Study of Lead Rubber Bearing and Friction Pendulum Base Isolation System for G+20 High Rise Building in Seismic Zone III

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Abstract: The fundamental goal of a base isolation system is to reduce the risk of death or injury to individuals inside or near buildings by preventing building collapse during earthquakes. Using SAP 2000 software, seismic analysis is carried out. SMRF is used to analyze the structures in Zone-III, and the structures responses, such as storey drift, base shear and time period, were observed and graphed.

Keywords: Lead Rubber Bearing (LRB), Friction Pendulum System (FPS), Fixed Frame Structure, SAP 2000 software, Base Isolation System.

Introduction: Base isolation has increasingly been used as a structural design strategy for structures such as buildings and bridges in seismically active areas in recent years. This method has been used to construct many different kinds of buildings, including residential, commercial, industrial, and institutional ones. Many more are now in the planning and design stages. Rubber and frictional pendulum bearings are used to build the majority of the constructions.

Introduction to Base Isolation Systems: For an isolation system, there are two basic strategies.

1. There is less lateral stiffness between the superstructure and the foundation, which causes the isolated base structure's fundamental natural time period to be longer than that of the fixed base structure. In recent years, the building sector has adopted this technique a lot.

2.Using the sliding system's description as an isolation system. The modification of the limiting shear over the isolation contact serves as the foundation for this system. Different sliding systems have been advocated for and utilised in the building sector. With a particular interfacial material sliding on, the friction-pendulum system is a sliding system.

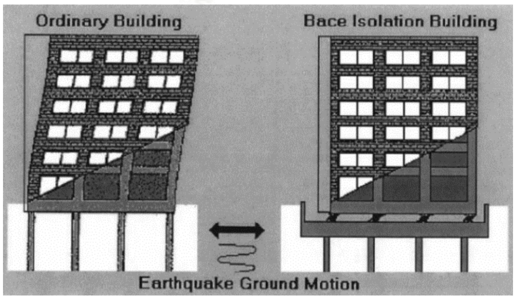

Fig. No. 1: Performance of fixed base and base isolated structure

Types of Base Isolation Systems: Many kinds of isolators are categorized as seen in fig**.** 2.Among these types of Isolation System Lead rubber bearing and friction pendulum system is used in this work.

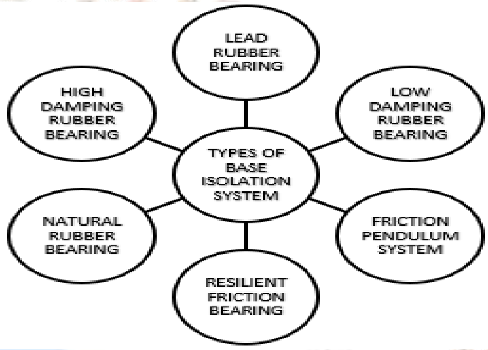

Fig. No. 2: Types of base isolation system

Lead Rubber Bearing (LRB): LRB was created in New Zealand in 1975. To make a lead-rubber bearing, a lead plug is pressed into a pre-formed hole in an elastomeric bearing. Under service loads, the lead core offers stiffness, while under severe lateral stresses, it dissipates energy. The lead-rubber bearing is rigid both laterally and vertically when subjected to mild lateral stresses, such as a moderate earthquake. Steel shims add vertical rigidity to the LRB, whereas rubber layers add lateral flexibility or horizontal stiffness. The lead core of the LRB adds rigidity to the isolators while also dampening the system.

