommends time history analysis due to its nearer perception of seismic response as compared to response spectrum analysis. Some of the papers conclude that the shortcomings of available elastomers and friction isolators can be minimised by combining them or adding damping.

4. Conclusion

There has been tremendous research work going on from past two decade on base isolation starting from retrofitting to new age building to counter fort seismic attack. Though Base isolator is universally accepted tool for seismic control following issues need to be studied further,

1. To enhance the energy dissipation characteristics of elastomeric isolators
2. Performance of structure under various isolation configurations (Hybrid system)
3. To study the performance of isolators on near faults, against pounding and aftershocks.

References

1. Beirami Shahabi, A., Zamani Ahari, G., &Barghian, M. (2020). Base Isolation Systems–AState of the Art Review According to Their Mechanism. Journal of Rehabilitation in CivilEngineering, 8(2), 37-61. https://doi.org/10.22075/jrce.2019.16186.1306
2. Buckle, I. G. (2000). Passive control of structures for seismic loads. Bulletin of the New Zealand Society for Earthquake Engineering, 33(3), 209-221. https://doi.org/10.5459/bnzsee.33.3.209-221
3. Cancellara, D., & De Angelis, F. (2017). Assessment and dynamic nonlinear analysis of different base isolation systems for a multi-storey RC building irregular in plan. Computers& Structures, 180, 74-88. https://doi.org/10.1016/j.compstruc.2016.02.012
4. Chandak, N. R. (2013). Effect of base isolation on the response of reinforced concrete building. Journal of civil engineering Research, 3(4), 135-142. http://dx.doi.org/10.5923/j.jce.20130304.02
5. Dhawade, S. M. (2014). Comparative study for seismic performance of base isolated & fixed base RC frame structure. *International Journal of civil engineering research*, *5*(2), 183-190. http://www.ripublication.com/ijcer.htm
6. Farzad Naeim, James M. Kelly- Design of Seismic Isolated Structures-From Theory to Practice- (1999) DOI:10.1002/9780470172742
7. Gupta, N., & Sharma, D. Poonam.(2014).“State Of Art Review-Base Isolation For Structures”. International Journal Of Scientific & Engineering Research, 5(5). https://doi.org/10.22075/jrce.2019.16186.1306
8. Hatami, F., Nademi, H., & Rahaie, M. (2015). Effects of soil-structure interaction on the seismic response of base isolated in high-rise buildings. *International Journal of Structural and Civil Engineering Research*, *4*(3), 237-242. doi: 10.18178/ijscer.4.3.237-242
9. J. P. Stewart, J. P. Conte, and I. D. Aiken, “Observed behavior of seismically isolated buildings,” *Journal of Structural Engineering*, vol. 125, no. 9, pp. 955–964, 1999. https://escholarship.org/uc/item/5847g3dr
10. Jain, M., & Sanghai, S. (2017). A review: on base isolation system. IJSART, 3(3), 326- 330. http://www.ijesi.org/
11. Jain, S. K. (2016). Earthquake safety in India: achievements, challenges and opportunities.Bulletin of Earthquake Engineering, 14(5), 1337-1436. http://link.springer.com/article/10.1007/s10518-016-9870-2
12. Jain, S. K., & Thakkar, S. K. (2004, August). Application of base isolation for flexible buildings. In 13th World Conference on Earthquake Engineering (p. 1924).
13. Kolekar, A. N., Pawar, Y. P., Pise, C. P., Mohite, D. D., Kadam, S. S., & Deshmukh, C. (2017). Comparative study of Performance of RCC Multi-Storey Building for Koyna and Bhuj Earthquakes. *J. Eng. Res. Appl*, *7*, 45-52. DOI: 10.9790/9622-0705024552
14. Landi, L., Grazi, G., & Diotallevi, P. P. (2016). Comparison of different models for friction pendulum isolators in structures subjected to horizontal and vertical ground motions. Soil Dynamics and Earthquake Engineering, 81, 75-83. https://doi.org/10.1016/j.soildyn.2015.10.016
15. Mazza, F., & Pucci, D. (2016). Static vulnerability of an existing rc structure and seismic retrofitting by CFRP and base-isolation: A case study. Soil Dynamics and Earthquake Engineering, 84, 1-12. https://doi.org/10.1016/j.soildyn.2016.01.010
16. Pokhrel, A., Li, J. C., Li, Y. C., Maksis, N., & Yu, Y. (2016). Comparative Studies of BaseIsolation Systems featured with Lead Rubber Bearings and Friction Pendulum Bearings. In *Applied Mechanics and Materials* (Vol. 846, pp. 114-119). Trans Tech Publications Ltd. https://doi.org/10.4028/www.scientific.net/AMM.846.114
17. Prof. Anjali Palheriya1, Mr. Gaurav D. Dhumane 2, Mr. Shreyas Kotangale 3, Mr. RatndipMore 4,Mr. Vikki Singh Rawate 5, Mr. Suprit Badwaik6(2022).Analysis Of Earthquake Resistant Structure By Base Isolation Method.International Research Journal of Engineering and Technology,9(03), https://doi.org/10.14445/22315381/IJETT-V33P282
18. Rakshith K J1, Spandana B2,(2017) Ganesh M3. Time History Analysis Of Fixed Base And Base Isolated Reinforced Concrete

Building .International Research Journal of Engineering and Technology,4(07)| https://irjet.net/archives/V4/i7/IRJET-V4I7173.pdf

19. Reddy, M. R., Srujana, N., &Lingeshwaran, N. (2017). Effect of base isolation in multistoried reinforced concrete building. International Journal of Civil Engineering and Technology, 8(3), 878-887. http://dx.doi.org/10.5923/j.jce.20130304.02
20. Shameena Khannavar1, M.H.Kolhar, Seismic Analysis Of Rc Structures Using Base Isolation Technique IRJET Volume: 03 Issue: 07 | July-2016
21. Sheikhi, J., & Fathi, M. (2020). Natural rubber bearing incorporated with steel ring damper(NRB-SRD). International Journal of SteelStructures,20(1),23-34.http://dx.doi.org/10.1007/s13296-019-00267-7
22. Sonawane, O., & Walzade, S. B. (2018). Effect of base isolation in multistoried RC regular and irregular building using time history analysis. International Journal of Engineering Research and Science, 4(5), 30-37. DOI: 10.36348/sjce.2020.v04i05.004
23. T.Sekar and PL Kadappan," Seismic analysis of multistory buildings resting on normal andsloping grounds in different seismic zones with and without base isolator, Imanager's Journal on Structural Engineering, Vol. 4 l No. 1,(2015) https://doi.org/10.26634/jste.4.1.3463
24. Wani, R. A., & Beigh, M. A. (2020). Design of Multistorey Building using Lead Rubber Bearing (LRB) in sap 2000. http://dx.doi.org/10.5935/jetia.v6i26.697
25. Warn and Ryan: "A Review of Seismic Isolation for Buildings: Historical Development and Research https://doi.org/10.3390/buildings2030300
26. Zou, X. K., & Chan, C. M. (2004, August). Integrated time history analysis and performance-based design optimization of base-isolated concrete buildings. In Proc. 13th world conference on earthquake engineering, paper (No. 1314). https://doi.org/10.1007/s00158-007-0184-5