Eurasian J. Sci. Eng., 2024, 10(1), 89-102
https://doi.org/10.23918/eajse.v10i1p8

Published by Tishk International University
Available at: https://eajse.tiu.edu.iq/submit/

RESEARCH ARTICLE Open Access

Dynamic Response of Multistory Reinforced Concrete Buildings Having Different Types of Isolators: A Parametric Study

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Article History
Receive: 04.12.2022
Revised: 29.01.2023
Accepted: 18.02.2024
Published: 03.04.2024
Communicated by: Asst. Prof. Dr. Abubakr M. Ashir
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Abstract:
Approaches to isolating the base have become a crucial element in enhancing quality stability during a seismic earthquake load. In the present day, base detachment is routinely utilized as an essential arrangement technique for structures and frameworks in seismically active zones. This paper aims towards the dynamic analysis of a multi-story RCC building with various parameters. For the sake of study and verification, a model of a ten-story RCC building with a symmetrical floor plan is considered. The study was conducted using SAP 2000's time-history-based software. In this paper,72 models were studied based on various parameters such as bay width, number of bays, number of floors, and various isolators (Lead Rubber Bearings, Friction Pendulum Bearing, Fixed, and Hinge). The reaction of the structure, for example, time period, base shear, and story displacements are studied and a comparison is made. The paper showed the clear superiority of isolation methods in resisting earthquakes. The friction pendulum support has been the preferred type due to the lowest drift story of the building when it was compared with other support systems. Also, as the results showed a high time period when using the lead rubber bearings, which shows the model's ability to withstand earthquakes.
Keywords: *Base Isolation; Multi-story RC Building; Base Shear; Drift; Earthquake; Rubber Supports; Seismic.*

1. Introduction

Earthquakes are among the most damaging natural disasters. A quake is a quick, temporary movement of the earth caused by the release of energy in a matter of seconds. Protection of civil structures, including their contents and people, is unquestionably a global concern. The goal of structural engineers is to design safer civil structures that can withstand natural disasters. Seismic isolation and energy dissipation techniques are used to strengthen earthquake resistance. Seismic isolation separates the superstructure from the ground to reduce the reaction to earthquakes, this decreases structural earthquake forces. Most isolators improve the damping ratio. This mechanism dissipates some of the earthquake's energy, increasing the structure's and its contents' seismic performance. This novel method is a practical and economical alternative to traditional seismic strengthening. This approach is being used for a variety of civil engineering construction projects.

In this paper, two models were examined for verification purposes, and the extracted findings were compared; the results were similar. Then, 72 parameter models were created by varying the number of floors (7, 10, and 13), the width of bays (4, 5, and 6), and the number of bays (3 and 4) and analyzing them using SAP-2000 (version 22.0.0). Where the results showed that the isolation methods raised the safety coefficients of the buildings, the base shear, time history, and displacement of the models were analyzed.

Islam et al., 2011 [1] studied the behavior of seismic insulation at low- to moderate-seismic sites, despite the fact that seismic insulation has been the subject of a great deal of paper. Earthquake protection systems are intended to separate the building from the harmful components of seismic input movement, preventing the building's superstructure from absorbing earthquake energy. This research provides a summary of several articles on incorporating primary insulation into architectural structures. A comprehensive analysis of the Lead Rubber Bearing (LRB), High Damping Rubber Bearing (HDRB), and Friction Pendulum System (FPS) was performed. In addition, the intricacies of the insulation system, its features, and characteristics of different types of devices were examined, and their impacts on building structures were identified. In addition, installation methods for a range of positions have been thoroughly taught. The entire superstructure is supported by separate insulators of selected dynamic qualities to isolate it from the movement of the earth. Insulation devices limit displacement and return, while the superstructure functions similarly to a rigid body. Strict accounting revealed that the insulation technology was highly innovative and suitable for use in structures to withstand seismic lateral forces. It also improved safety by keeping the chassis flexible.