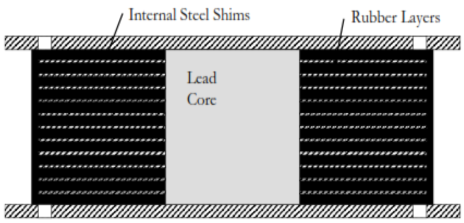

Fig No. 3: Lead rubber bearing section

Friction pendulum bearings (FPS): As with a flat slider, the isolator offers a barrier to service load through the coefficient of friction. When the coefficient of friction is reduced, the articulated slider moves, and because the mass is spherical, a vertical movement of the mass occurs simultaneously with a lateral movement. A spherical slider bearing counterattacks a total force precisely proportionate to the weight it is supporting. If every isolator in a project has the same shape, friction, and displacement characteristics, then each bearing's total force is a fixed multiple of the weight it is supporting. As a result, there won't be a torsion moment and the isolation system's center of mass and rigidity will coincide.

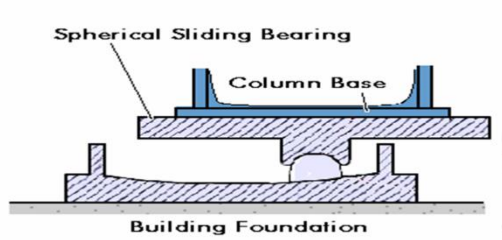

Fig No. 4: Friction pendulum bearings (FPS)

Relevance to Civil Engineering: Both residential and commercial tall buildings have significantly increased in number recently, and the present tendency is towards higher structures. The impacts of lateral loads, such as wind loads and earthquake forces, are becoming more and more significant, and nearly every designer must now consider how to provide sufficient strength and stability against lateral loads. According to the 2002 seismic zone map of India, 59% of the country's land is subject to seismic hazard damage; as a result, civil engineers have developed a way to lessen the damage and developed the idea of base isolation.

Need for the Study: The base isolation approach was created to lessen the impact of earthquakes on structures, and it has been demonstrably one of the most successful ways over the previous few decades. Base isolation is the installation of support systems that isolate the structure from earthquake-related ground vibrations. The protection of the building from increasing seismic pressures and the filtering of the input forcing functions are made possible by base isolation.

Objective of the project:

1. To make the building earthquake-proof.
2. To prolong the base isolated structure's time period in comparison to conventional buildings.
3. A base isolated structure's base shear should be lower than it would be for a fixed base structure.
4. To reduce the story drift of a base isolated structure when compared with fixed base structure.
5. To be familiar with the SAP 2000 & response spectrum analysis procedure.
6. To learn about the fundamental isolation systems.
7. To understand the friction pendulum system and lead rubber bearing design.

Literature Survey:

1. **Srijit Bandopadhay, Y.M. Parulkar, et.al** have discovered the interaction between the soil structure and the two buildings, one of which is an RC-framed construction and the other installed on a base isolator (Lead Rubber Bearing). The frequency of base isolated structures was found to be lower than that of RC framed structures.
2. **Salah AlMusbahi, Ali Gungor, et.al**
   A 40-story building was selected to be modified with the suggested hybrid isolation system and analyzed using ANSYS simulation software. The outcome demonstrates a decrease in the displacement, velocity, and acceleration.
3. **Vlad Lupasteanu, Lucian Soveja**, **et.al**
   The remedy involves shifting the church's superstructure to the seismic isolators by placing 48 friction pendulum sliding (FPS) isolators between two horizontal reinforced concrete carrying components that were cast at the infrastructure level.
4. **M.Tamim Tanwer, Tanveer Ahmed Kazi, et.al**
   Systems for base isolation are being used more and more in modern earthquake resistance structures. In this article, the impact of various foundation isolator types on earthquake-resistant constructions is investigated. In base-isolated structures, displacement is decreasing because the base isolation systems retain a longer basic lateral period than a permanent base structure and shield the structure from earthquake-induced stress.
5. **Dhiraj Narayan Sahoo, Dr. Prof. Pravat Kumar Parhi, et.al**
   This study offers a comprehensive outcome comparison analysis of structures with increasing storey counts. Base isolator design was made in accordance with the loads of the buildings and the characteristics of the base isolators found concurrently with the examination of the two building structures.
6. **Venkatesh, MR. Arunkumar, et.al** Response spectrum analysis from these building models was used to analyze Model 1's fixed base and Model 2's base isolation by lead rubber bearing. It concluded, LRB reduces story shear, story drift, point displacements, mode periods, and increases reaction time, making structures more stable and economical.

