REFERENCES

1. Domenicoa, D. D., Gandellib, E., & Virginio. (2020). Effective base isolation combining low-friction curved surface sliders and hysteretic gap dampers. *Soil Dynamics and Earthquake Engineering*, 1-20.
2. Deringol, A. H., & Gunyesi, E. M. (2020). Single and combined used of friction-damped and base-isolated system in ordinary buildings. *Journal of Constructional Steel Research*, 1-18.
3. Lina, Y.-S., Chana, R. W., & Tagawa, H. (2020). Earthquake early warning-enabled smart base isolation system. *Automation in Construction*, 1-12.
4. Angelis, F. D., & Cancellara, D. (2019). Dynamic analysis and vulnerability reduction of asymmetric structures: Fixed base vs base isolated system. *Composite Structures*, 203-220.
5. Khana, B. L., Azeem, M. A., & Usman, M. A. (2019). Effect of near and far Field Earthquakes on performance of various base isolation systems. *International Conference on Fracture and Structural Integrity*,108-118.
6. Calvia, P. M., & Calvib, G. M. (2018). Historical development of friction-based seismic isolation systems. *Soil Dynamics and Earthquake Engineering*, 14-30
7. Santhosh, H. P., Harsha, M. S., Manohar, K., & Pradeep, B. B. (2017). Seismic Isolation of RC framed Structures with and Without Infills. *International Journal of Civil Engineering and Technology (IJCIET)*, 316-327.
8. Cancellara, D., & Angelis, F. D. (2016). Assessment and dynamic nonlinear analysis of different base isolation system for a multi-storey RC building irregular in plan. *Computers and Structures*, 1-15.
9. Somasekhariah, H. M., Dharmesh, N., & Ghouse, M. (2016). A Comparative study on RC frame structure considering Lead Rubber Bearing and Triple Friction Pendulum Bearing. *International Journal of Innovative Research in Science, Engineering and Technology*, 14907-14918.
10. Nitya , M., & Arathi , S. (2016). Study on the earthquake response of a RC building with base isolation. *International journal of science and research*, 1002-1005.

11. Thomas, T., & Mathai, A. (. (2016). Study of base isolation using friction pendulum bearing system. *Journal of Mechanical and Civil Engineering*, 19-23.
12. Vijaykumar, M., Manivel, S., & Arokiaprakash, A. (2016). A study on seismic performance of RCC frame with various bracing systems using base isolation technique. *International journal of applied engineering research*, 7030-7033.
13. Prasada Rao, D. V., & Sulochana, G. (2016). Modelling of an infill wall for the Analysis of a Building frame subjected to Lateral force. *International Journal of Civil Engineering and Technology*, 180-187.
14. Desai, M., & John, R. (2015). Seismic performance of base isolated multi-storey building. *International journal of scientific & engineering research*, 84-89.
15. Naveen, K., Prabhakara, H., & Eramma, H. (2015). Base isolation of mass irregular RC multi-storey building. *International research journal of engineering and technology*, 902-906.
16. Noorzai, M., Bajad, M., & Dodal, N. (2015). Study response of fixed base and isolation base. *International journal of innovative research in science, engineering and technology*, 3674-3681.
17. Ghodke, R. B., & Admane, S. V. (2015). Effect of base-isolation for building structures. *International journal of science, engineering and technology research*, 971-974.
18. Dia, N. E., & Mustafa, W. A. (2015). Seismic base isolation in reinforced concrete structures. *International journal of research studies in science, engineering and technology*, 1-13.
19. Khan, M., & Bakre, S. (2015). Design and study of seismic base isolators. *Journal of basic and applied engineering research*, 734- 739.
20. Barmo, A., Mualla, I. H., & Hasan, H. T. (2015). The behaviour of multi-story buildings seismically isolated hybrid isolation (friction, rubber and with the addition of rotational friction dampers). *Open journal of earthquake research*, 1-13.
21. Keerthana, S., Sathish Kumar, K., & Balamonica, K. (2015). Seismic response reduction of structures using base isolation. *International journal of innovative science, engineering and technology*, 33-40.

22. Warrier, G. A., Balamonica, K., & Sathish Kumar, K. (2015). Study on laminated rubber bearing base isolators for seismic protection of structures. *International journal of research in engineering and technology*, 466-476.
23. El-Bayoumi, K., Naguib, M., & Fikry, S. A. (2015). Dynamic analysis of high rise seismically isolated building. *American journal of civil engineering*, 43-50.
24. Khooshki, M. E., & Shahri, A. A. (2015). Seismic response controlling of structures with a new semi base isolation devices. *Walia journal*, 30-38.
25. Reddy, A. R., & Ramesh, V. (2015). Seismic analysis of Base Isolated Building in RC framed structures. *International journal of civil and structural engineering research*, 170-176.
26. Taywade, P. W., & Savale, M. N. (2015). Sustainability of structure using base isolation techniques for seismic protection. *International journal of innovative research in science, engineering and technology*, 1215-1228.
27. El-Bayoumi , K. (2015). Modelling of Triple Friction Pendulum Bearing in SAP2000. *International journal of advances in engineering and technology*, 1964-1971.
28. Arya, G., Alice, T. V., & Mathai, A. (2015). Seismic analysis of high damping rubber bearings for base isolation. *International journal of research in engineering and technology*, 321-327.
29. Ramani, T. (2015). Smart Base Isolators for Seismic Control of Structures. *Vellore Institute of Technology*, Chennai.
30. Warrier, G. A., & Sathish Kumar, K. (2015). Response Control of Structures using Base Isolation.
31. Moretti, S., Trozzo, A. C., Terzic, V., Cimellaro, G. P., & Mahin, S. (2014). Utilizing base-isolation systems to increase earthquake resiliency of healthcare and school buildings. *4th International conference on building resilience*, 969-976.
32. Nautiyal, P., Singh, S., & Batham, G. (2013). A COMPARATIVE STUDY OF THE EFFECT OF INFILL WALLS ON SEISMIC PERFORMANCE OF REINFORCED CONCRETE BUILDINGS. *International Journal of Civil Engineering and Technology (IJCIET)*, 208-218.
33. Rezaei, S., Amiri, G. G., & Namiranian, P. (2014). Effects of Triple Pendulum

Bearing on Seismic response of Isolated Buildings under near field excitations. *Earthquake engineering and Structural dynamics*.

34. Kubo, T., Yamamoto, T., & Sato, K. (2014). A seismic design of nuclear reactor building structures applying seismic isolation system in a high seismicity region – A feasibility case study in Japan. *Nuclear engineering and technology,* 581-594.
35. Nhan, D. D. (2013). Predicting the displacement of Triple Pendulum Bearings in a full scale shaking experiment using a three dimensional element. *Earthquake engineering & Structural dynamics*.
36. EFILOGLU, M. (2013). Understanding the concepts of base isolation.
37. Nautiyal, P., Singh, S., & Batham, G. (2013). A Comparative study of the effect of infill walls on seismic Perfomance of Reinforced Concrete Buildings. *International Journal of Civil Engineering and Technology,* 208-218.
38. Petti, L., Polichetti, F., & Lodato, A. (2013). Modelling and analysis of Base Isolated Structures with Friction Pendulum System considering near fault events. *Open journal of civil engineering,* 86-93.
39. Jamnekar, V. P., & Durge, P. V. (2013). Seismic evaluation of brick.
40. Computers and Structures (2012). SAP2000 Integrated Finite Element Analysis and Design of Structures, Analysis Reference. Berkeley, California, USA: Computers and Structures. 29
41. Wancheng, Y., Binbin, W., Pakchiu, C., Xinjian, C., & Zhaojun, R. (2012). Seismic performance of cable-sliding friction bearing system for isolated bridges. *Earthquake Engineering and Engineering Vibration*, 173-183
42. Malekzadeh, M., & Taghikhany, T. (2012). Multi-Stage performance of seismically isolated bridge using Triple Pendulum Bearing. *Advances in structural engineering*.
43. T. Okazaki, E, Sato K. Kajiwara, K. Ryan and S. Mahin, (2012). Defense Base Isolation Tests: Performance of Triple-Pendulum Bearings. 15 WCEE, LISBOA2012.
44. UC Berkeley (2010). Peer ground motion database. Technical report, *Pacific Earth- quake Engineering Research Center*: 26
45. Kravchuk, N., Colquhoun, R., & Porbaha, A. (2008). Development of a friction pendulum bearing base isolation system for earthquake engineering

education. *American society for engineering education*.

46. Hussain, S., Lee, D., & Retamal, E. Viscous damping for base isolated structures.
47. Deb, S.K. (2004). Seismic base isolation – An overview. *Geotechnics and earthquake hazards*, 1426-1430.
48. Kunde , M. C., & Jangid, R. S. (2003). Seismic behavior of isolated bridges: A state of the-art review. *Electronic Journal of Structural Engineering*, 3, 140 170. 9, l8, 19, 20, 21.
49. Connor, J. (2002). Introduction to Structural Motion Control. *Massachusetts Institute of Technology*. 12, 31, 34, 39
50. Trombetti, C., Ceccoli, C., & Silvestri, L. (2001). A simplified approach to the analysis of torsional problems in seismic base isolated structures. In A. Singh (Ed.), *Creative Systems in Structural and Construction Engineering*.
51. Naeim, F., & Kelly, J. (1999). Design of Isolated Structures from Theory to Practice. *John Wiley Sons*., 19, 20
52. Charng, P. H. (1998). Base Isolation for Multistorey Building Structures. Ph. D. thesis, *University of Canterbury*.
53. Tsai, C. (1997). Finite element formulations for friction pendulum seismic isolation bearings. *International Journal for Numerical methods in Engineering*, 29-49
54. Krawinkler, H. and M. Rahnama (1992). Effects of soft soils on design spectra. In A. Balkema (Ed.), Proceedings of the Tenth. *World Conference on Earthquake Engineering*, 5841-5844
55. Mokha, A., Constantinou, M., Reinhorn, A., & Zayas, V. (1991). Experimental study of friction-pendulum isolation system. *Journal of Structural Engineering*., 1201-1217
56. Andriono, T. (1990). Seismic Resistant Design of Base Isolated Multistorrey Structures. Ph.D. thesis, *University of Canterbury*.
57. Jenkins, H. Velocity Displacement for NS El Centro Acceleration. *Mercer University*.
58. Mostaghel, N., & Khodaverdia, M. (1987). Dynamics of resilient-friction base isolator. *Earthquake Engineering and Structural Dynamics*.,379-390
59. Zayas, V., Low, S., & Mahin, S. (1987). The fps earthquake resisting system,

experimental report. Technical Report UCB/EERC-87/01,, *Earthquake Engineering Research Center, University of California*, Berkeley.

60. Ehrlich, E., Flexner, S. B., Carruth, G., & Hawkins, J. (1980). *Oxford American Dictionary*. Avon Books.
61. Skinner, R., & McVerry, G. (1975). Base isolation for increased earthquake resistance of buildings. *Bulletin of New Zealand Society for Earthquake Engineering*, 93-101

I.S. CODE

62. IS 456:2000 Plain and Reinforced Concrete - Code of Practice.
63. IS: 875 (part 1-5) Standards for structural safety building loading - code of practice.
64. IS 1893:2016 Criteria for Earthquake Resistant Design of Structures - Part 1: General Provisions and Buildings
65. IS 13920:2016 Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice.
66. SP: 16 Design aids for reinforced concrete.
67. IBC 2000 International Building Code.
68. UBC 1997 Uniform Building Code - Structural Design Requirements.

BOOK

69. Dr. Jain k., Explanatory example on Indian seismic code IS 1893 (Part-1).
70. Dr. Shah H.J. & Dr. Jain Sudhir k., Design example of a six storey building.
71. Earthquake tips (1 to 24), Learning earthquake design and construction.

WEBSITE

72. https://www.youtube.com/watch?v=J2eHCxB-K7s
73. https://www.youtube.com/watch?v=Tqr0k4Dw2FM
74. https://www.youtube.com/watch?v=thIRPajbxTU
75. https://www.youtube.com/watch?v=LTa9q6noUAQ
76. https://www.youtube.com/watch?v=Fooo6lqMepU

77. https://www.youtube.com/watch?v=Plpjx_UffBM
78. https://www.youtube.com/watch?v=e3Erp-6FNsg
79. https://www.youtube.com/watch?v=Nc4JcWn6nYs
80. https://www.youtube.com/watch?v=sJQCWfXSgSs
81. https://www.youtube.com/watch?v=DuDf8jFBEOk

A Study on Different Types of Base Isolation System over Fixed Based

M. Tamim Tanwer, Tanveer Ahmed Kazi and Mayank Desai

Abstract Based isolation is a technique which is used to prevent or reduce damage to a structure at a time of earthquake. It is a design principle by which flexible supports (isolators) are installed under every supporting point of a structure. It is generally located across a foundation (substructure) and superstructure. Seismic hazards are key concern for a earthquake prone areas of the world. Performance-based earthquake design has brought recent technological advances which has established new approach to construct earthquake resistant structure. Base isolation systems are progressively used technique for advanced earthquake resistance structure. The effect of different types of base isolator over earthquake resistant structures is studied in this paper. The work focuses on comparative study of different types of base isolators such as lead rubber bearings (LRB), friction pendulum bearings (FPB), elastomeric rubber bearing (ERB), high damping rubber bearings (HDRB), and low damping rubber bearing (LDRB) and compared for time period, base shear, fundamental period, frequency, storey drift, time history analysis, and displacement of the fixed base.

Keywords Base isolation system · Lead rubber bearings (LRB)
Friction pendulum bearings (FPB) · Elastomeric rubber bearing (ERB)
High damping rubber bearings (HDRB) · Low damping rubber bearing (LDRB)
Earthquake

M. Tamim Tanwer (✉)
Pacific University, 76/77 Amber Colony Harinagar-1, Udhna, Surat
Gujarat 394210, India
e-mail: tamimtanwer@gmail.com

T. A. Kazi
Pacific University, Pacific Hills, Pratapnagar Extension, Airport Road, Debari,
Udaipur 313003, India
e-mail: tanveerkz79@gmail.com

M. Desai
SVNIT Surat, Keval Chowk, SVNIT Campus, Athwa, Surat, Gujarat 395007, India
e-mail: dmayank@gmail.com

S. C. Satapathy and A. Joshi (eds.), *Information and Communication Technology for Intelligent Systems*, Smart Innovation, Systems and Technologies 106,
https://doi.org/10.1007/978-981-13-1742-2_71

1 Introduction

An earthquake is one of nature's most dangerous disasters which results in significant loss of life and terrible harm to the property, especially man-made structures. An earthquake is a shaking of the earth surface which results from the sudden release of accumulated energy in the tectonic plates of the earth lithosphere and due to which seismic waves occurs. Earthquake is a natural calamity which has destroyed millions of lives throughout in the past historic time. Due to earthquake, a force is precipitate from the earth lithosphere and which lasted for short duration of time.

Base isolation system is a technique introduced in a structure which separates the structure from damaging induced by seismic waves and it will prevent the superstructures from engrossing the earthquake force. Base isolator mechanism helps to increase the natural time period of the structure and decreases the earthquake acceleration response. The base isolation system rests on the structural bearing which lies between the superstructure and substructure and helps to dissolve the horizontal displacement, rotation or translation. The bearing which helps to prevents translation is known as a fixed bearing or fix-point bearing and if this bearing is fixed in all directions, then it is known as a guided bearing or unidirectional movable bearing. Earthquakes study provides guidance to architects and engineers with a number of important design criteria foreign to the normal design process. From the well-established methods reviewed by many researchers, base isolation system proves to be the most effective solution for a broad range of earthquake design problems and the effect of these systems over seismic responses of the structures are studied in this paper.

2 Objective of Study

The key objective of the base isolation system is to save the structure from earthquake's effect or to minimize the earthquake's effect. Many comparative researches have disclosed that the reaction of the isolated structure is remarkably less than the fixed (regular) base structure. The main objective of the study is to compare different types of base isolators such as lead rubber bearings (LRB), Friction pendulum bearings (FPB), elastomeric rubber bearing (ERB), high damping rubber bearings (HDRB), and low damping rubber bearing (LDRB) with time period, base shear, fundamental period, frequency, storey drift, time history analysis, and displacement of the fixed base.

3 Literature Study

Nitya and Arathi [1] have published a research paper for "Study of earthquake response of a RC building with base isolation" on International Journal of Science and Research (IJSR). In this research, a RCMR frame structure of G+6 storey's with fixed base and with base isolation system is considered. Analysis is performed by using SAP 2000. They come to a conclusion that the base isolation system substantially increases the time period of the structure. It reduces correspondingly the base shear up to 75% as compared to fixed one. With the increase in fundamental period, RCMR frame with base isolation system completely removed the structure from the resonance range of the seismic waves. Analysis shows that the fundamental period of the structure is approximately twice for the isolated structure. Increment in fundamental period reduces the maximum acceleration and hence it reduces the earthquake force from the structure. From the tables and graphs, it gets clear that the storey displacements are much higher for isolated buildings, also the displacement of all the storeys are almost same. The isolator with rubber has more displacement as of friction isolator (Fig. 1).