Prajapati & Panchal in 2013 [2] provided the analysis and design technique that may be used for the assessment of a symmetric multi-story structure subject to wind and seismic stresses. Structures are intended to withstand moderate, commonly occurring earthquakes and wind and must have adequate stiffness and strength to avoid displacement and damage. Due to cost restrictions, it is inappropriate to design a structure to stay in the elastic area during strong earthquakes and wind lateral pressures. The inherent dampening of yielding structural parts may be exploited to reduce the required strength, resulting in a more cost-effective design. This yielding often offers the structure's ductility or toughness against a rapid brittle-type structural breakdown.

Sambhav in 2017 [3]compared the performances of the isolated base with fixed base buildings. Response spectra and Time history analysis were carried out for 4 and 12 story RC buildings. The results show a reduction in the base shear and roof acceleration, while natural period, displacement was increased for isolated base buildings compared to the fixed one. It was found that the percentage reduction in the base shear of 12 stores isolated base building is 22% more than the 4 stores isolated base building.

Yurdakul and Yldz in 2020 [4] used lead-rubber bearings (LRB) to protect buildings from seismic damage. The LRB-designed insulated building has been assessed under the Uniform Building Code (UBC-97) and Fixed Building. The six-story building is designed by SAP2000 using the LRB and a static structure with the same dynamic loads. Comparisons are made between the relative displacement of the floor and the internal forces of an earthquake-isolated, stable structure. The longitudinal and transverse reinforcements are also compared for each axis of a seismically insulated and immobile structure. The investigation revealed the effectiveness of the seismic isolation mechanism at the facility. The longitudinal and transverse reinforcements of the insulated structure are 36 and 40% lighter, respectively, then those of the stationary structure.

2. Objectives of The Paper

- To study the comparative analysis of fixed, lead rubber bearings, friction pendulum bearings, and hinges.
- To study the behavior of structures with and without base isolation.
- To study different techniques of earthquake resistance.
- To know the best base isolation system for various structures.
- To compare the seismic response with and without base isolation, utilizing the time-history method in SAP 2000 software.

3. Analysis Verification Models

A reanalysis of multi-story RC structures was performed and compared other researchers' studies. Used the SAP 2000 v22 program to conduct a study of multi-story reinforced concrete structures, during which non-linear dynamic analysis (time history method) was utilized in the analysis.

3.1 First Case Study

A model of an RC building with ten stories is utilized for validation purposes. (Farqaleet, 2016) [5] offered a method that was similar to this one. Following the modeling phase comes the use of imperial (El Centro) time-history for the nonlinear time-history analysis. For validation, a model of an RC building with ten stores is employed. After modeling, nonlinear time history analysis is carried. The model was introduced by (Farqaleet, 2016).

Table 1: Description of the building [5]

Height of the story	3.1 m	Thick. of slab	0.15 m
Density of concrete	2500 kg/m3	Live Load on Typical floors	3.5 KN/m^2
Density of brick wall	2000 kg/m3	Dead load of slab	3.75kN/m^2
Strength of Concrete	30 MPA	Wall load intensity	12.19kN/m
Dimension of beam	0.45 m x 0.23 m	Type of supports	Fixed
Col. size	0.5 m x 0.5 m		

Result of analysis model in SAP 2000 V22, the changes between the current verification model and the model used in (farqaleet, 2016) research is evident from the figures and tables provided below.

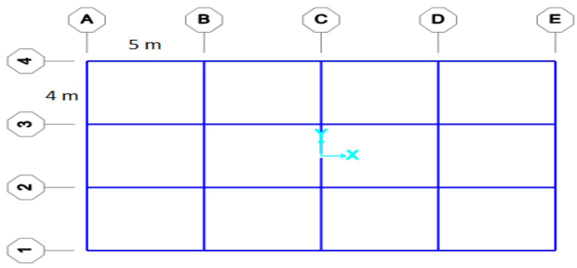

Figure 1: Plan of first model.