Methodology:

1. The appropriate standard codes were inserted for usage in design.
2. Creation of Grid points & Generation of structure After getting opened with SAP 2000 we select a new model and a window appears where we had entered the grid dimensions and story dimensions of our building.
3. Defining of property Here we had first defined the material property by selecting define menu material properties. We add new material for our structural components (beams, columns, slabs) by giving the specified details in defining. After that we define section size by selecting frame sections & added the required section for beams, columns etc.
4. To transfer of Property After specifying the property, we use the command menu to draw the structural elements.
5. Assigning of Supports by keeping the selection at the base of the structure and selecting all the columns we assigned supports by going to assign menu joint/frame Restraints (supports) fixed.
6. In SAP 2000, all load considerations are established first, and then they are allocated.
7. Assigning of Dead loads After defining all the loads. Dead loads are assigned for external walls, internal walls in SAP 2000 automatically taken care by software.
8. Delegating live loads for the whole structure, distinct live loads are allocated to the roof and the floor.
9. Identifying wind loads According to IS 875 1987 Part 3, wind loads are described and allocated by providing wind speed and wind angle.
10. Calculating seismic loads According to IS 1893:2002, seismic loads are defined and allocated by providing zone, soil type, and response reduction factor in the X and Y directions.

11. Assigning load combinations, the load combinations function in the define menu generates load combinations based on the codes entered.

12. Analysis We ran the analysis and verified for mistakes after completing all of the preceding stages. The comparison graphs are created once the mistakes have been corrected.

13. Give Base isolation parameters of LRB and FPS. After analysis with fixed base, the base is isolated by LRB and FPS technique to make structure earthquake resistant. As a result, its LRB and FPS characteristics are determined and allocated using the isolation design technique.

Modeling and Analysis:

Building Details:

No. of Floors	G+20
Height of Floor	3m
Size of Beam	0.25m*0.45m
Size of Column	0.3m*0.6m
Thickness of Slab	0.15m
Seismic Zone	III
Zone Factor	0.16
Soil Type	Hard Soil
Response Reduction Factor	5
Importance Factor	1
Damping of Structure	5%
Grade of Concrete	M25
Grade of Reinforcement	FE500
Density of concrete	25 KN/m3
Modulus of elasticity	25000 N/mm2
Span width in X-Axis	12m
Span width in Y-Axis	12m

Table No. 1

Model 1: Fixed Frame Structure

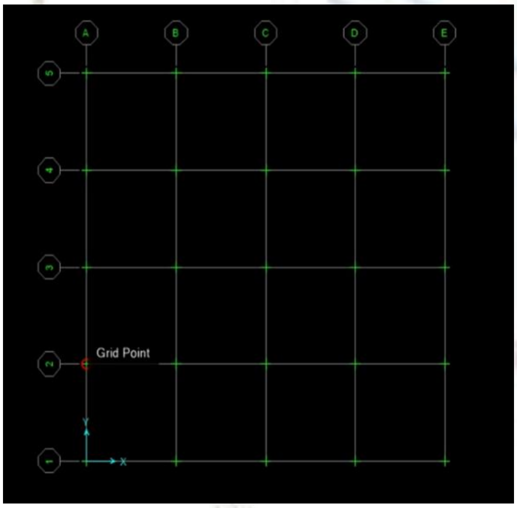

Fig No. 5: Plan of Building

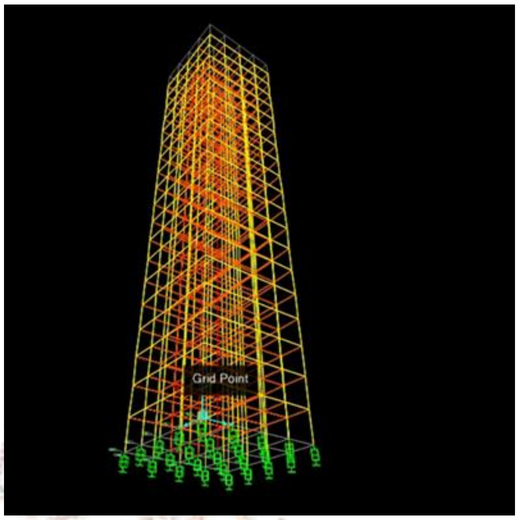

Fig No. 6: Isometric View of model

Model 2: Lead Rubber Bearing (LRB)