Thomas and Mathai [2] have published a research paper for "Study of base isolation using friction pendulum bearing system" on Journal of Mechanical and Civil Engineering. They had created FEM model of base isolator in ANSYS 14.5 software. They had analyzed and compared the behavior of the friction pendulum bearing with rubber base isolator. Static analysis of base isolator as nonlinear is performed for different storey under different load value. They came to a conclusion that as we increase the number of storey load value, then stress intensity value also gets increased. The stress intensity value was found under permissible limits up to 30-storeys and we can design the base isolators for 22 storeys to 30 storey buildings. From this analysis, it gets clear that the slider movement produced a dynamic friction force which provides the required damping for engrossing the earthquake energy (Fig. 2).

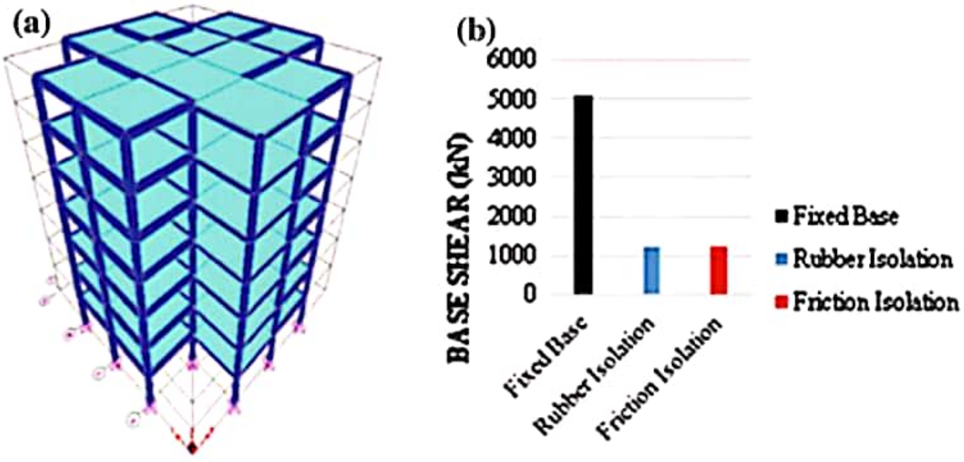


Fig. 1 **a** Perspective view of model, **b** comparison of base shear

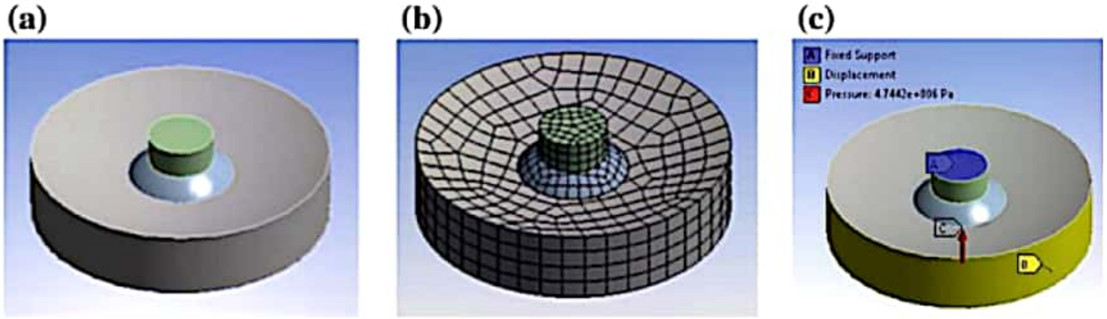


Fig. 2 **a** Model of the base isolator, **b** mesh configuration of the base isolator, **c** boundary condition of base isolator

Vijaykumar et al. [3] have published a research paper for "A Study on Seismic Performance of RCC Frame with Various Bracing Systems using Base Isolation Technique" on International Journal of Applied Engineering Research. In these research paper, a G+25 storey building square in plan is analyzed using design software SAP 2000. They come to a conclusion that the performance of the structure with base isolation systems proves more effective than a fixed base. The structure is analyzed for displacement and drift parameters and they noted that displacement in base isolation structure is high compared to fixed base. The main factor responsible for collapse of structure is its storey drift. The research shows that storey drift in base isolation structure is very much reduced compared to regular base structure. Though the cost of installation adds to drawback of base isolation, the performance proves its necessity in hospitals, public places, and essential buildings. Hence from the study, it can be observed that the bracing system performs better by the use of base isolation in seismic prone area (Fig. 3).

Desai and John [4] have published a research paper for "Seismic Performance of Base Isolated Multi-Storey Building" on International Journal of Scientific and Engineering Research. In this research paper, Dynamic Response Spectrum Analysis is worked out for 8-storey office building. The structure is analyzed with fixed

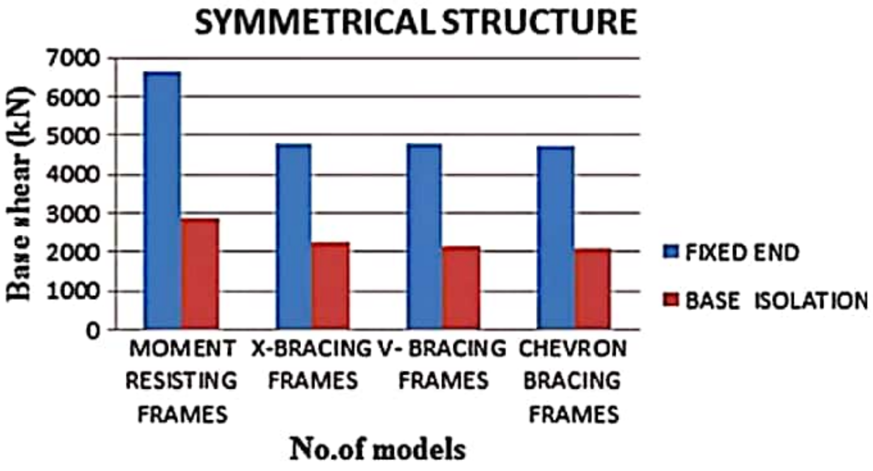


Fig. 3 Comparison of base shear

base structure and with different types of base isolator. Comparative study of different parameters like frequency, spectral acceleration, base shear, displacement, and storey drift is worked out without provision of base isolator and with provision of different base isolators. From the summary of results, it can be seen that In base-isolated structure, frequency has reduced as compared to the fixed base structure. Fundamental mode is more effective in seismic analysis. Frequency is minimum in LRB structure in fundamental mode compared to HDRB and LDRB. Acceleration has reduced when isolators are provided. LRB structure gives the least acceleration compared to HDRB and LDRB isolators. Base shear reduces considerably in base-isolated structure. The base shear in LRB structure is reduced to 47%, in HDRB structure it reduced to 33% and in LDRB structure it reduced to 34%, respectively, as compared to the fixed base structure. Displacement is very high in LRB, HDRB, and LDRB compared to fixed base structure. The Average displacement is maximum in LRB as compared to HDRB and LDRB. Storey drift has reduced considerably by provision of isolator. The reduction in storey drift at 9 m height are 13%, 13%, and 15%, respectively for HDRB, LDRB and LRB structures as compared to the fixed base structure. It can be concluded that the performance of the structure with base isolation systems proves more effective than a fixed base. Performance of LRB proves more effective as compared to the HDRB and LDRB (Fig. 4).

Naveen et al. [5] have published a research paper for “Base Isolation of Mass Irregular RC Multi-Storey Building” on International Research Journal of Engineering and Technology (IRJET). In this research paper, a G+9 storey building square is analyzed using design software SAP 2000. They come to a conclusion that the reduction in lateral displacement at top storey of regular structure was found to

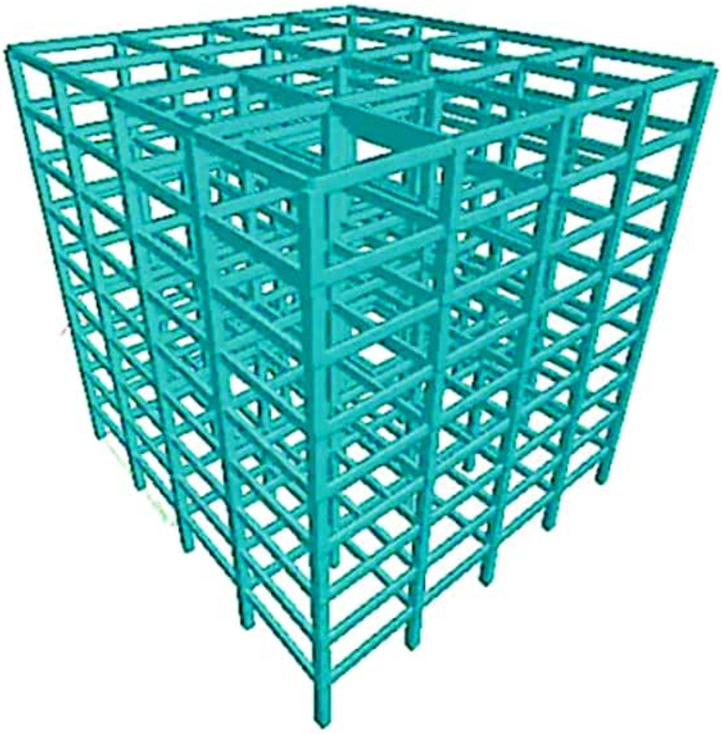


Fig. 4 Perspective view of 8-storey office building model

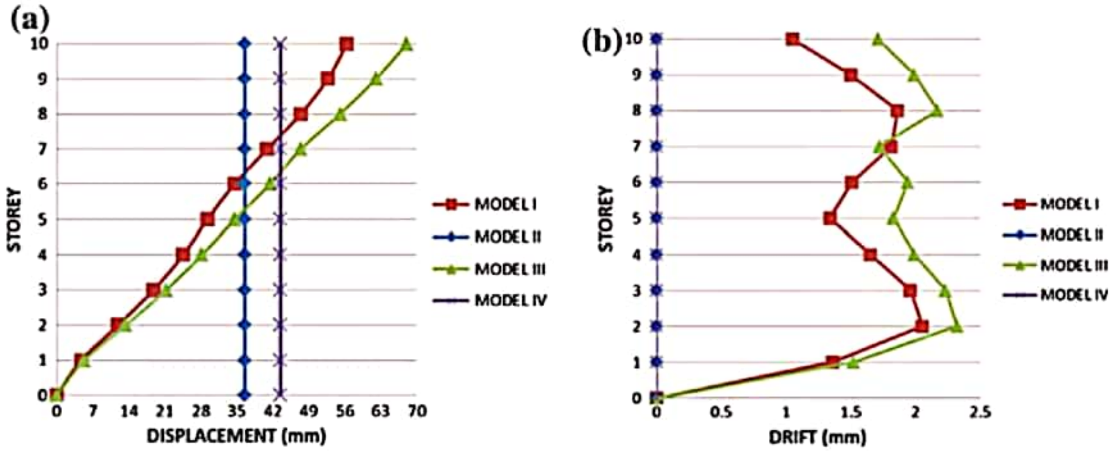


Fig. 5 **a** Graph showing displacement (mm) of all IV module, **b** graph showing drift (mm) of all IV module

be 35% whereas in mass irregular structure the lateral displacement at top storey was 36% from the history time analysis of El centro earthquake. From the analysis of lateral displacements in both directions, it came to know that torsion occurs due to mass irregularity in a structure. No inter-storey drifts was found in base-isolated structure, whereas in mass irregular structure large amount of inter-storey drifts found, which means that the structure takes rigid body movements in base-isolated structure as compared to a fixed base structure (Fig. 5).

Noorzai et al. [6] have published a research paper for "Study Response of Fixed Base and Isolation Base" on International Journal of Innovative Research in Science Engineering and Technology. In their research (G+25), RCC frame structure with fixed base and with isolated LRB base was analyzed and design using design software ETABS. They come to a conclusion that the structure with isolated base discloses less lateral deflection. The lateral displacement at base in base-isolated structure never equals zero and less amount of moment is generated than the fixed base structure. The base isolation systems separate the structure from the earthquake-induced load and also maintain larger fundamental lateral period as compared to a fixed base structure. Base isolation system also known as seismic base isolation is one of the most recent technique to protect the structure against seismic forces. It also helps in pertaining the passive vibration control to structure. Structure with isolated base separates the substructure and superstructure during the earthquake, and as a result, the substructure will move along the ground and the superstructure will be dormant. LRB proves to be the most effective base isolators as compared to fixed base and any other types of isolators (Fig. 6).

Ghodke and Admane [7] have published a research paper for "Effect Of Base-Isolation for Building Structures" on International Journal of Science, Engineering and Technology Research (IJSETR). In this research paper, a G+5 storey building is analyzed using design software SAP 2000. They come to a conclusion that with increasing the height of the structure, displacement is decreasing in

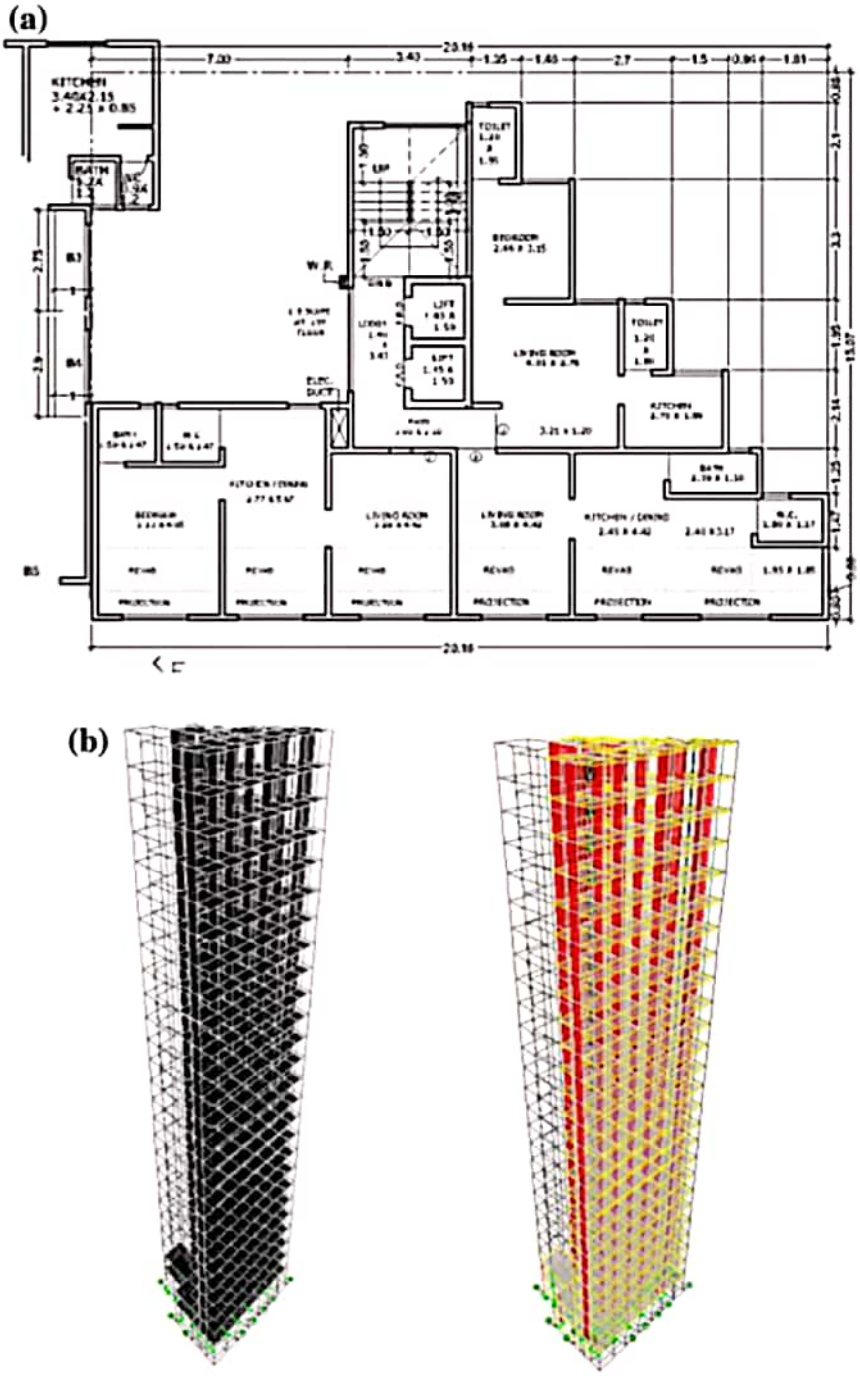


Fig. 6 a G+25 storey plan, b analytical models

base-isolated structure. The displacement is less in isolated—base structure than to a fixed base (Fig. 7).