- Compared the Results between the work of (Farqaleet, 2016) and the present work:

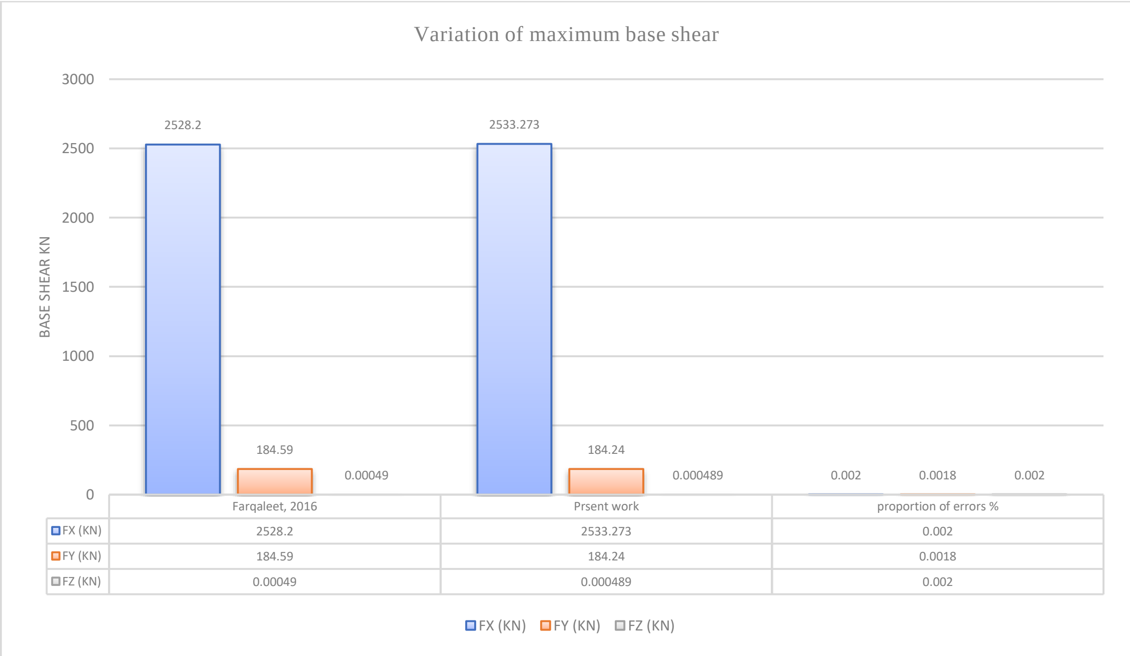

Figure 2: Changes in maximum base shear for first case study

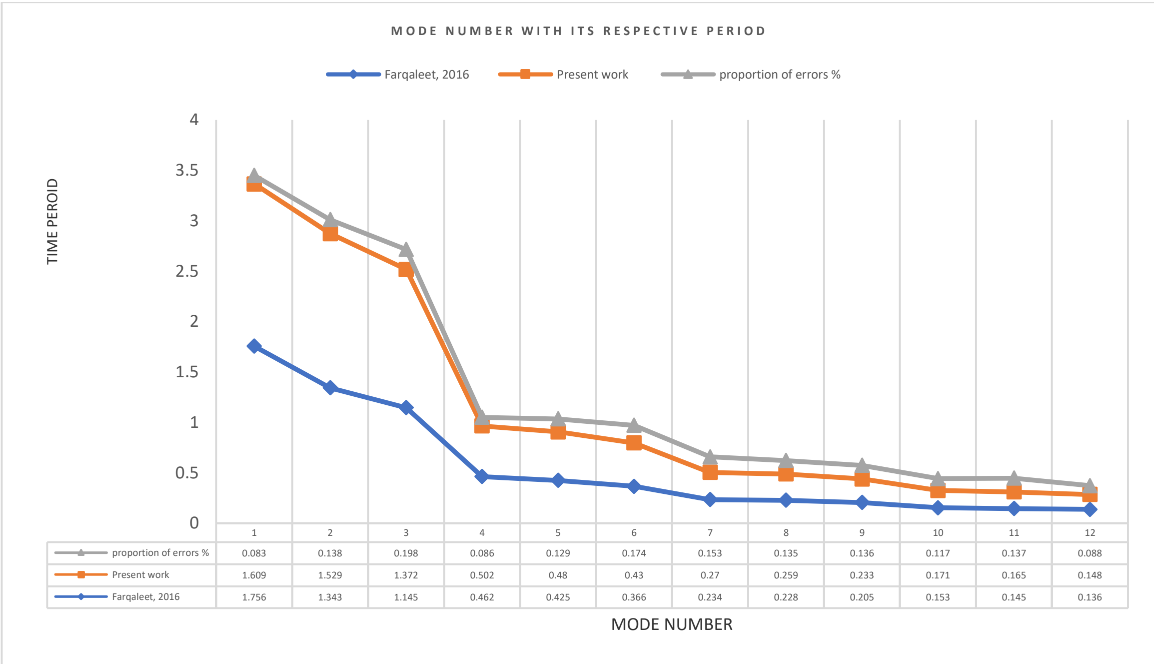

Figure 3: Mode number with its respective period for first case study

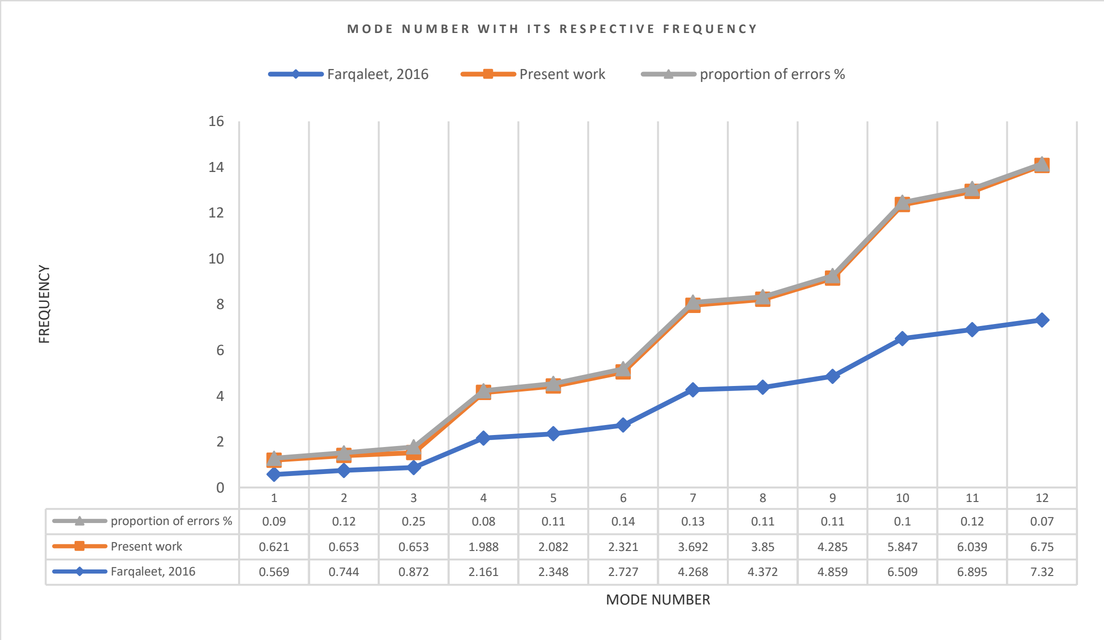

Figure 4: Mode number with its respective frequency for first case study

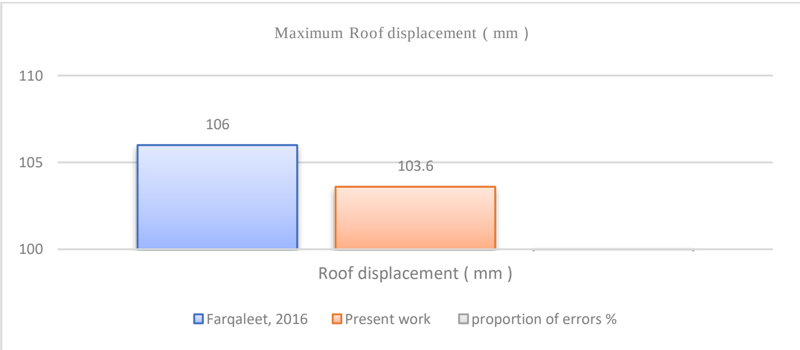

Figure 5: Maximum Roof displacement (mm) for first case