Design of LRB: The procedure of design of lead rubber bearing is referred from Textbook of (DESIGN OF SEISMIC ISOLATED STRUCTURE from theory of practice by JAMES M. KELLY and FARZAD NAEIM)

Input Data of LRB in Sap 2000:

Rotational Inertia	0.01664343 Kn/M
For U1 Effective Stiffness	743251706 Kn/M
For U2 & U3 Effective Stiffness	2148.45293 Kn/M
For U2 & U3 Effective Damping	5%
For U2 &U3 Yield Strength	62.8697143 Kn
For U2 &U3 Distance from End-J	0.00317581m
For U2 & U3 Stiffness	19796.4592 Kn

Table No. 2

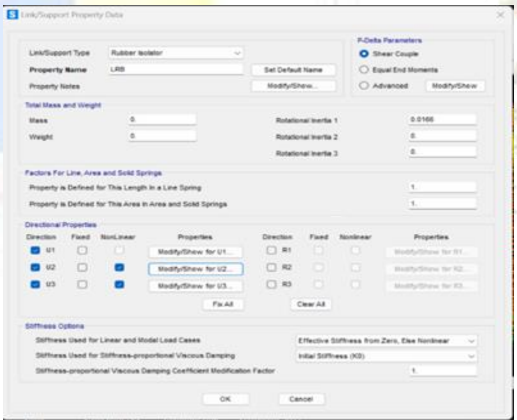

Fig No. 7: Input Data of LRB system

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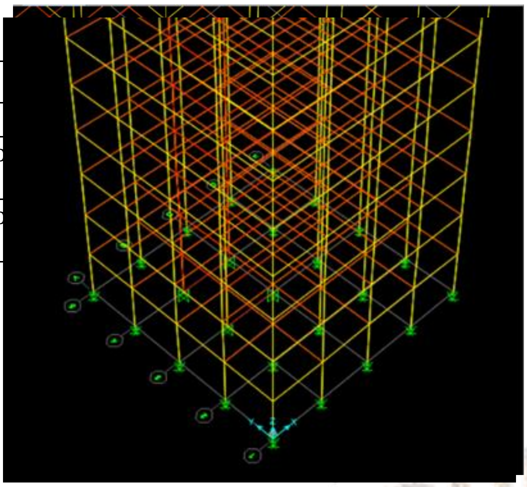


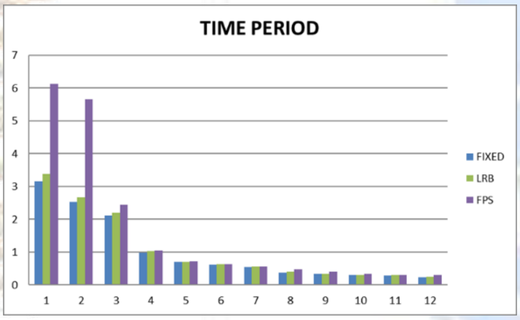


Fig No. 8: LRB system

Model 3: Friction Pendulum System (FPS)

Design of FPS: The procedure of design of friction pendulum system is referred from Textbook of (DESIGN OF SEISMIC ISOLATED STRUCTURE from theory of practice by JAMES M. KELLY and FARZAD NAEIM)

Input Data of FPS in Sap 2000:

Fig No. 9: Input Data of FPS system

Table No. 3

Fig No. 10: FPS system

Results And Discussion:

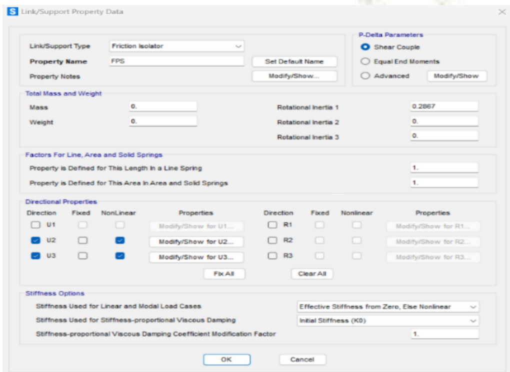
1.Time Period: One of the most crucial and essential analyses in a graph is the time period between Fixed base, LRB, and FPS. Furthermore, we can see how time has progressed with the addition of more stories in our scenario. Time extends in base isolated structures. Structure encounters fewer seismic forces as a result of an extended period. As we can see, the model 3 FPS has a longer time period than the model 1 Fixed Base and the model 2 LRB. We can therefore draw the conclusion that when time is extended following the provision of FPS, the structure becomes more earthquake-resistant than LRB and Fixed structures.

Fixed Base	**Lead Rubber Bearing**	**Friction Pendulum System**
2.118477	3.72344	3.84255

Table No. 4

Fig No. 10: Graph representing results of Time Period for Fixed, LRB & FPS

2. Base Shear: In the graph, the base shear in the y-y direction is plotted for each model. It is clear from this graph that model-3, which features a base isolation, has less base shear than models 1 and 2, respectively. When compared to model-1 fixed based structure, the base shear in model-2 (LRB) was reduced by 4.75% in response spectrum analysis. In parallel, the base shear in model-3 (FPS) was reduced by



36.60%, is decreased in comparison to model-1. Finally, it can be said that the provision of FPS reduces maximum base shear, making the structure more earthquake-resistant than LRB and Fixed structures.

	Fixed Base	Lead Rubber Bearing	Friction Pendulum System
Base Shear (KN)	1095.4	1043.77	694.4

Table No. 5

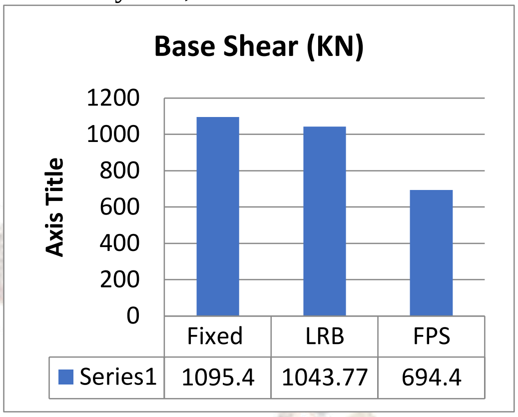


Fig No. 11: Graph representing results of Base Shear (KN) for Fixed, LRB & FPS

3. Storey Drift: In graph it is observed that storey drifts in y-y direction is increased in storey 1, 2 and 3 of model-3 FPS and in storey 4 to storey 20 the storey drifts in y-y direction are reduced in model-3 FPS which is the effect of FPS at base. It is important to reduce storey drifts of top stories which damage structure during earthquake. Similarly, it is observed that storey drift in y-y direction is increased in story 1 to 10 of model 2 LRB and in storey 11 to storey 20 the storey drifts in y-y direction are reduced in model 2 LRB which is the effect of LRB at base. In model-3 FPS storey drift in y-y direction at storey 4 is reduced by 43.98% when compared to model-1 fixed base and in model-2 fixed base storey drift in y-y direction of storey 11 reduced by 28.95% when compared to model-1 Finally it is concluded that maximum storey drift is reduced after providing FPS which makes structure more stable during earthquake then LRB & Fixed structure.