Nassani and Wassef [8] have published a research paper for “Seismic Base Isolation in Reinforced Concrete Structures” on International Journal of Research Studies in Science, Engineering and Technology. G+4 storeys are analyzed with isolated base and without isolated base. The analysis was performed in design software SAP2000. They come to a conclusion that the structure with isolated base

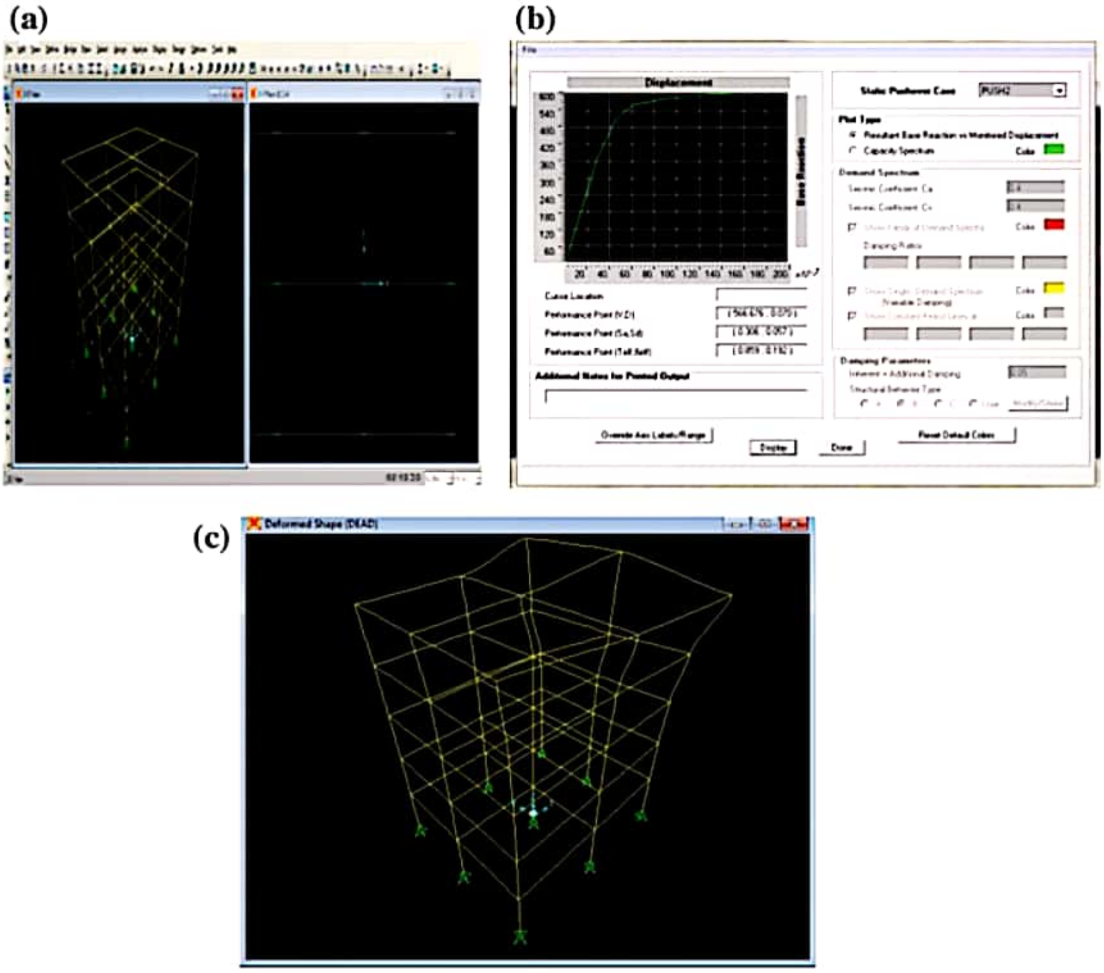


Fig. 7 **a** Model generation in SAP 2000, **b** displacement curve, **c** deformed shape of building

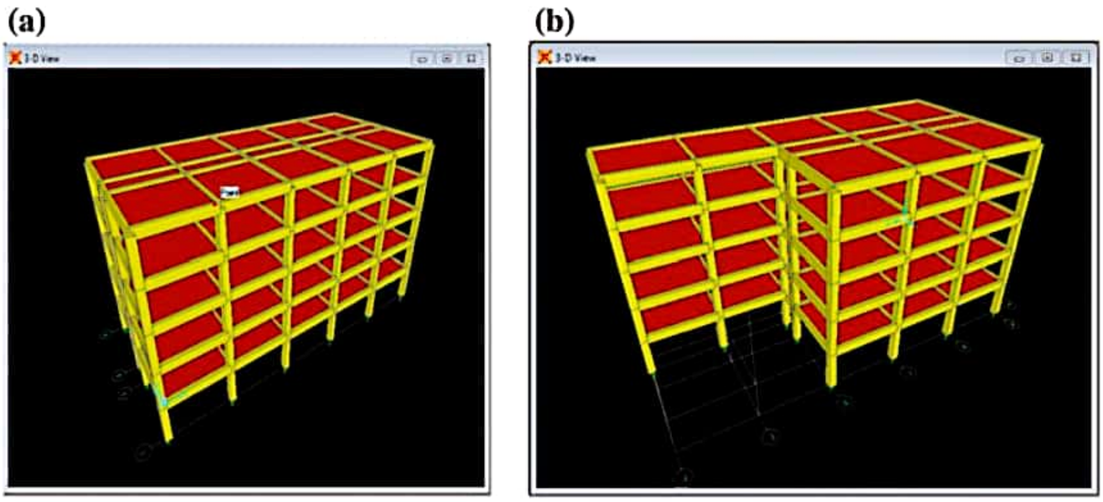


Fig. 8 **a** Perspective view of symmetric building, **b** perspective views of nonsymmetric building reduces the base shear and storey drifts, on the other hand, it also increased the displacement as compared to fixed base systems where base shear and storey drift are too high and the displacement of structure get decreased (Fig. 8).

4 Conclusion

The base isolation system substantially increases the time period of the structure. It reduces correspondingly the base shear up to 75% as compared to fixed one. Fundamental period of the structure is approximately twice for the isolated structure. Fundamental modes prove more effective in seismic analysis. Performance of the structure with base isolation systems proves more effective than a fixed base. In base-isolated structure frequency has reduced as compared to the fixed base structure. Storey drift has considerably reduced by provision of a base isolator. The reduction in storey drift at 9 m height are 13%, 13%, and 15%, respectively, for HDRB, LDRB, and LRB structures as compared to the non-isolated structure. Performance of lead rubber bearing is better as compared to the HDR bearing and LDR bearing. In a time history analysis for EI Centro, earthquake reduction in top storey lateral displacement is 35% in 10 storied fixed base structures, whereas the reduction of lateral displacement is 36% in 10 storied mass irregular structures. No inter-storey drifts were found in base-isolated structure, whereas in mass irregular structure large amount of inter-storey drifts found, which means that the structure takes rigid body movements in base-isolated structure as compared to a fixed base structure. The base isolation systems separate the structure from the earthquake-induced load and also maintain larger fundamental lateral period as compared to a fixed base structure. It is concluded that with increasing the height of the structure, displacement is decreasing in base-isolated structure.

References

1. Nitya, M., Arathi, S.: Study on the earthquake response of a RC building with base isolation. Int. J. Sci. Res. **5**, 1002–1005 (2016)
2. Thomas, T., Mathai, A.: Study of base isolation using friction pendulum bearing system. J. Mech. Civil Eng. 19–23 (2016)
3. Vijaykumar, M., Manivel, S., Arokiaprakash, A.: A study on seismic performance of RCC frame with various bracing systems using base isolation technique. Int. J. Appl. Eng. Res. **11**, 7030–7033 (2016)
4. Desai, M., John, R.: Seismic performance of base isolated multi-storey building. Int. J. Sci. Eng. Res. **6**, 84–89 (2015)
5. Naveen, K., Prabhakara, H.R., Eramma, H.: Base isolation of mass irregular RC multi-storey building. Int. Res. J. Eng. Technol. **2**, 902–906 (2015)
6. Noorzai, M., Bajad, M.N., Dodal, N.: Study response of fixed base and isolation base. Int. J. Innov. Res. Sci. Eng. Technol. **4**, 3674–3681 (2015)

7. Ghodke, R.B., Admane, S.V.: Effect of base-isolation for building structures. Int. J. Sci. Eng. Technol. Res. **4**, 971–974 (2015)
8. Nassani, D.E., Wassef, M.A.: Seismic base isolation in reinforced concrete structures. Int. J. Res. Stud. Sci. Eng. Technol. **2**, pp. 1–13 (2015)
9. Kravchuk, N., Colquhoun, R., Porbaha, A.: Development of a friction pendulum bearing base isolation system for earthquake engineering education. In: Proceedings of the 2008 American Society for Engineering Education Pacific Southwest Annual Conference, Pittsburg, Pennsylvania, June (2008)
10. Keerthana, S., Sathish Kumar, K., Balamonica, K.: Seismic response reduction of structures using base isolation
11. Taywade, P.W., Savale, M.N.: Sustainability of structure using base isolation techniques for seismic protection. Int. J. Innov. Res. Sci. Eng. Technol. **4**(3) (2015)
12. Kooshki, M.E., Shahri, A.A.: Seismic response controlling of structures with a new semi base isolation device (2015)
13. Deb, S.K.: Seismic base isolation—an overview. Current Sci. 1426–1430 (2004)
14. Kelly, J.M.: Earthquake-Resistant Design with Rubber (1993)
15. Moretti, S., et al.: Utilizing base-isolation systems to increase earthquake resiliency of healthcare and school buildings. Proced. Econ. Finance **18**, 969–976 (2014)
16. Nitya, M., Arathi, S.: Design and study of seismic base isolators. J. Basic Appl. Eng. Res. **2** (9), 734–739 (2015)
17. Hussain, S., Lee, D., Retamal, E.: Viscous damping for base isolated structures. Taylor Devices (1998). http://www.taylordevices.com/Tech-Paper-archives/literature-pdf/36-ViscousDamping.pdf
18. Kubo, T., et al.: A seismic design of nuclear reactor building structures applying seismic isolation system in a high seismicity region—a feasibility case study in Japan. Nucl. Eng. Technol. **46**(5), 581–594 (2014)
19. Arya, G., Alice, T.V., Alice, M.: Seismic analysis of high damping rubber bearings for base isolation

International Journal of Civil Engineering and Technology (IJCIET)
Volume 10, Issue 11, November 2019, pp. 423-433, Article ID: IJCIET_10_11_043
Available online at https://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=11
ISSN Print: 0976-6308 and ISSN Online: 0976-6316
DOI: https://doi.org/10.17605/OSF.IO/95CNW

COMPARATIVE STUDY ON LEAD RUBBER BEARING (LRB) BASE ISOLATION SYSTEM ON G+12 & G+22 STORY RCC STRUCTURE OVER FIXED BASED FOR INDIAN SUBCONTINENT

M. Tamim Tanwer
Research Scholar, Pacific Academy of Higher Education & Research University-Udaipur, Rajasthan, India.

Prof. Dr. Tanveer Ahmed Kazi
Professor, Pacific Academy of Higher Education & Research
University-Udaipur, Rajasthan, India.

Prof. Dr. Mayank Desai
Assistant Professor, Sardar Vallabhbhai National Institute of
Technology-Surat, Gujarat, India.

ABSTRACT

Earthquake is a very dangerous natural disaster which occurs by movement of the tectonic plates in the core of earth. Due to earthquake many structures collapse which result into human life losses. Base Isolation System is the technique to absorb the earthquake forces and reduces the earthquake effects in the structure at the time of earthquake. In this paper, we are considering the design of G+12 & G+22 story RCC building with fixed base and with base isolation system. Lead rubber bearing (LRB) is used for the design of based isolated structure. Analyzing and designed of these two type of buildings are carried out by response spectrum method in ETABS 2016 software. After analyzing the Structure, time period, base shear, story displacement, story-drift, percentage reduction in steel and overall cost economy will be obtained for both type of structure. From this study, it is found that time period and story displacement increased while base shear, story drift, percentage of steel and overall cost is reduced with provision of Lead Rubber Bearing (LRB) as base isolators.

Keywords: Earthquake, Base Isolation System, Lead Rubber Bearings, Time Period, Base Shear, Story Drift, Story Displacement, Reinforcement, Cost Economy, Response

Cite this Article: M.Tamim Tanwer, Prof.Dr.Tanveer Ahmed Kazi and Prof.Dr.Mayank Desai, Comparative Study on Lead Rubber Bearing (LRB) Base Isolation System on G+12 & G+22 Story RCC Structure Over Fixed Based for Indian Subcontinent. International Journal of Civil Engineering and Technology 10 (11), 2019, pp. 423-433.
https://iaeme.com/Home/issue/IJCIET?Volume=11&Issue=11

1. INTRODUCTION

1.1. General

Earthquake is occurring due to movement of the tectonic plates in core of the earth. It is a horizontal movement of earth surface. By earthquake the top surface of earth is shake and foundation is also shake with them. Results the superstructure experience seismic forces and structural members are may collapse. Due to collapse of the structure humans can buried under debris. Peoples are lost their life and also their properties. We cannot construct earthquake proof structure but we can construct earthquake resistant structure.

1.2. Base Isolation System

Base isolation system is also famous in the name of seismic isolation system. It is a method which is protect the structure against seismic force. Base isolation is the effective technique of earthquake engineering appurtenance to the no action in structural vibration control technologies. The System is innovated by Dr. Bill Robinson at New Zealand in 1974. It is very popular system to protect the structures from seismic forces. This technique is useful for new structures as well as can also use in old structure. The base isolation is installing between the foundation and superstructure. It is not allowed to transfer the seismic forces from ground to the superstructure. Base isolation is work as a suspension type system and absorb seismic forces without transferring to superstructure.

Lead Rubber Bearings is very popular and expanded all over worldwide. It is also used in India. The first lead rubber bearing installed in India at G.K. general Hospital, Bhuj, Gujarat in 2001. In this hospital total 280 bearings are used. The LRB is made with rubber and lead core.

Lead Rubber Bearings are made up of alternate layers of hot vulcanized rubber and steel laminates with a cylindrical lead core in the center of the bearing. The energy can be dissipated by providing the lead core, by its yielding, it is allowed to achieve an equivalent with viscous damping coefficient about 30 %. The lead rubber bearings may show that the best economic solution for seismic base isolation problems because it brings the functions of vertical support, hardness at service load levels and horizontal flexibility at seismic load.

2. LITERATURE REVIEW

Khin Thanda Htun, Kyaw Kaung Cho (2019), has published a paper title **“Experimental in Structural Dynamics (Base Isolation System: Modelling)”** in International Journal of Trend in Scientific Research and Development **(IJTSRD).** The authors has determined dynamic behaviour of a steel structure model for without base isolated structure and with base isolated structure. They concluded that, the experimental result shows that the system used for base isolation reduced the time period of the structure and the relative displacement of the top with respect to the support. The base isolated system introduces in the structure make the structure more flexible thus reduced the effect of the earthquake loads on the structure. The base isolated method largely depends on the behaviours of the springs attached which provided the stability to the structure.

The experimental results are also affected by the distribution of the sensors. The mass of the sensor also contributes to the response of the structure. The sensor arrangement had mass concentration in every floor. The sensor arrangement should be arranged that there is no mass concentration and thus result minimum contribution to the structural response. [1]

Dhiraj Narayan Sahoo, Dr. Pravat Kumar Parhi (2018), has published a paper title "Base Isolation of Residential Building using Lead Rubber Bearing Technique" in International Journal of Engineering, Research and Technology (IJERT). They has designed G+10 and G+15 buildings with fixed base and with base isolation techniques. They design the buildings for Bhubaneswar, Odisha which is located in earthquake zone II.