So, the results are the maximum base shear (2533.273 kN) and the roof displacement (103.6 mm) for first case study, The present results are compared and found to be in close agreement with the results reported by (Farqaleet, 2016) [5].

3.2 Second Case Study

(Verma et al., 2021) [6] studied a ten-story building with a 10-story RC building, non-linear chronological analysis is performed using time history (El Centro).

Table 2: Description of the building.[6]

Height of the story	3.1 m
Dimension of beam	0.45 m x 0.23 m
Col. size	0.5 m x 0.5 m
Thick. of slab	0.15 m
Live Load on Typical floors	3.5 KN/m2
Dead load of slab	3.75kN/m

Density of concrete	2500 kg/m3
Density of brick wall	2000 kg/m3
Strength of Concrete	30 MPA
Wall load intensity	12.19kN/m
Type of supports	Fixed

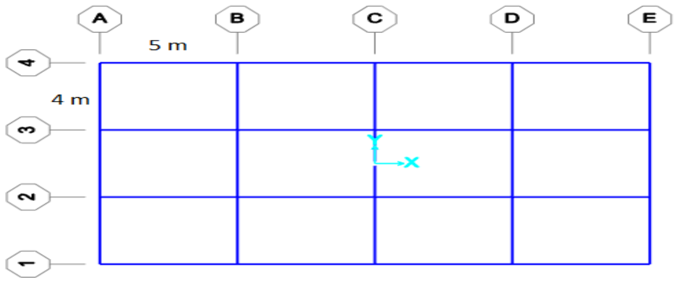

Figure 6: Plan of model.

- Result of analysis model in SAP 2000 V22. The changes between the current model and the model
- used in (Verma et al., 2021) research is evident from the figures and tables provided below.

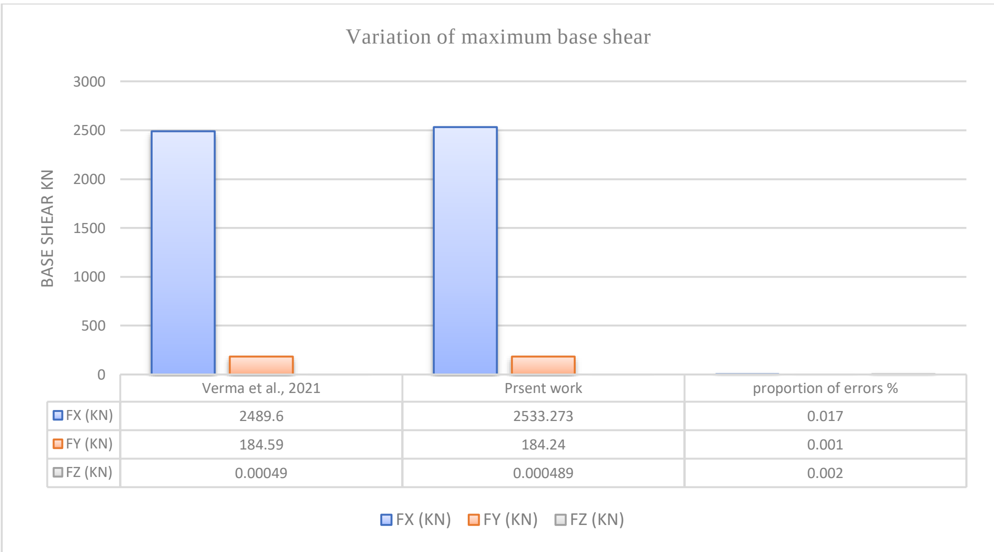

Figure 7: Variation of maximum base shear for second case.