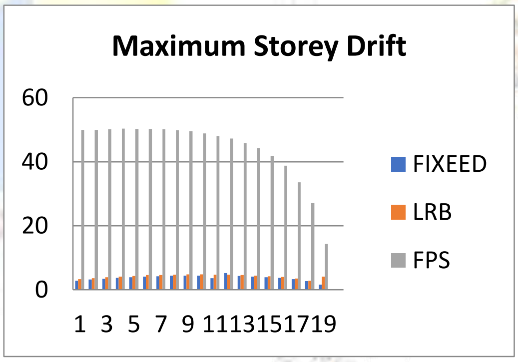


Fig No. 12: Graph representing results of Storey Drift for Fixed, LRB & FPS

Conclusions:

1. The time period of the FPS is greater than LRB system & fixed base structure and both provides flexibility to the structure. This is because of the structure was separated from the ground in case of the isolator.
2. The maximum base shear is reduced after providing FPS which makes structure more stable during earthquake then LRB & Fixed structure.
3. The storey drift of the LRB and FPS models are more than fixed base models but are in permissible limit as prescribed by the codal provision of IS 1893:2016.
4. Finally, it is concluded that FPS is provided as base isolation system, it increases the structures stability against earthquake and hence make structure economical. Hence, we can conclude that we have got the desired outcomes thus the design of FPS is safe.

References:

1. Bandyopadhyay, S., Parulekar, Y. M., Sengupta, A., & Chattopadhyay, J. (2021). Structure soil structure interaction of conventional and base-isolated building subjected to real earthquake. *Structures*, *32*, 474–493. https://doi.org/10.1016/j.istruc.2021.03.069

2. Murota, N., Suzuki, S., Mori, T., Wakishima, K., Sadan, B., Tuzun, C., Sutcu, F., & Erdik, M. (2021). Performance of high-damping rubber bearings for seismic isolation of residential buildings in Turkey. *Soil Dynamics and Earthquake Engineering*,143 https://doi.org/10.1016/j.soildyn.2021.106620

3. Kazeminezhad, E., Kazemi, M. T., & Mirhosseini, S. M. (2020). Modified procedure of lead rubber isolator design used in the reinforced concrete building. *Structures*, *27*, 2245–2273. https://doi.org/10.1016/j.istruc.2020.07.056

4. Nepal, S., & Saitoh, M. (2020). Improving the performance of conventional base isolation systems by an external variable negative stiffness device under near-fault and long-period ground motions. *Earthquake Engineering and Engineering Vibration*, *19*(4), 985–1003. https://doi.org/10.1007/s11803-020-0609-3

5. AlMusbahi, S., & Güngör, A. (2019). A composite building isolation system for earthquake protection. *Engineering Science and Technology, an International Journal*, *22*(2), 399–404. https://doi.org/10.1016/j.jestch.2018.08.015

6. Lupăşteanu, V., Soveja, L., Lupăşteanu, R., & Chingălată, C. (2019). Installation of a base isolation system made of friction pendulum sliding isolators in a historic masonry orthodox church. *Engineering Structures*, *188*, 369–381. https://doi.org/10.1016/j.engstruct.2019.03.040

7. Tamim Tanwer, M., Kazi, T. A., & Desai, M. (2019). A study on different types of base isolation system over fixed based. *Smart Innovation, Systems and Technologies*, *106*, 725–734. https://doi.org/10.1007/978-981-13-1742-2_71
8. Narayan Sahoo, D., TECH Student, M., & Kumar Parhi, P. (n.d.). *Base Isolation of Residential Building using Lead Rubber Bearing Technique*. www.ijert.org
9. Chang, C. M., Shia, S., & Yang, C. Y. (2017). Design of Buildings with Seismic Isolation Using Linear Quadratic Algorithm. *Procedia Engineering*, *199*, 1610–1615. https://doi.org/10.1016/j.proeng.2017.09.069
10. Cancellara, D., & de Angelis, F. (2016). A base isolation system for structures subject to extreme seismic events characterized by anomalous values of intensity and frequency content. *Composite Structures*, *157*, 285–302. https://doi.org/10.1016/j.compstruct.2016.09.002