The designing of buildings was completed in ETABS software. In base isolation system they used lead rubber bearings in their buildings. They concluded that, the time period of structure increases approximate 2 times after providing the base isolator to fixed base structure. Due to this increase in the time period, structure experiences less amount of seismic force. The lateral earthquake load, storey shear, column force and moment are reduced to significant amount due to base isolator to the structure. The maximum storey displacement in base isolated structure increases. The maximum storey stiffness of structure decreases in base isolated structure. From the above results, the damage to the base isolated structure will be less as compared to fixed base structure. [2]

Manoj Prajapati, Dr. Savita Maru (2018), has published a paper title **"Base Isolation for Earthquake Resistance: A Review"** in International research Journal of Engineering and Technology **(IRJET)**. They has concluded from review that researchers introduce the new technology of base isolation system which protects building to damage under seismic action and the results like drift, displacement and base shear are better with building performance in case of base isolation then fixed base. Further, some more concluded points are: cost can be reasonable using software simulating applications, high rise building can be design for safety using design software's, column beam design to optimize the size and strength, quality with cost optimize it can be design for future construction, effective planning and control can be performed for high rise building using simulation and design software's. [3]

Saurabh P. Kharat, Dinesh N. Biradar, Ajay S. Sagekar, Prathamesh V. Chavan, Prof. Reshma Saikh (2018), has published a paper title "Case study on Lead Rubber Isolation Bearing" They concluded that, the study shows the effectiveness of the LRB base isolation system in terms of reduced structural responses under seismic loading. As the base isolators are extensively used worldwide in high seismic areas in near future, we will accept the same in India also. At least in seismic zone IV and V the use of base isolators has to be encouraged as they are technically very effective and economically feasible. The use of base isolators reduces inter-story drift and structural damages during earthquake. The building will be ready to occupy with the minor repair. The results of this work demonstrated that base isolators are excellent seismic control devices for high raise symmetric buildings. Base isolation method has proved to be a reliable method of earthquake resistant design. [4]

3. SAMPLE MODEL DETAILS

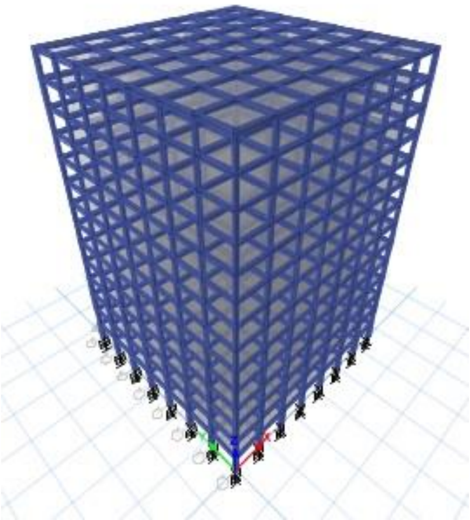


Figure 1: (G+12 Storey)

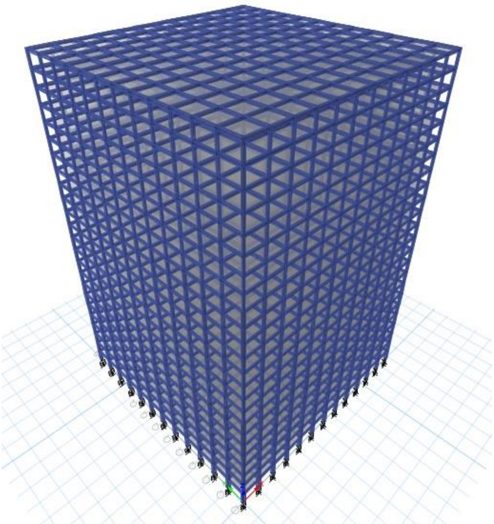


Figure 2: (G+22 Storey)

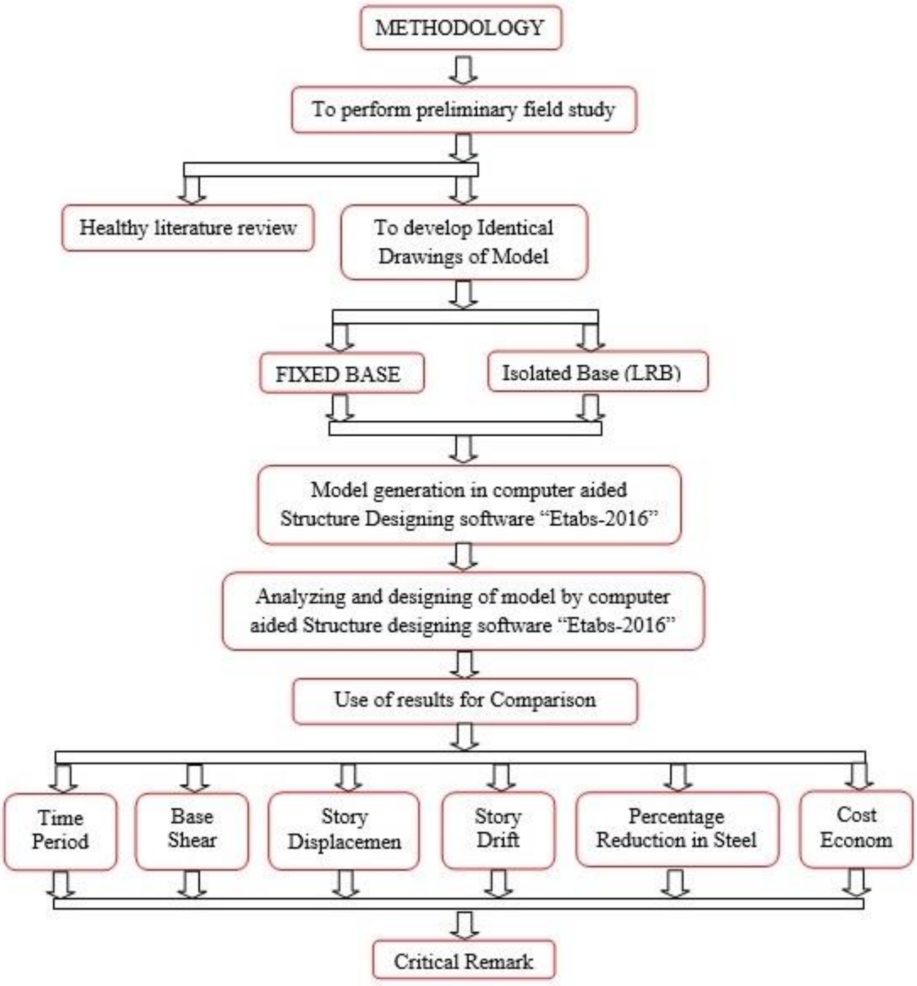
Sample Modal – 1 & 2		G+12 (7 Bay x 7 Bay)	Sample Modal – 3 & 4		G+22 (12 Bay x 12 Bay)
Beam	=	230 x 450 mm	Beam	=	230 x 450 mm
Column	=	300 x 300 (Storey 8 to Terrace) 375 x 375 (Plinth to Storey 7) 450 x 450 (Base)	Column	=	300 x 300 (Storey 16 to Terrace) 375 x 375 (Storey 8 to Storey 16) 450 x 450 (Plinth to Storey 7) 525 x 525 (Base)
Floor to Floor Height	=	3.0 m.	Wall Thickness	=	115 mm.
Floor Load					
Live Load	=	3 KN/m^2	Floor Finish	=	1 KN/m^2
Earthquake Load					
EQ load	=	Response Spectrum Method	Seismic Zone	=	Zone 3
Soil Type	=	Hard Soil (Type-I)	Percentage Damping	=	5%
Modal Method	=	SRSS			
Material					
Grade of Concrete	=	M20 [20 N/mm^2]	Grade of Steel	=	Fe500 [500 N/mm^2]
Unit weight of Concrete	=	25 KN/m^2	Unit weight of brick masonry	=	20 KN/m^2
Design basis	=	Limit State Method (IS: 456-2000)			

The sample model of 7 bay x 7 bay for G+12 story building & 12 bay x 12 bay for G+22 Story building (1 bay = 4 m.) is taken with Seismic Zone III on hard soil type – I with the above following details is considered for Analysis & Design.

1. Model 1: - G+12 storey building with fixed base.
2. Model 2: - G+12 storey building with LRB base isolation.

1. Model 1: - G+22 storey building with fixed base.
2. Model 2: - G+22 storey building with LRB base isolation.

4. METHODOLOGY



5. ANALYSIS & DESIGN OF LEAD RUBBER BEARING (LRB)

For the Analysis & Design of Lead Rubber Bearing, the cumulative load at the base is obtained from the fixed based design model in Etabs. This load are categorized into three group's viz. Biaxial, Uniaxial and Axial loaded. Sample Calculation for one group is shown below.

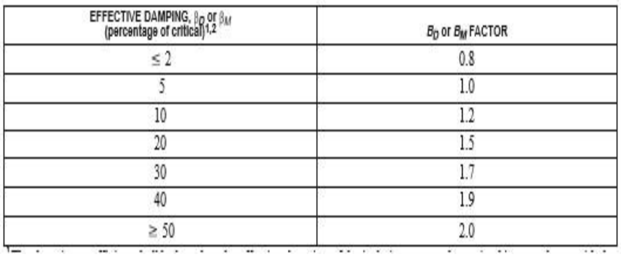
Biaxial Load (W) = 1638 kN.

Design Shear Strain (γmax) = 50% = 0.5 kN/m^2.

Time Period (T_D) = 2.5 sec.

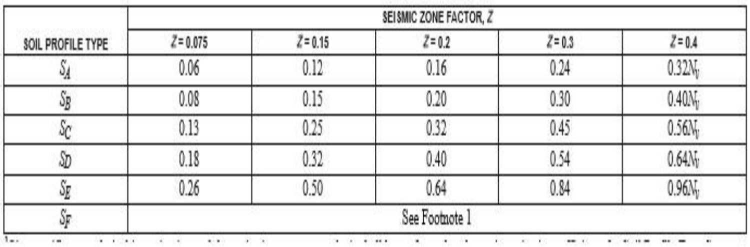
Effective Damping (ξeff) = 5 % = 0.05 For U_1, U_2, U_3.

TABLE A-16-C—DAMPING COEFFICIENTS, B_D AND B_M



EFFECTIVE DAMPING, β_D or β_M (percentage of critical)[1,2]	B_D or B_M FACTOR
≤ 2	0.8
5	1.0
10	1.2
20	1.5
30	1.7
40	1.9
≥ 50	2.0

TABLE 16-R—SEISMIC COEFFICIENT C_V

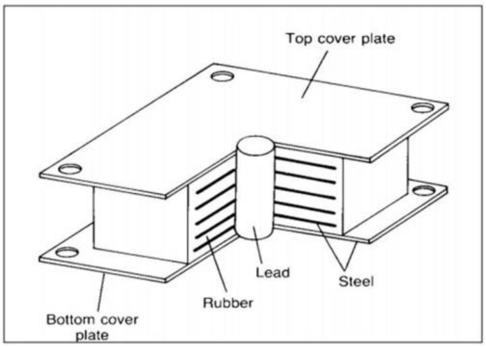


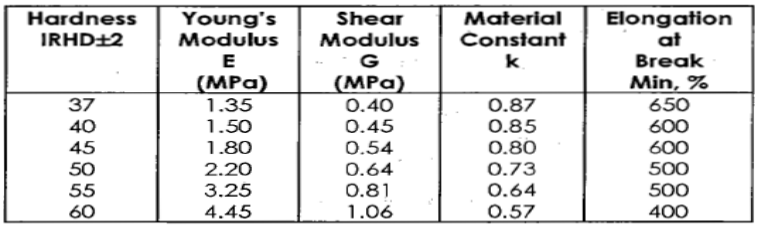
SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	Z = 0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

Damping Coefficient (B_D) = 1 (UBC-97, Vol-2, Pg. No. 414)

Seismic Coefficient (S_D) = 0.54 (UBC-97, Vol-2, Pg. No. 35)

Selecting 60 as Rubber Hardness for analysis in critical conditions





Hardness IRHD±2	Young's Modulus E (MPa)	Shear Modulus G (MPa)	Material Constant k	Elongation at Break Min. %
37	1.35	0.40	0.87	650
40	1.50	0.45	0.85	600
45	1.80	0.54	0.80	600
50	2.20	0.64	0.73	500
55	3.25	0.81	0.64	500
60	4.45	1.06	0.57	400

Table 5.4: Vulcanized Natural Rubber Compounds

Young's Modulus (E) = 4.45Mpa 4450 kN/m^2

Modification factor (k) = 0.57

Shear modulus (G) = 1.06 Mpa 1060 kN/m^2

Elongation of rubber at break (ε_b) = 4 (400%)

Allowable normal stress = 7840 kN/m^2.

Yield strength of core(f_{py}) = 8500 kN/m^2.

onsulted manufacture, usually 7 to 8.5 Mpa Page No.132, Table 5.7

Yield strength of steel plate (f_y) = 274400 kN/m^2.

Shear Yield strength of steel (F_s) = 164640 kN/m^2.

Part-1 Analysis of LRB

a) Effective Horizontal stiffness $K_{eff\,H}$

$K_{effH} = \frac{W}{g}\left(\frac{2\pi}{T_D}\right)^2$ **$K_{eff\,H}$ = 1054.69 kN/m** **U_2 & U_3 Linear effective stiffness**

b) Lateral displacement or Design displacement (DD)

$$D_D = \left(\frac{g}{4\pi^2}\right) \times \frac{S_D T_D}{B_D} = 0.335 \text{ m.}$$

c) Strength or short term yield force Qd

$$\mathbf{Q_d} = \frac{W_D}{4 \times D_D} = \frac{\pi}{2} \times K_{effH} \times \xi_{effH} \times D_D = \mathbf{27.788\ kN}$$

d) Post-yield horizontal stiffness K_d

K_U = Pre yield stiffness, K_d = Post yield stiffness, Where K_U = 10 K_d

Note- Initial elastic stiffness was estimated from experimental results in the range of 9 to 16 K_d

$K_d = K_{effH} - \frac{Q_d}{D_D}$ = 971.854 kN/m.

K_U = 10 K_d

e) Post yield stiffness ratio.

$\frac{K_d}{K_U} = \frac{971.854}{9718.54} = \mathbf{0.1}$ **U_2 & U_3 Post yield stiffness ratio**.

Part-2 Design of LRB

a) Lead Core Area A_p

$Ap = \frac{Q_d}{f_{py}}$ = 0.00327 m^2

b) Dia. of lead core d_p

$Ap = \frac{\pi d^2}{4} = d_p = \sqrt{\frac{4A_p}{\pi}} = 0.06452$ m.

c) Total height of rubber layer t_r

$t_r = \frac{D_D}{\gamma_{max}}$ = 0.67092 m.

d) Shape factor S

$\frac{E(1+2kS^2)}{G} \geq 400, S = 9.09409,$

For $S < 10$, Take $S = 10$

e) Compressive modulus of rubber & steel (Ec)

Ec = E (1+2kS^2) = 511750 kN/m^2.

f) Effective area of bearing A_o

A_o = W / Allowable normal stress. = 0.20893m^2.

g) Effective area from the shear strain A_1

$$\frac{6SW}{E_c \times A_1} \leq \frac{\varepsilon_b}{3} = 0.14404 \text{ m}^2.$$

h) Elastic Stiffness K_r of the bearing

$$K_d = K_r \times \frac{1+12 \times A_P}{A_o} = 818.219 \text{ kN/m}.$$

i) Effective area of individual rubber layer (A_{sf})

$$A_{sf} = \frac{\pi d^2}{4} = 0.51789 \text{ m}^2.$$

j) Diameter of Rubber (d)

$$d = \sqrt{\frac{4A_{sf}}{\pi}} = 0.81203 \text{ m}.$$

k) Effective vertical stiffness (k_v)

$K_v = \frac{E_C \times A_{sf}}{t_r}$, **$K_v$ = 395022 kN/m, U_1 Vertical Linear effective stiffness.**

l) Damping reduction factor (β)

$$\beta = 2 \times \cos^{-1}\left(\frac{D_D}{d}\right) = \mathbf{2.29}$$

m) Reduced area (A_2)

$$A_2 = \frac{d^2 \times (\beta - \sin\beta)}{4} = 0.25348 \text{ m}^2.$$

n) Details of Lead Rubber Bearing

$A = 0.25348$ m^2 (max Area of A_O, A1, & A_2), d = 0.56811 m.

No. of layer (N) = t_r/t, Where t = 0.0203

N = 33.0491 say N = 34.00

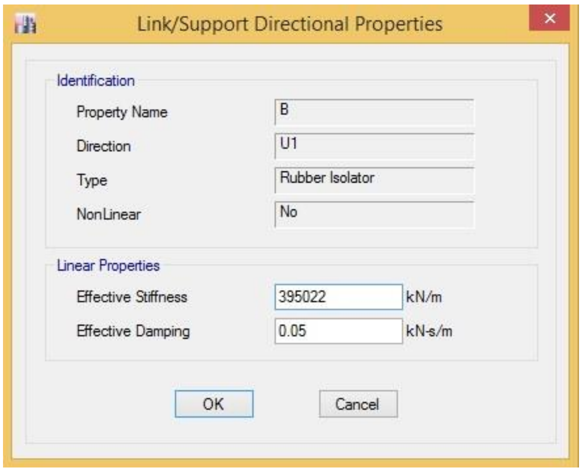
Steel Plate thickness (ts)

$ts = \frac{2 \times W \times 2t}{A \times Fs}$, ts = 0.00319 ≥ 0.002 m.

Total height of bearing (h)

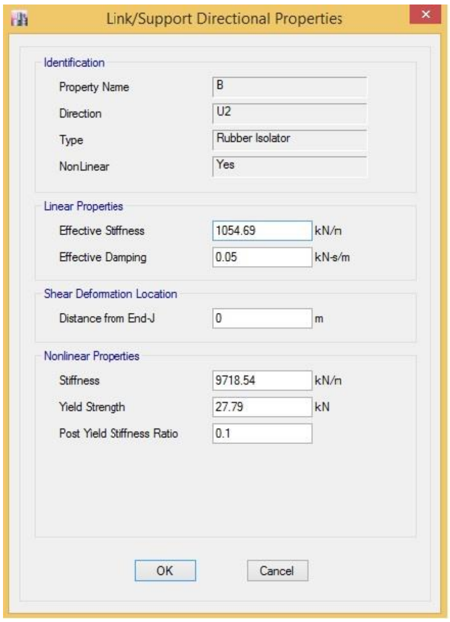
h = tr + N x (ts + 2*0.0025), h = 0.94929 m.

Input Values for Etabs :



Identification
Property Name: B
Direction: U1
Type: Rubber Isolator
NonLinear: No

Linear Properties
Effective Stiffness: 395022 kN/m
Effective Damping: 0.05 kN-s/m



Identification
Property Name: B
Direction: U2
Type: Rubber Isolator
NonLinear: Yes

Linear Properties
Effective Stiffness: 1054.69 kN/m
Effective Damping: 0.05 kN-s/m

Shear Deformation Location
Distance from End-J: 0 m

Nonlinear Properties
Stiffness: 9718.54 kN/m
Yield Strength: 27.79 kN
Post Yield Stiffness Ratio: 0.1

		G+12 Storey			**G+22 Storey**			**Units**
Direction U1	**Cumulative Load**	**Biaxial**	**Uniaxial**	**Axial**	**Biaxial**	**Uniaxial**	**Axial**	
		1638 KN	**2487 KN**	**3920 KN**	**3342 KN**	**4627 KN**	**6860 KN**	
	Linear Properties							
	Effective Stiffness	395022	599768	945352	805961	1115853	1654366	KN/m
	Effective Damping	0.05	0.05	0.05	0.05	0.05	0.05	KN-s/m
Direction U2 & U3	Linear Properties							
	Effective Horizontal Stiffness	1054.69	1601.35	2524.043	2151.88	2979.27	4417.08	KN/m
	Effective Damping	0.05	0.05	0.05	0.05	0.05	0.05	KN-s/m
	Non Linear Properties							
	Pre-yield Stiffness	9718.54	14755.8	23258.05	19828.7	27452.8	40701.6	KN/m
	Strength	27.788	42.191	66.501	56.696	78.495	116.377	KN
	Post Yield Stiffness ratio	0.1	0.1	0.1	0.1	0.1	0.1	

6. RESULTS

6.1. Time Period

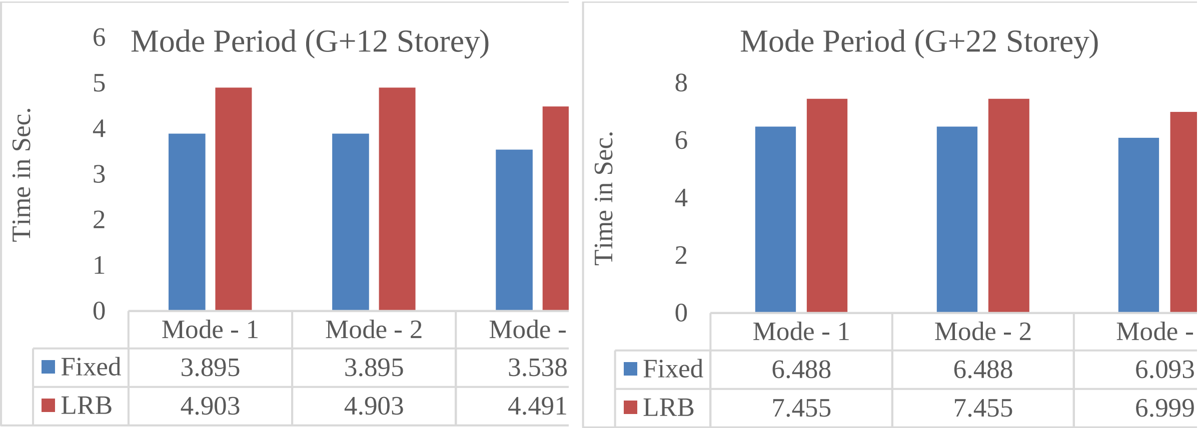


Figure 3: Time Period of G+12 & G+22 Storey models

Figure 3 shows the time period for fixed base and LRB base of G+12 & G+22 Storey models. Time period of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 26.23% and 14.89 % respectively.

6.2. Base Shear

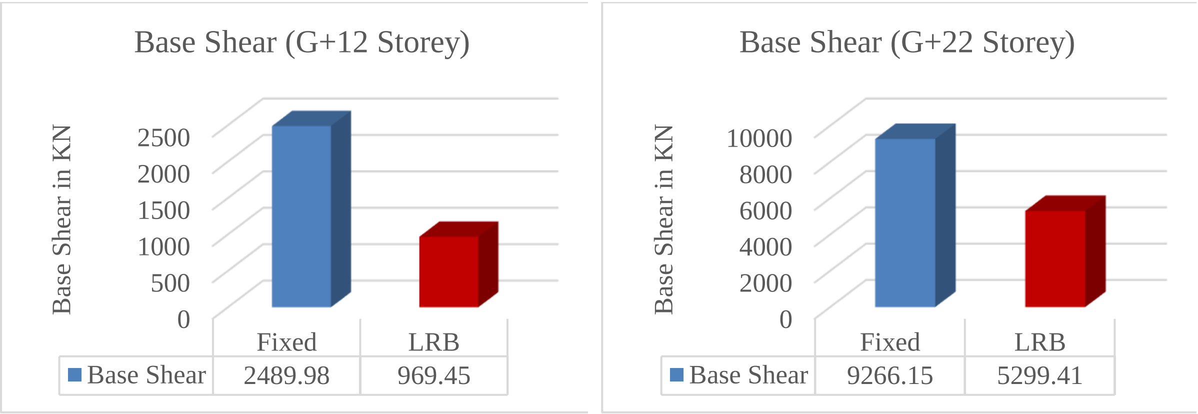


Figure 4: Base Shear of G+12 & G+22 Storey models

Figure 4 shows the base shear for fixed base and LRB base of G+12 & G+22 Storey models. Base shear of base isolated structure over fixed base structure of G+12 & G+22 Storey is decreased by 61.07% and 42.81 % respectively.

6.3. Storey-Drift

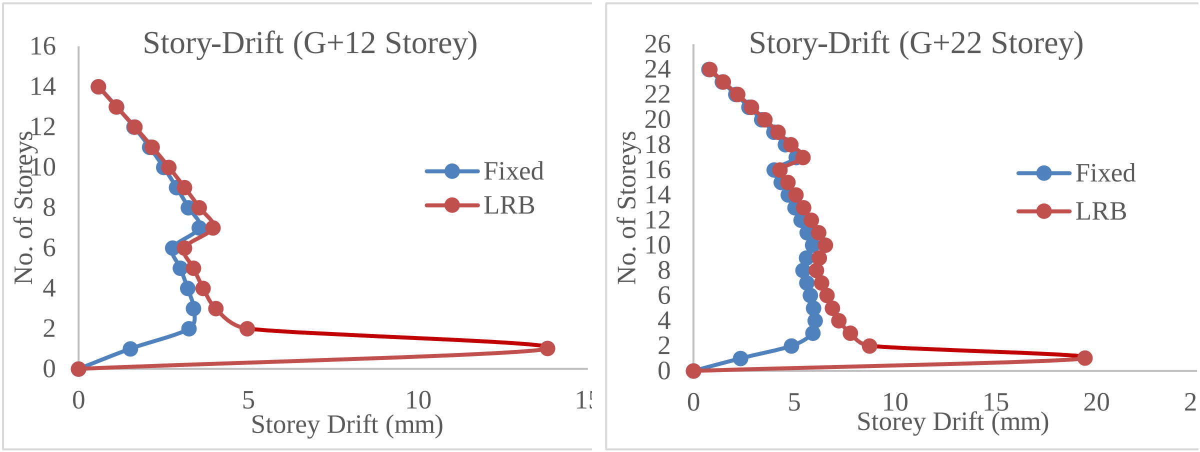


Figure 5: Storey-Drift of G+12 & G+22 Storey models

Figure 5 shows the storey-Drift for fixed base and LRB base of G+12 & G+22 Storey models. Storey-Drift of base isolated structure over fixed base structure of G+12 & G+22 Storey is reduced well within the limit as per IS1893 and in higher stories which makes structure safe against earthquake.

6.4. Storey Displacement

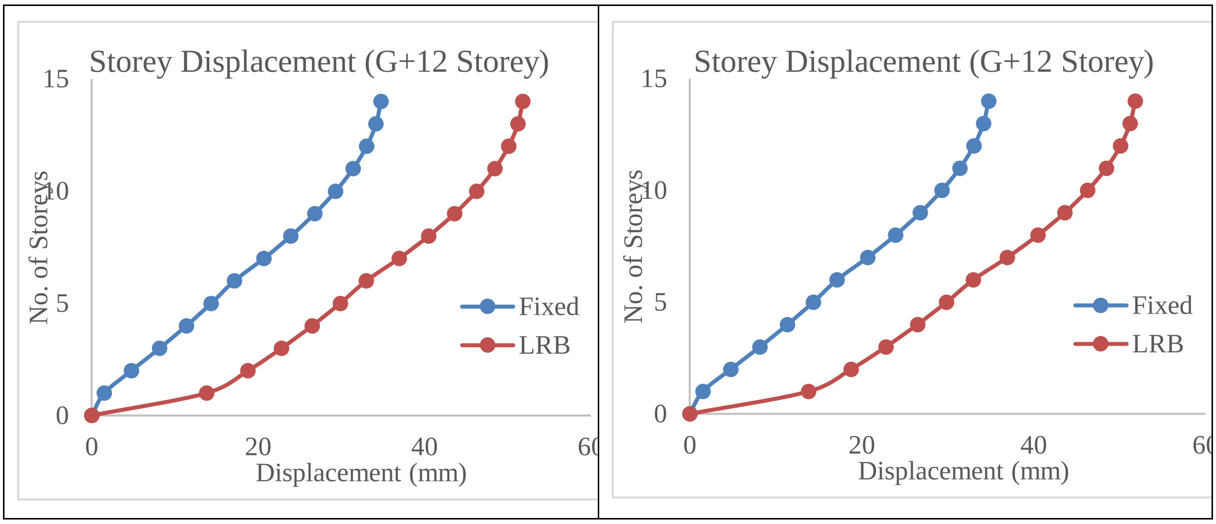


Figure 6: Story Displacement of G+12 & G+22 Storey models.

Figure 6 shows the storey displacement for fixed base and LRB base of G+12 & G+22 Storey models. Storey displacement of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 58.74% and 39.76 % respectively.

6.5. Percentage Reduction in Steel

G+12 Storey				G+22 Storey		
Sr.No.	Description	Fixed	LRB	Fixed	LRB	Remark
1	Column-Biaxial	77586	61581	265416	225700	
2	Column-Uniaxial	764810	552144	4513480	3995044	
3	Column-Axial	1606393	1433588	16957790	15971568	
Total Reinforcement in mm^2 =		2448789	2047313	21736686	20192312	
Reinforcement Reduction in Column =		16.39%		7.10%		
1	Beam	2898050	2629336	17355952	14908932	
Reinforcement Reduction in Beam =		9.27%		14.10%		
Total Reinforcement Reduction =		**25.67%**		**21.20%**		

Above table shows the percentage reduction in steel for fixed base and LRB base of G+12 & G+22 Storey models. Percentage reduction in steel of base isolated structure over fixed base structure of G+12 & G+22 Storey is decreased by 25.67% and 21.20 % respectively.

6.6. Cost Economy

Sr.No.	**Description**	**Quantity**	**Units**	**Remark**
1	Approx. Reinforcement Quantity	5	Kg/Sft	
2	Total Reinforcement Reduction (approx. 26%)	1.3	Kg/Sft	
3	Total Cost Reduction due to LRB (Round off)	65	Rs.	Steel 50 Rs./Kg
4	Cost of Lead Rubber Bearing	150	Rs./Sft	
5	Net Cost for Lead Rubber Bearing	85	Rs.	
6	Approx. cost of Construction	1200	Rs./Sft	
7	Effective Incremental in Construction Cost	7.14	%	G+12 Storey
		8.57	%	G+22 Storey

Above table shows the cost economy for fixed base and LRB base of G+12 & G+22 Storey models. Effective incremental in construction cost of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 7.14% and 8.57 % respectively.

7. CONCLUSION

In the present study, a G+12 storey & G+22 storey RC building was analysed using response spectrum method for both fixed and Lead Rubber Bearing (LRB) isolation. From the above result it can be concluded that Lead Rubber Bearing plays a vital role during earthquake as its increase the time period by 26.23% and 14.89% respectively which result into increase in reaction time of structure during earthquake, storey displacement by 15.87% and 22.07 % respectively which make structure more flexible, reduces base shear by 61.07% and 42.81 % respectively which reduces the seismic effect on structure and storey drift is reduced well within the limit as per IS1893 which makes structure safe against earthquake. Using of LRB as base isolators over fixed base decrease the steel quantity by 25.67% and 21.20% respectively and which results in reduction of cost economy by fairly incremental of construction cost by 7.14% and 8.57%.

From the above studied, we can conclude that the performance of the LRB based isolated structure is better than fixed base structure. Cost difference is also very limitedly increased by approx. 7 to 8 %. Also discount of 30% is offered by Insurance Company to a base isolated structure and the maintenance of the (LRB) base isolated structure is very low as compared to fixed base structure.

REFERENCES

[1] Khin Thanda Htun, Kyaw Kaung Cho (2019), “Experimental in Structural Dynamics (Base Isolation System: Modelling)” IJTSRD volume 3, Issue 3 e-ISSN 2456-6470 (2019).

[2] Dhiraj Narayan Sahoo, Dr. Pravat Kumar Parhi, “Base Isolation of Residential Building using Lead Rubber Bearing Technique” IJERT volume7, Issue 5, ISSN: 2278-0181 (2018).

[3] Manoj Prajapati, Dr. Savita Maru, “Base Isolation for Earthquake Resistance: A Review” IJRASET volume 6, Issue 7, ISSN: 2321-9653 (2018).

[4] Saurabh P. Kharat, Dinesh N. Biradar, Ajay S. Sagekar, Prathamesh V. Chavan, Prof. Reshma Saikh, “Case study on Lead Rubber Isolation Bearing” IRJET volume 5, Issue 3, e-ISSN: 2395-0056 (2018).

[5] Prof. R. B. Ghodke, Dr. S. V. Admane, “Effect of Base Isolation for Building Structures” IJSETR volume 4, Issue 4, ISSN: 2278-7798 (2015).

[6] Nirav G. Patel, “Study on a Base Isolation System” IJISET ISSN 2348-7968 (2014).

[7] O. V. Mkrtychev, G.A. Dzhinchvelashvili, A. A. Bunov, “Study of Lead Rubber Bearings Operation with Varying Height Buildings at Earthquake” XXIII R-S-P seminar, TFoCE (2014).

[8] Prashika Tamang, Bijay Kumar Gupta, Bidisha Rai, Karsang Chukey Bhutia, Chungku Shepa, “Study on Earthquake Resistant Building (Base Isolation)” IJETT volume 33, Number 9, ISSN: 2231-5381 (2016).

[9] Poornima B S, Dr. B S Jayashankar Babu, “Comparative Study on Seismic Response of Regular and Irregular RC Framed Buildings with HDRB, LRB and FPS Base Isolation Systems” IJRASET volume 7 ISSN: 2321-9653 (2019).

[10] Mital Desai, Prof. Roshni John, “Seismic performance of Base Isolated Multi-storey Building” IJSER volume 6 ISSN 2229-5518 (2015).

[11] Mithun, Dileep Kumar U, “Comparative Study on Seismic Response of Irregular Structure with Lead Rubber Bearing and Friction Pendulum Bearing Base Isolation System” IJIRSET volume 6 ISSN 2319-8753 (2017).

[12] Sindhala Raju, Dr. Chenna Rajaram, “Seismic Base Isolation of Multi- Storey Building” IJEECS VOLUME 6 ISSN 2348-117X (2017).

[13] Sabale Nikhil Laxman, Ansari Ubaids, Karale Sandip A. “Base Isolation Study for Multistoried Buildings” IJARIIE volume 3 ISSN 2395-4396 (2017).

[14] Naveen K, Dr H. R. Prabhakara, Dr. H. Eramma, “Base Isolation of Mass Irregular RC Multi-storey Building” IRJET volume 2 ISSN 2395-0056 (2015).

[15] Nithin A. V., Jayalekshmi R., “Seismic Analysis of Multi-storey RC Buildings supported on single and combined Base Isolation Systems” IJSER volume 8 ISSN 2229-5518 (2017).

[16] IS 1893:2016 Criteria for Earthquake Resistant Design of Structures - Part 1: General Provisions and Buildings.

[17] IS 456:2000 Plain and Reinforced Concrete - Code of Practice.

[18] IBC 2000 International Building Code.

[19] UBC 1997 Uniform Building Code - Structural Design Requirements.

International Journal of Advanced Research in Engineering and Technology (IJARET)
Volume 11, Issue 11, November 2020, pp. 2637-2651 Article ID: IJARET_11_11_262
Available online at https://iaeme.com/Home/issue/IJARET?Volume=11&Issue=11
ISSN Print: 0976-6480 and ISSN Online: 0976-6499

COMPARATIVE STUDY ON TRIPLE FRICTION PENDULUM BEARING (TFPB) BASE ISOLATION SYSTEM ON G+12 & G+22 STORY RCC STRUCTURE OVER FIXED BASED FOR INDIAN SUBCONTINENT

M. Tamim Tanwer

Research Scholar, Pacific Academy of Higher Education & Research University-Udaipur, Rajasthan, India.

Prof. (Dr.) Tanveer Ahmed Kazi

Professor, Pacific Academy of Higher Education & Research University-Udaipur, Rajasthan, India.

Prof. (Dr.) Mayank Desai

Assistant Professor, Sardar Vallabhbhai National Institute of Technology-Surat, Gujarat, India.

ABSTRACT

Earthquake is a very dangerous natural disaster which occurs by movement of the tectonic plates in the core of earth. Due to earthquake many structures collapse which result into human life losses. Base Isolation System is the technique to absorb the earthquake forces and reduces the earthquake effects in the structure at the time of earthquake. In this paper, we are considering the design of G+12 & G+22 story RCC building with fixed base and with base isolation system. Triple Friction Pendulum Bearing (TFPB) is used for the design of based isolated structure. Analyzing and designed of these two type of buildings are carried out by response spectrum method in ETABS 2016 software. After analyzing the Structure, time period, base shear, story displacement, story-drift, percentage reduction in steel and overall cost economy will be obtained for both type of structure. From this study, it is found that time period and story displacement increased while base shear, story drift, percentage of steel and overall cost is reduced with provision of Triple Friction Pendulum Bearing (TFPB) as base isolators.

Key words: Earthquake, Base Isolation System, Triple Friction Pendulum Bearings, Time Period, Base Shear, Story Drift, Story Displacement, Reinforcement, Cost Economy, Response Spectrum Method, Seismic forces, ETABS 2016.

Cite this Article: M. Tamim Tanwer, Tanveer Ahmed Kazi and Mayank Desai, Comparative study on Triple Friction Pendulum Bearing (TFPB) Base Isolation System on G+12 & G+22 story RCC Structure over Fixed Based for Indian Subcontinent, *International Journal of Advanced Research in Engineering and Technology (IJARET)*, 2020, 11(11), pp. 2637-2651
https://iaeme.com/Home/issue/IJARET?Volume=11&Issue=11

1. INTRODUCTION

1.1. General

Earthquake is occurring due to movement of the tectonic plates in core of the earth. It is a horizontal movement of earth surface. By earthquake the top surface of earth is shake and foundation is also shake with them. Results the superstructure experience seismic forces and structural members are may collapse. Due to collapse of the structure humans can buried under debris. Peoples are lost their life and also their properties. We cannot construct earthquake proof structure but we can construct earthquake resistant structure.

1.2. Base Isolation System

Base isolation system is also famous in the name of seismic isolation system. It is a method which is protect the structure against seismic force. Base isolation is the effective technique of earthquake engineering appurtenance to the no action in structural vibration control technologies. The System is innovated by Dr. Bill Robinson at New Zealand in 1974. It is very popular system to protect the structures from seismic forces. This technique is useful for new structures as well as can also use in old structure. The base isolation is installing between the foundation and superstructure. It is not allowed to transfer the seismic forces from ground to the superstructure. Base isolation is work as a suspension type system and absorb seismic forces without transferring to superstructure.

The TFPB consists of a spherical stainless steel surface and a slider, covered by a Teflon-based composite material. During severe ground motion, the slider moves on the spherical surface lifting the structure and dissipating energy by friction between the spherical surface and the slider. This isolator uses its surface curvature to generate the restoring force from the pendulum action of the weight of the structure on the TFPB.

2. LITERATURE REVIEW

Nitya M and Arathi S (July-2016) has published a research paper for **“Study of earthquake response of a RC building with base isolation”** on International Journal of Science and Research (IJSR). In this research a reinforced concrete moment resisting frame of G+6 storey with and without base isolation are considered. Analysis is done by using SAP 2000 software. They conclude that The Base isolation substantially increases the time period of the building & hence correspondingly reduces the base shear .The base shear is reduced up to 75 % of that of fixed one. The increase in period for structure with isolated base makes sure that the structure being completely removed from the resonance range of the earthquake. Analysis shows that the fundamental period of the structure is approximately doubled for the isolated structure. Increment in fundamental period reduces the maximum acceleration and hence the earthquake induced forces in the structure. From the tables and graphs it is clear that the storey displacements are much higher for isolated buildings, also the displacement of all the storey’s are almost same. The isolator with rubber has more displacement compared to friction isolator**.** [1]

Tessy Thomas and Dr. Alice Mathai (ICETEM-2016) has published a research paper for **“Study of base isolation using friction pendulum bearing system”** on Journal of Mechanical and Civil Engineering. In this research Finite element model of base isolator is created in ANSYS 14.5 software. The behaviour of the friction pendulum as base isolator also analysed. The nonlinear static analysis of base isolator is done for different storey load values. It is concluded that as the number of storey load value increases, stress intensity value also increases. The stress intensity value obtained up to 30-storeyes is within the permissible limits and base isolator can be designed for 22 to 30 storeyed building. From this analysis it is clear that the movement of slider generates a dynamic friction force that provides the required damping for absorbing the energy of the earthquake. [2]

M.Vijayakumar, Mr. S.Manivel and Mr. A.Arokiaprakash (2016) has published a research paper for **"A Study on Seismic Performance of RCC Frame with Various Bracing Systems using Base Isolation Technique"** on International Journal of Applied Engineering Research. In these research paper a G+25 storey building square in plan is analysed using SAP 2000 software. They conclude that the performance of building with base isolation technique is much better than fixed base one. The parameters such as displacement and drift have been analysed. Hence it is seen that displacement is higher in base isolation when compared to fixed base. The main factor governing the building is its storey drift. The study shows that drift is very much reduced in base isolation. Though the cost of installation adds to drawback of base isolation, but the performance proves its necessity in hospitals, public places and essential buildings. Hence from the study, it can be observed that various bracing system performs better by the use of base isolation in seismic prone area**.** [3]

3. SAMPLE MODEL DETAILS

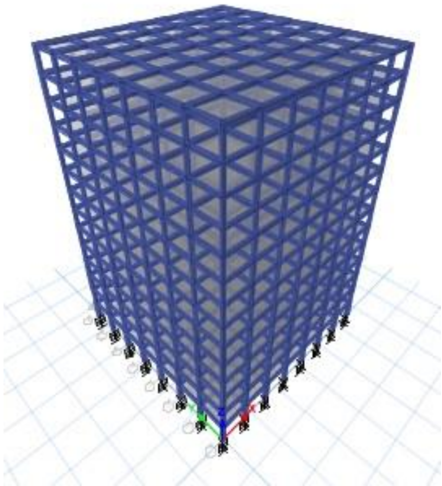


Figure 1: (G+12 Storey)

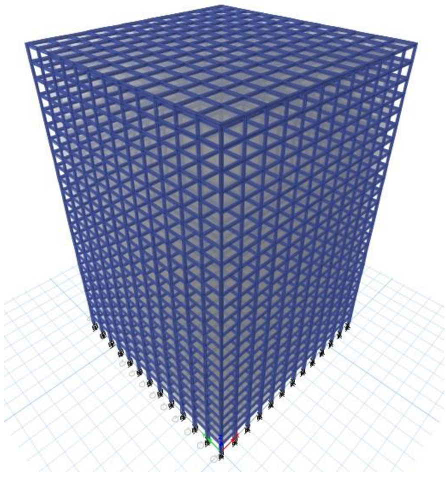


Figure 2: (G+22 Storey)

Sample Modal – 1 & 2	G+12 (7 Bay x 7 Bay)	Sample Modal – 3 & 4	G+22 (12 Bay x 12 Bay)
Beam	= 230 x 450 mm	Beam	= 230 x 450 mm
Column	= 300 x 300 (Storey 8 to Terrace) 375 x 375 (Plinth to Storey 7) 450 x 450 (Base)	Column	= 300 x 300 (Storey 16 to Terrace) 375 x 375 (Storey 8 to Storey 16) 450 x 450 (Plinth to Storey 7) 525 x 525 (Base)
Floor to Floor Height	= 3.0 m.	Wall Thickness	= 115 mm.
Floor Load			
Live Load	= 3 KN/m^2	Floor Finish	= 1 KN/m^2

Earthquake Load

EQ load = Response Spectrum Method
Seismic Zone = Zone 3
Soil Type = Hard Soil (Type-I)
Percentage Damping = 5%
Modal Method = SRSS

Material

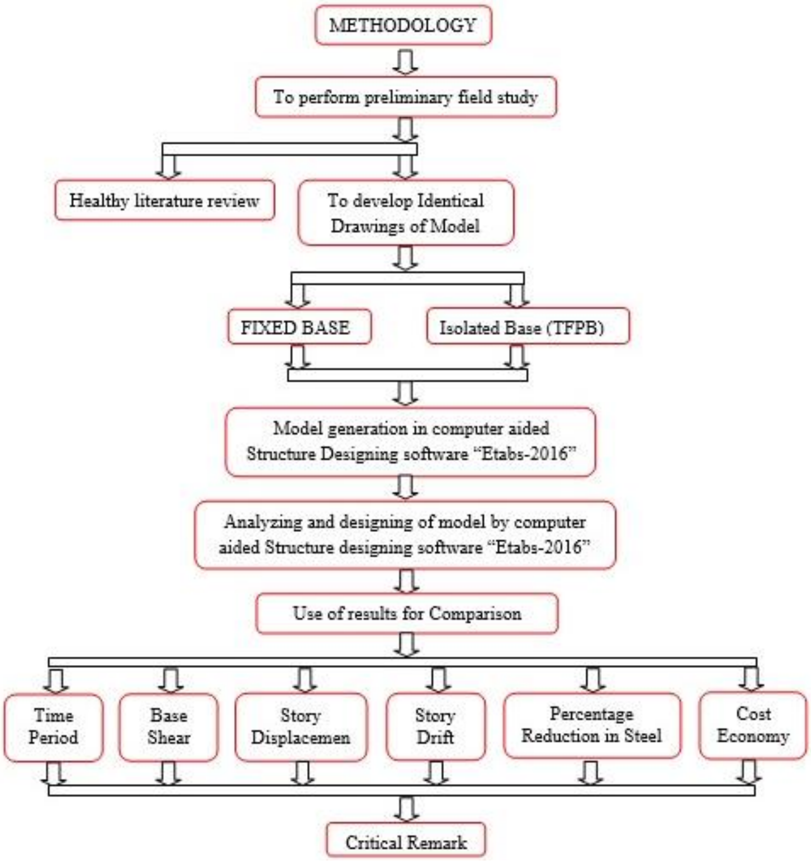
Grade of Concrete = M20 [20 N/mm^2]
Grade of Steel = Fe500 [500 N/mm^2]
Unit weight of Concrete = 25 KN/m^2
Unit weight of brick masonry = 20 KN/m^2
Design basis = Limit State Method (IS: 456-2000)

The sample model of 7 bay x 7 bay for G+12 story building & 12 bay x 12 bay for G+22 Story building (1 bay = 4 m.) is taken with Seismic Zone III on hard soil type – I with the above following details is considered for Analysis & Design.

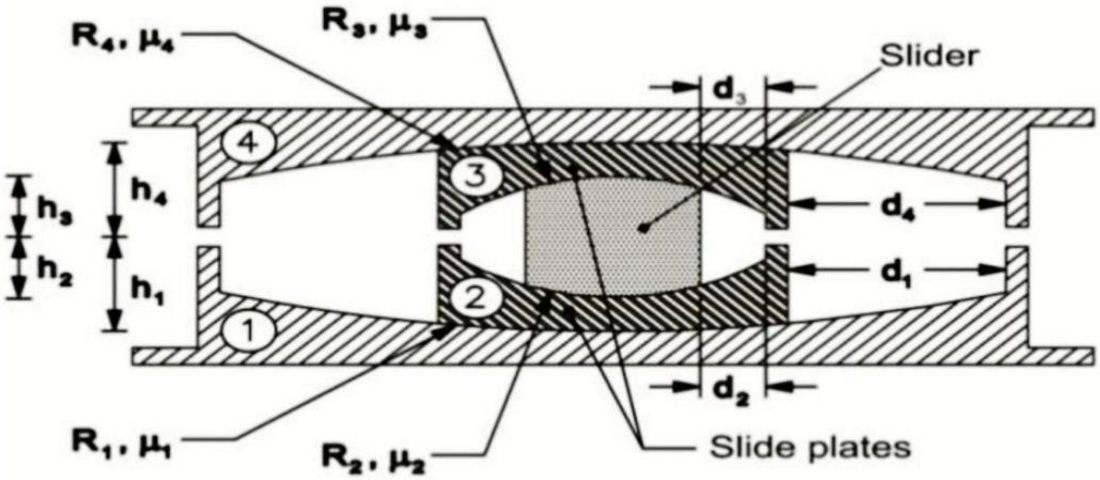
1. Model 1: - G+12 storey building with fixed base. 1. Model 1: - G+22 storey building with fixed base.

2. Model 2: - G+12 storey building with TFPB base isolation. 2. Model 2: - G+22 storey building with TFPB base isolation.

4. METHODOLOGY



5. ANALYSIS & DESIGN OF TRIPLE FRICTION PENDULUM BEARING (TFPB)



For the Analysis & Design of Triple Friction Pendulum Bearing, the cumulative load at the base is obtained from the fixed based design model in Etabs. This load are categorized into three group's viz. Biaxial, Uniaxial and Axial loaded. Sample Calculation for one group is shown below.
Biaxial Load (W) = 1638 kN.

(A) Calculation of geometric, frictional and D_D

1) Geometric Properties

R1 = R4 = 1778 x 2 = 3556 mm = 3.556 m.

R2 = R3 = 647 mm = 0.647 m.

h1 = h4 = 161 mm = 0.161 m.

h2 = h3 = 121 mm = 0.121 m.

d1 = 566.02 mm d2 = 81.05 mm

R_{1eff4} = R_{4eff4} = R_1 - h_1 = 3556 – 161 = 3395 mm.

R_{2eff4} = R_{3eff4} = R_2 - h_2 = 647 – 121 = 526 mm.

$d_1^* = d_4^* = \frac{d_1 \times R_{1eff}}{R_1} = 540.39$ mm ≈ 540.40 mm. $d_2^* = d_3^* = \frac{d_2 \times R_{2eff}}{R_2} = 65.89$ mm ≈ 65.90 mm.

2) Calculating Frictional Properties of the bearing

Bearing pressure at surfaces 1 and 4

P = Load / Area Load W = 163.8 ton (1638 kN) Area $A = \pi \times r^2$

$r = h_1 + h_4 = 161+161 = 322$ mm.

$P = 0.000503$ ton/mm^2,

P = 0.000503 x 1450 = 0.73 ksi.

1 ksi = Kilo square inch = 1450 ton/mm^2.

3- Cycle friction, μ = 0.122 - 0.01 P,

μ = 0.1147

Adjust for high velocity = μ -0.033 = 0.1147 - 0.033
= 0.081 (Lower bound friction)

I - cycle friction μ = 1.2 x 0.081 = 0.0977
Say = 0.098

Lower bound $\mu_1 = \mu_4 = 0.081$
Upper bound $\mu_1 = \mu_4 = 0.098$

Bearing pressure at surfaces 2 and 3

P = Load / Area Load W = 163.8 ton (1638 kN) Area A = π x r^2

$r = h_2 + h_3$ = 121+121 = 242 mm. P = 0.00089 ton/mm^2 = 1.29 ksi.

1 ksi = 1450 ton/mm^2.

3- Cycle friction, μ = 0.122 - 0.01 P,
μ = 0.1091

Adjust for high velocity = μ - 0.036 = 0.1091 - 0.036
= 0.073 (Lower bound friction)

I - cycle friction μ = 1.2 x 0.073 = 0.0877
Say = 0.088

Lower bound $\mu_2 = \mu_3 = 0.073$
Upper bound $\mu_2 = \mu_3 = 0.088$

μ = force at zero displacement divided by the normal load

For Lower bound, $\mu = \mu_1 - (\mu_1 - \mu_2) \times \frac{R_{2eff}}{R_{1eff}}$
μ = 0.080

For Upper bound, $\mu = \mu_1 - (\mu_1 - \mu_2) \times \frac{R_{2eff}}{R_{1eff}}$
μ = 0.096

3) D_D Calculation (Upper bound Analysis)

$S_d = 0.5074$, μ = 0.096 μ1 = 0.098 $Dy = (\mu_1 - \mu_2) * R_{2eff} = 0.005250$,

Fd = 0.277243, W = 163.8 Ton. No. of Bearing = 12

ΣFd = Fd x W x Total Bearing ΣFd = 0.277243 x 163.8 x 12 = 544.95

Σw = Load x No. of bearing Σw = 1965.6 tons

i. Let the displacement be $D_D = 0.07202$ m.
ii. Effective stiffness, Qd = μ * Σw = 0.096 x 1965.6
Q_d = 188.98 ton

$k_D = \Sigma F_D / D_D = 544.95 / 0.07202$ $k_D = 7566.63$ ton/m.

$K_{eff} = k_D + (Q_d / D_D) = 7566.63 + (188.98 / 0.07202)$.

$K_{eff} = 10190.63$ ton/m.

iii. Effective period, $T_{eff} = 2\pi\sqrt{((\Sigma w)/(K_{eff} \times g))}$

$T_{eff} = 0.88103$ sec.

iv. Effective damping, $\beta_D = \frac{E}{2\pi K_{eff} \times {D_D}^2} = \frac{4\mu \Sigma w(D_D - D_y)}{2\pi K_{eff} \times {D_D}^2}$

$\beta_{eff} = \beta_D = 0.1520$ (15.20%)

Refer Eq. 17.5-2 & 17.8-7, ASCE 7-10 for iii & iv.

v. Damping reduction factor, $\beta = \left(\frac{\beta_{eff}}{0.05}\right)^{0.3}$

$\boldsymbol{\beta = 1.3959}$

vi. ${D_D}^1 = \frac{S_{D!} \times {T_{eff}}^2}{4\pi^2 \times \beta} \times g$

${D_D}^1 = 0.0701$ m.

(B) Calculating SAP2000 or Etabs links / support property data (upper bound)

1) Main Properties

i. Rotational Inertia

Considering the isolator with diameter Ø = 0.305 m. (cylinder), h = 0.32 m (Total height)

Ø = 0.484 m, h = 0.5 m. $\mathbf{A} = \frac{\pi \times Ø^2}{4} = \frac{\pi \times 0.484^2}{4}$

$A = 0.1840 \ m^2$

$K_{eff} = \frac{W}{R_{1eff}} + \frac{\mu w}{D_D}$ $K_{eff} = 266.91$ ton/m

$I_1 = \frac{K_{eff} \times h^3}{12E} = \frac{638.012 \times 0.5^3}{12 \times 10000000}$

$= 2.78035E\text{-}07 \ m^4$.

Note:- Young's modulus 'E' was assumed 1×10^7 N/mm² equal to half of actual steel modulus as the bearing is not a solid piece of metal. $E = 1.00E+07 \ N/mm^2$.

ii. Determine of Bearing mass

$D_{m\text{-}max} = 0.0702$ m. $D_{TM} = 1.15 \times 0.0702$ refer (Eq. 17.5.3.5 – ASCE 7-10)

$D_{TM} = 0.0807$ m. $D = 2\ D_{TM} = 2 \times 0.0807$

$D = 0.16146$ m.

$W = 0.241\ D^2 - 0.00564\ D$

$W = 0.0053721$ ton.

$M = w / g = 0.005372 / 9.81$

$M = 0.000548$ ton sec^2/m.

2) Directional properties (U_1)

Ø = 0.484 m, h or L = 0.5 m

Effective stiffness = AE / L

$K_{eff} = 3679684.643$ ton/m.

K_{eff} = 36796846.43 KN/m.

Effective damping from the D_D calculation

Keff = 3679684.64 ton/m.

βeff = 0.1520 (15.20%)

3) Directional properties (U_2 - U_3)

i. Determination of liner properties.

Effective stiffness **K_{eff} = 266.914 ton/m. = 2669.14 KN/m**. Effective damping β_{eff} = 0.1520

Height for outer surface = $h_1 = h_4$ = 161 mm **(0.161 m.)**

Height for Inner surface = $h_2 = h_3$ = 121 mm **(0.121 m.)**

ii. Determination of Non - liner properties.

Stiffness = $\frac{\mu_1 w}{D_y}$

Dy = $(\mu 1 - \mu 2)\ R_{2eff}$ = (0.098 – 0.088) x 0.526

Dy = 0.00525 m.

Stiffness of outer surface = $\frac{\mu 1\ w}{D_y}$ = $\frac{0.098 \times 163.8}{0.00525}$ = 3047.855 ton/m. **= 30478.55 KN/m.**

Stiffness of Inner surface = $\frac{\mu 2\ w}{D_y}$ = $\frac{0.088 \times 163.8}{0.00525}$ = 2736.448 ton/m. **= 27364.48 KN/m.**

Friction slow = µ1 for outer surface = **0.098**

= µ2 for Inner surface = **0.088**

Friction fast = 2xµ1 for outer surface = **0.195**

= 2 x µ2 for Inner surface = **0.175**

Rate Parameter = Friction slow / Friction fast = 0.098 / 0.195 = 0.5 = **0.0005**

- Radius of sliding surface For outer = R_{1eff} = **3.395 m**.

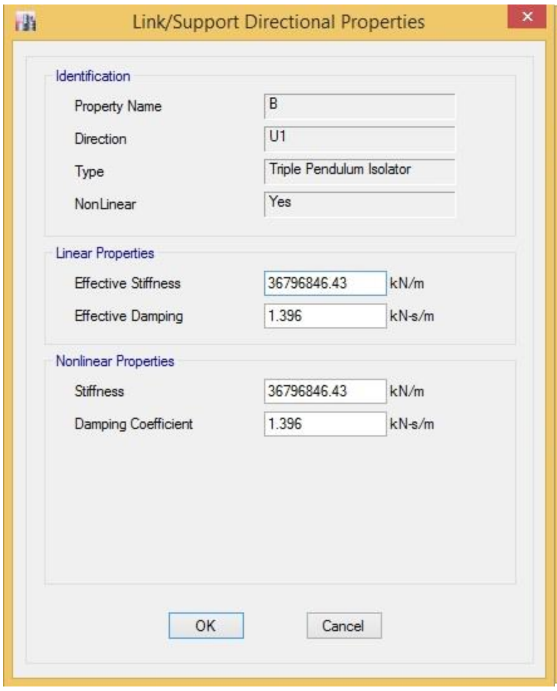
  For inner = R_{2eff} = **0.526 m**.

- Stop distance

  For outer surface $u_1^* = 2\ D_y + 2\ d_1^*$ = 1.09130 m. = **1091.30** mm.

  For Inner surface $u_2^* = 2\ D_y$ = 0.0105 m. **=** **10.50** mm.

Input Values for Etabs:

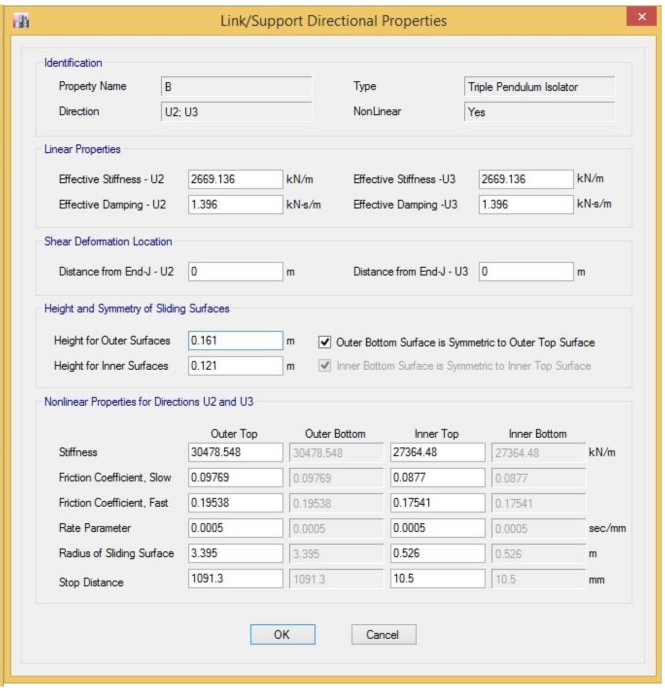


Link/Support Directional Properties

Identification
Property Name: B
Direction: U1
Type: Triple Pendulum Isolator
NonLinear: Yes

Linear Properties
Effective Stiffness: 36796846.43 kN/m
Effective Damping: 1.396 kN-s/m

Nonlinear Properties
Stiffness: 36796846.43 kN/m
Damping Coefficient: 1.396 kN-s/m



Link/Support Directional Properties

Identification
Property Name: B
Type: Triple Pendulum Isolator
Direction: U2; U3
NonLinear: Yes

Linear Properties
Effective Stiffness - U2: 2669.136 kN/m
Effective Stiffness -U3: 2669.136 kN/m
Effective Damping - U2: 1.396 kN-s/m
Effective Damping -U3: 1.396 kN-s/m

Shear Defomation Location
Distance from End-J - U2: 0 m
Distance from End-J - U3: 0 m

Height and Symmetry of Sliding Surfaces
Height for Outer Surfaces: 0.161 m
☑ Outer Bottom Surface is Symmetric to Outer Top Surface
Height for Inner Surfaces: 0.121 m
☑ Inner Bottom Surface is Symmetric to Inner Top Surface

Nonlinear Properties for Directions U2 and U3

	Outer Top	Outer Bottom	Inner Top	Inner Bottom	
Stiffness	30478.548	30478.548	27364.48	27364.48	kN/m
Friction Coefficient, Slow	0.09769	0.09769	0.0877	0.0877	
Friction Coefficient, Fast	0.19538	0.19538	0.17541	0.17541	
Rate Parameter	0.0005	0.0005	0.0005	0.0005	sec/mm
Radius of Sliding Surface	3.395	3.395	0.526	0.526	m
Stop Distance	1091.3	1091.3	10.5	10.5	mm

<table>
<tr><th colspan="9">G+12 Storey Model</th></tr>
<tr><td rowspan="7">Direction U1</td><td>Load</td><td colspan="2">1638 KN</td><td colspan="2">2487 KN</td><td colspan="2">3920 KN</td><td></td></tr>
<tr><td colspan="8">Linear Properties</td></tr>
<tr><td>Effective Stiffness</td><td colspan="2">36796846.43</td><td colspan="2">36796846.43</td><td colspan="2">36796846.43</td><td>KN/m</td></tr>
<tr><td>Effective Damping</td><td colspan="2">1.396</td><td colspan="2">1.367</td><td colspan="2">1.317</td><td>KN-s/m</td></tr>
<tr><td colspan="8">Non-Linear Properties</td></tr>
<tr><td>Effective Stiffness</td><td colspan="2">36796846.43</td><td colspan="2">36796846.43</td><td colspan="2">36796846.43</td><td>KN/m</td></tr>
<tr><td>Effective Damping</td><td colspan="2">1.396</td><td colspan="2">1.367</td><td colspan="2">1.317</td><td>KN-s/m</td></tr>
<tr><td rowspan="7">Direction U2 & U3</td><td colspan="8">Linear Properties</td></tr>
<tr><td>Effective Stiffness</td><td colspan="2">2669.14</td><td colspan="2">3877.29</td><td colspan="2">5644.98</td><td>KN/m</td></tr>
<tr><td>Effective Damping</td><td colspan="2">1.396</td><td colspan="2">1.367</td><td colspan="2">1.317</td><td>KN-s/m</td></tr>
<tr><td>Ht. for outer Surface</td><td colspan="2">0.161</td><td colspan="2">0.161</td><td colspan="2">0.161</td><td>m</td></tr>
<tr><td>Ht. for inner Surface</td><td colspan="2">0.121</td><td colspan="2">0.121</td><td colspan="2">0.121</td><td>m</td></tr>
<tr><td colspan="8">Non-Linear Properties</td></tr>
<tr><td></td><td>Outer Top</td><td>Inner Top</td><td>Outer Top</td><td>Inner Top</td><td>Outer Top</td><td>Inner Top</td><td></td></tr>
</table>

	Stiffness	30478.55	27364.48	32685.61	27957.47	32890.68	25438.21	KN/m
	Friction Coeff. Slow	0.0977	0.0877	0.0931	0.0797	0.0855	0.0661	
	Friction Coeff. Fast	0.1954	0.1754	0.1863	0.1593	0.1710	0.1322	
	Rate Parameter	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	Sec/mm
	sliding surface (R)	3.395	0.526	3.395	0.526	3.395	0.526	m
	Stop Distance	1091.30	10.50	1094.98	14.18	1101.18	20.38	mm
G+22 Storey Model								
Direction U1	**Load**	**3342 KN**		**4627 KN**		**6860 KN**		
	Linear Properties							
	Effective Stiffness	36796846.43		36796846.43		36796846.43		KN/m
	Effective Damping	1.338		1.292		1.205		KN-s/m
	Non-Linear Properties							
	Effective Stiffness	36796846.43		36796846.43		36796846.43		KN/m
	Effective Damping	1.338		1.292		1.205		KN-s/m
Direction U2 & U3	**Linear Properties**							
	Effective Stiffness	4973.01		6391.50		8204.24		KN/m
	Effective Damping	1.338		1.292		1.205		KN-s/m
	Height for Outer Surface	0.161		0.161		0.161		m
	Height for Inner Surface	0.121		0.121		0.121		m
	Non-Linear Properties							
		Outer Top	**Inner Top**	**Outer Top**	**Inner Top**	**Outer Top**	**Inner Top**	
	Stiffness	33120.41	26766.80	32262.31	23465.73	28922.27	15880.44	KN/m
	Friction Coefficient Slow	0.0886	0.0716	0.0817	0.0594	0.0698	0.0383	
	Friction Coefficient Fast	0.1771	0.1432	0.1634	0.1189	0.1396	0.0766	

	Rate Parameter	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	Sec/mm
	Radius of sliding surface	3.395	0.526	3.395	0.526	3.395	0.526	m
	Stop Distance	1098.68	17.88	1104.24	23.44	1113.91	33.11	mm

6. Results

6.1. Time Period

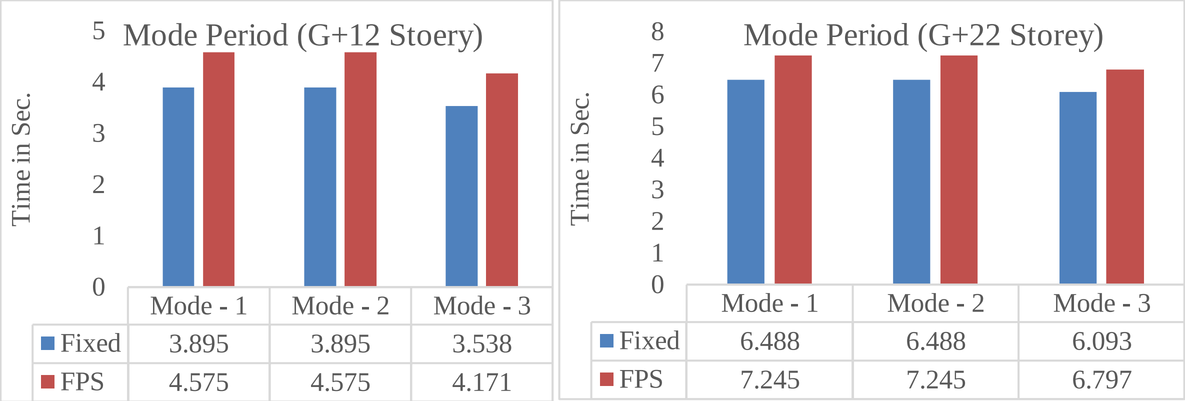


Figure 3: Time Period of G+12 & G+22 Storey models

Figure 3 shows the time period for fixed base and TFPB base of G+12 & G+22 Storey models. Time period of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 17.60% and 11.63 % respectively.

6.2. Base Shear

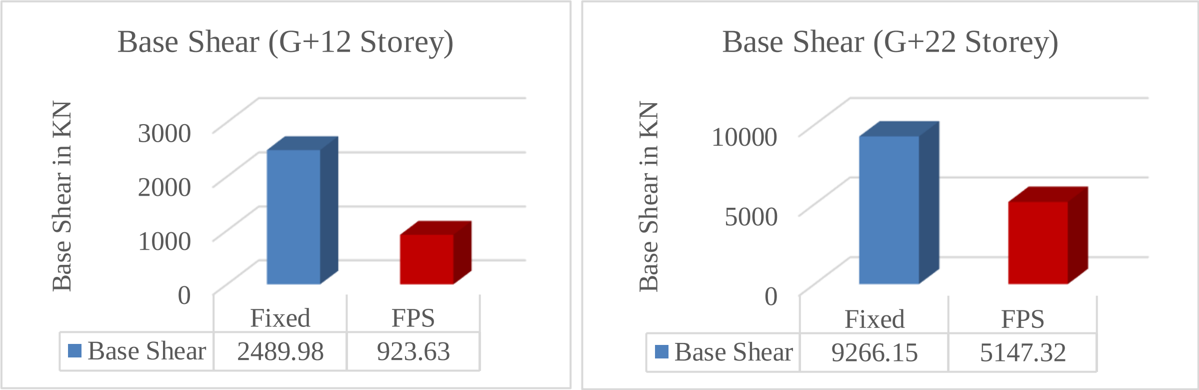


Figure 4: Base Shear of G+12 & G+22 Storey models

Figure 4 shows the base shear for fixed base and TFPB base of G+12 & G+22 Storey models. Base shear of base isolated structure over fixed base structure of G+12 & G+22 Storey is decreased by 62.91% and 44.45 % respectively.

6.3. Storey-Drift

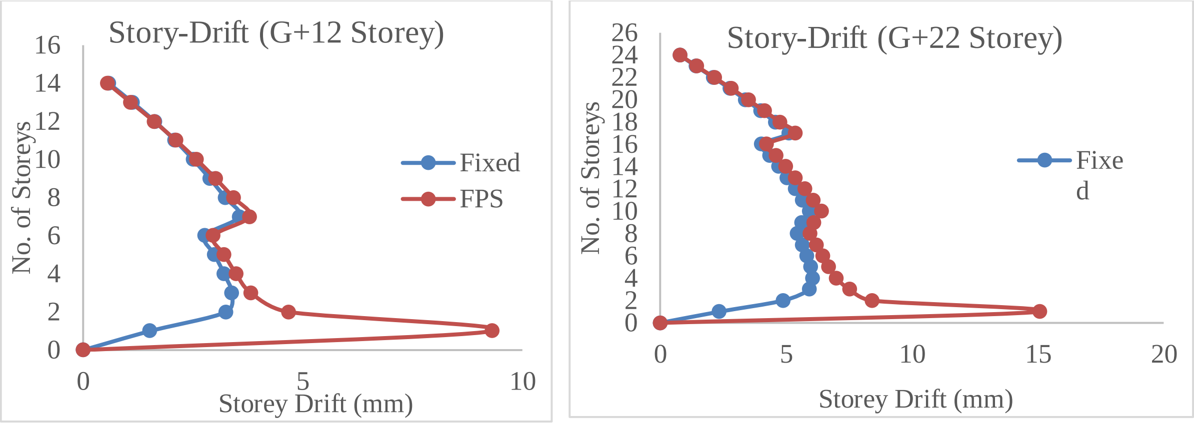


Figure 5: Storey-Drift of G+12 & G+22 Storey models

Figure 5 shows the storey-Drift for fixed base and TFPB base of G+12 & G+22 Storey models. Storey-Drift of base isolated structure over fixed base structure of G+12 & G+22 Storey is reduced well within the limit as per IS1893 and in higher stories which makes structure safe against earthquake.

6.4. Storey Displacement

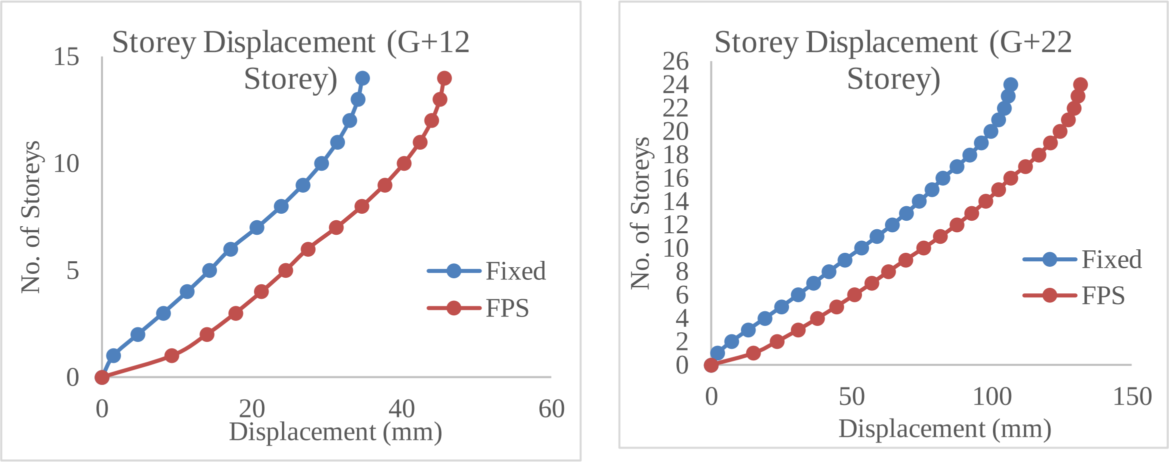


Figure 6: Story Displacement of G+12 & G+22 Storey models.

Figure 6 shows the storey displacement for fixed base and TFPB base of G+12 & G+22 Storey models. Storey displacement of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 49.41% and 30.94 % respectively.

6.5. Percentage Reduction in Steel

G+12 Storey				G+22 Storey		
Sr.No.	Description	Fixed	TFPB	Fixed	TFPB	Remark
1	Column-Biaxial	77586	61998	265416	229720	
2	Column-Uniaxial	764810	557424	4513480	4021152	
3	Column-Axial	1606393	1431680	16957790	15960503	
Total Reinforcement in mm^2 =		2448789	2051102	21736686	20211375	
Reinforcement Reduction in Column =		16.24%		7.02%		
1	Beam	2898050	2595148	17355952	14759524	
Reinforcement Reduction in Beam =		10.45%		14.96%		
Total Reinforcement Reduction =		26.69%		21.98%		

Above table shows the percentage reduction in steel for fixed base and TFPB base of G+12 & G+22 Storey models. Percentage reduction in steel of base isolated structure over fixed base structure of G+12 & G+22 Storey is decreased by 26.69% and 21.98 % respectively.

6.6. Cost Economy

Sr.No.	Description	Quantity	Units	Remark
1	Approx Reinforcement Quantity	5	Kg/Sft	
2	Total Reinfocement Reduction (Approx 27%)	1.35	Kg/Sft	
3	Total Cost Reduction due to TFPB (Round off)	68	Rs.	Steel 50 Rs./Kg
4	Cost for Triple Friction Pendulum Bearing	110	Rs./Sft	

5	Net Cost for Triple Friction Pendulum Bearing	42	Rs.	
6	Approx cost of Construction	1200	Rs./Sft	
7	Effective Incremental in Construction Cost	3.57	%	G+12 Storey
		4.64	%	G+22 Storey

Above table shows the cost economy for fixed base and TFPB base of G+12 & G+22 Storey models. Effective incremental in construction cost of base isolated structure over fixed base structure of G+12 & G+22 Storey is increased by 3.57% and 4.64 % respectively.

7. CONCLUSION

In the present study, a G+12 storey & G+22 storey RC building was analysed using response spectrum method for both fixed and Triple Friction Pendulum Bearing (TFPB) isolation. From the above result it can be concluded that Triple Friction Pendulum Bearing plays a vital role during earthquake as its increase the time period by 17.60% and 11.63% respectively which result into increase in reaction time of structure during earthquake, storey displacement by 49.41% and 30.94% respectively which make structure more flexible, reduces base shear by 62.91% and 44.45% respectively which reduces the seismic effect on structure and storey drift is reduced well within the limit as per IS1893 which makes structure safe against earthquake. Using of TFPB as base isolators over fixed base decrease the steel quantity by 26.69% and 21.98% respectively and which results in reduction of cost economy by fairly incremental of construction cost by 3.57% and 4.64%.

From the above studied, we can conclude that the performance of the TFPB based isolated structure is better than fixed base structure. Cost difference is also very limitedly increased by approx. 3 to 4 %. Also discount of 30% is offered by Insurance Company to a base isolated structure and the maintenance of the (TFPB) base isolated structure is very low as compared to fixed base structure.

REFERENCES

[1] Nitya, M., &Arathi, S. (July-2016). Study on the earthquake response of a RC building with base isolation. International journal of science and research, 5, 1002-1005.

[2] Thomas, T., &Mathai, A. (2016).Study of base isolation using friction pendulum bearing system.Journal of Mechanical and Civil Engineering, 19-23.

[3] Vijaykumar, M., Manivel, S., &Arokiaprakash, A. (2016).A study on seismic performance of RCC frame with various bracing systems using base isolation technique. International journal of applied engineering research, 11, 7030-7033.

[4] Naveen, K., Prabhakara, H.R., &Eramma, H. (Oct-2015). Base isolation of mass irregular RC multi-storey building.International research journal of engineering and technology, 2, 902-906.

[5] Desai, M., & John, R. (Dec-2015). Seismic performance of base isolated multi-storey building. International journal of scientific & engineering research, 6, 84-89.

[6] Noorzai, M., Bajad, M.N., &Dodal, N. (May-2015). Study response of fixed base and isolation base. International journal of innovative research in science, engineering and technology, 4, 3674-3681.

[7] Ghodke, R.B., &Admane, S.V. (April-2015). Effect of base-isolation for building structures.International journal of science, engineering and technology research, 4, 971-974.

[8] Nassani, D.E., &Wassef, M.A. (Feb-2015). Seismic base isolation in reinforced concrete structures.International journal of research studies in science, engineering and technology, 2, 1-13.

[9] Moretti, S., Trozzo, A., Terzic, V., Cimellaro, G.P., &Mahin, S. (Sept-2014). Utilizing base-isolation systems to increase earthquake resilency of healthcare and school buildings. 4th International conference on building resilience, 14, 969-976.

[10] Khan, M., &Bakre S.V. (April-June 2015). Design and study of seismic base isolators.Journal of basic and applied engineering research, 2, 734-739.

[11] Barmo, A., Mualla, I.H., &Hasan, H.T. (Feb-2015). The behaviour of multi-story buildings seismically isolated hybrid isolation (friction, rubber and with the addition of rotational friction dampers). Open journal of earthquake research, 4, 1-13.

[12] Keerthana, S., Sathishkumar, K., &Balamonica, K. (Feb-2015).Seismic response reduction of structures using base isolation.International journal of innovative science, engineering and technology, 2, 33-40. [13] Sabale Nikhil Laxman, Ansari Ubaids, Karale Sandip A. **“Base Isolation Study for Multistoried Buildings”** IJARIIE volume 3 ISSN 2395-4396 (2017).

[13] Nithin A. V., Jayalekshmi R., **“Seismic Analysis of Multi-storey RC Buildings supported on single and combined Base Isolation Systems”** IJSER volume 8 ISSN 2229-5518 (2017).

[14] Santhosh H.P., Harsha M.S., Manohar K & Pradeepa B.B. (Feb-2017). “Seismic isolation of RC framed structure with and without infills.” International Journal of Civil Engineering and Technology (IJCIET) Volume 8 ISSN 0976-6316.

[15] Dr. H.M. Somasekharaiah, Er. Dharmesh N. & Mohammed Ghouse. (Aug-2016).”A comparative study on RC frame structure considering lead rubber bearing and triple friction pendulum bearing.” International journal of innovative research in science engineering and technology. Volume -4, Issue-8 ISSN 2319-8753.

[16] IS 1893:2016 Criteria for Earthquake Resistant Design of Structures - Part 1: General Provisions and Buildings.

[17] IS 456:2000 Plain and Reinforced Concrete - Code of Practice.

[18] IBC 2000 International Building Code.

[19] UBC 1997 Uniform Building Code - Structural Design Requirements.

IAEME PUBLICATION

Publishers of High Quality Peer Reviewed Refereed Scientific,
Engineering & Technology, Medicine and Management International Journals

INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY (IJCIET)

Scopus

SCOPE
DATABASE
INDEXED

Certificate of Publication

This is to certify that the research paper entitled "COMPARATIVE STUDY ON LEAD RUBBER BEARING (LRB) BASE ISOLATION SYSTEM ON G+12 & G+22 STORY RCC STRUCTURE OVER FIXED BASED FOR INDIAN SUBCONTINENT" authored by "M. Tamim Tanwer ; Prof. Dr. Tanveer Ahmed Kazi ; Prof. Dr. Mayank Desai " had been reviewed by the Editorial Board and published in “INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY (IJCIET), Volume 10, Issue 11, November 2019, pp. 423-433; ISSN Print: 0976-6308 and ISSN Online: 0976-6316;"

Article Id - IJCIET_10_11_043 Date of Publication - 30 November 2019

Article Link - https://iaeme.com/Home/article_id/IJCIET_10_11_043

Chief Editor

Plot: 03, Flat- S 1, PoomalaiSantosh Pearls Apartment, Plot No. 10, VaikoSalai 6th Street, Jai Shankar Nagar,
Palavakkam, Chennai - 600 041, Tamilnadu,India. E-mail: editor@iaeme.com

IAEME PUBLICATION

Publishers of High Quality Peer Reviewed Refereed Scientific,
Engineering & Technology, Medicine and Management International Journals

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING AND TECHNOLOGY (IJARET)

Scopus

SCOPE DATABASE INDEXED

Certificate of Publication

This is to certify that the research paper entitled "COMPARATIVE STUDY ON TRIPLE FRICTION PENDULUM BEARING (TFPB) BASE ISOLATION SYSTEM ON G+12 & G+22 STORY RCC STRUCTURE OVER FIXED BASED FOR INDIAN SUBCONTINENT" authored by "Mr.M. Tamim Tanwer ; Prof.Dr.Tanveer Ahmed Kazi ; Prof.Dr.Mayank Desai " had been reviewed by the Editorial Board and published in "INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING AND TECHNOLOGY (IJARET), Volume 11, Issue 11, November 2020, pp. 2637-2651; ISSN Print: 0976-6480 and ISSN Online: 0976-6499;"

Article Id - IJARET_11_11_262 Date of Publication - 30 November 2020

Article Link - https://iaeme.com/Home/article_id/IJARET_11_11_262

Chief Editor

Plot: 03, Flat- S 1, PoomalaiSantosh Pearls Apartment, Plot No. 10, VaikoSalai 6th Street, Jai Shankar Nagar,
Palavakkam, Chennai - 600 041, Tamilnadu,India. E-mail: editor@iaeme.com

22nd ISTE State Annual Faculty Convention 2017

Indian Society for Technical Education

A. D. Patel Institute of Technology (ADIT)

Certificate

This is to certify that a paper titled **Introduction to base isolation system** *was presented in National Conference on* ***"Engineering Innovations for Social and Environmental Development"****, during 22nd ISTE State Annual Faculty Convention, jointly organized by* ***ISTE Gujarat Section*** *and* ***A.D. Patel Institute of Technology, New Vallabh Vidyanagar, Anand*** *on* ***30th December, 2017*** *authored by* ***M.Tamim.A.Tanwer, Mr. Savban Shaikh, Mr. Jignesh Panchal.***

Dr. A.S. Nandane
Convener-ISTE State Convention

Dr. R.K. Jain
Principal, ADIT

KMBhavsar
Prof. K. M. Bhavsar
Chairman-ISTE Gujarat Section

Third International Conference on

INFORMATION AND COMMUNICATION TECHNOLOGY FOR INTELLIGENT SYSTEMS

ICTIS 2018

Certificate

This is to certify that ~~Prof. / Dr. /~~ Mr. / ~~Ms.~~ Prof. M. Tamim Tanwal participated in International Conference on ICT for Intelligent Systems (ICTIS 2018) held during 6 - 7 April, 2018 at Hotel Pride Plaza, Ahmedabad, INDIA.

He / ~~She~~ also presented a paper / ~~delivered an Invited talk~~ / ~~chaired a technical session~~ titled A Study on different types of Base isolation System over fixed based.

We wish his / ~~her~~ the best for future endeavours.

Dr. Priyanka Sharma
Professor, Raksha Shakti Universty

Bharat Patel
Chairman, CEDB, IE(I)

Mihir Chauhan
Organizing Secretary, ICTIS - 2018

GR FOUNDATION

Springer

Gujarat Innovation Society

ICRAET-2022

Certificate

This certificate is awarded to

~~Dr~~/~~Prof~~/Mr/~~Ms~~ M. Tamim Tanwer *of*

PAHER University *for being a paper presenter/~~participant~~/~~Chaired~~*

on title Analysis & design of Lead Rubber bearing (LRB) *in*

International Conference on Recent Advancements in Engineering & Technology-2022

organized by SS College of Engineering, Udaipur on 18th - 19th February.

Sheikh

M. Firdos Sheikh
conference convener,
SS college of engineering

Dr. Prashant sharma
Principal,
SS college of engineering

Ministry Of MSME, Govt. Of India

Indian Institute Of Industrial Engineering

FBSPL

Pride of Knowledge

4TH INTERNATIONAL CONFERENCE ON CREATIVITY & INNOVATION IN TECHNOLOGY DEVELOPMENT

Certificate

This certificate is awarded to

~~Dr/Prof~~/Mr/~~Ms~~. ......M.....Tamim.....Tanwer.......... *of*
.......PAHER....University... *for being a Paper Presenter/Participant/Chaired*
on title .Analysis.....&.design.....of.....Triple.....friction...pendulum. bearing (TFPB) *in*
4th International Conference on Creativity & Innovation in Technology
Development organized on 9-10th December 2022.

Date : 23/12/2022
Place : Udaipur

Convenor
Dr. Prashant Sharma
Principal,SSCE

Convenor
Dr. Deepak Tak
Principal,SSPC

Co-Convener
Mr Piyush Sharma
HOD EE

Co-Convener
Mr. Dheeraj Soni
HOD ME

Co-Convener
Mr. M. Firdos Sheikh
HOD CSE