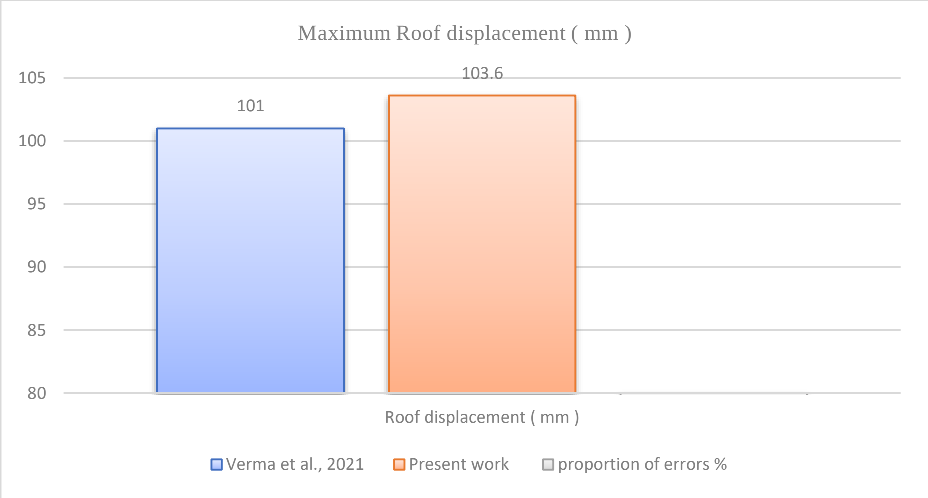

Figure 8: Maximum Roof displacement (mm) for second case.

3.3 Result and Discussion of Verification Study

Reached some conclusions based on conducted the case studies: -

- After modeled and analyzed two models, the results were based on the base shear, displacements, and Time period values. All results obtained in the present work were close to those of previous literatures.
- For example, in the first study case, the maximum base shear value and maximum displacements in the present work were 2533.273 kN and 103.6 mm, respectively, while their values were 2528.2 kN and 106 mm according to the results of Farqaleet, 2016.
- The verification modeling method was beneficial because it provided an understanding of the findings of earlier studies, improved the user's proficiency with SAP 2000, and increased confidence in the findings of the current study.

4. Parameters Study

In this part, the comparison of various parameters like displacement, base shear and time period is done and tabulated from the outcomes obtained from time history of RCC, structures in fixed base, LRB, FPB base, and hinge base isolated base isolated conditions.

4.1 Base Shear Results:

1. Figure 9 show the result of first model story height =3.1 m, bay width =4 m, number of bays= 4 and number of stories 7,10 and 13 floor.
2. Figure 10 show the result of second model story height =3.1 m, bay width =6 m, number of bays= 4 and number of stories 7,10 and 13 floor.
3. Figure 11 show the result of third model story height =3.1 m, bay width =4 m, number of bays= 3 and number of stories 7,10 and 13 floor.
4. Figure 12 show the result of fourth model story height =3.1 m, bay width =6 m, number of bays= 3 and number of stories 7,10 and 13 floor.
5. The Base shear value increased as the number of floors increased with all different types of isolators, as shown in Fig.9, 10, 11 and 12.
6. The value of the base shear increased significantly when increased the number of bays from (3) to (4), as shown in Fig. (9 and 11).
7. The base shear values increased with the increase in the number of storeys, as it increased by 27% when increased the number of storeys from 7 to 10, while the increase was 84% at the 13 storey when types of isolators is Fix, while it increased by 36.42 % when increased the number of storeys from 7 to 10, while the increase was 91% at the 13 storey when types of isolators is

Rubber, and it increased by 29 % when increased the number of storeys from 7 to 10, while the increase was 70% at the 13 storey when types of isolators is Friction.

8. The value of the base isolated structures reduces compared with that of fixed base structures 17 % when use Friction.
9. The value of the base isolated structures increases 25% when increased bay width from (4 m) to (6 m), as shown in Fig. (9 and 10).

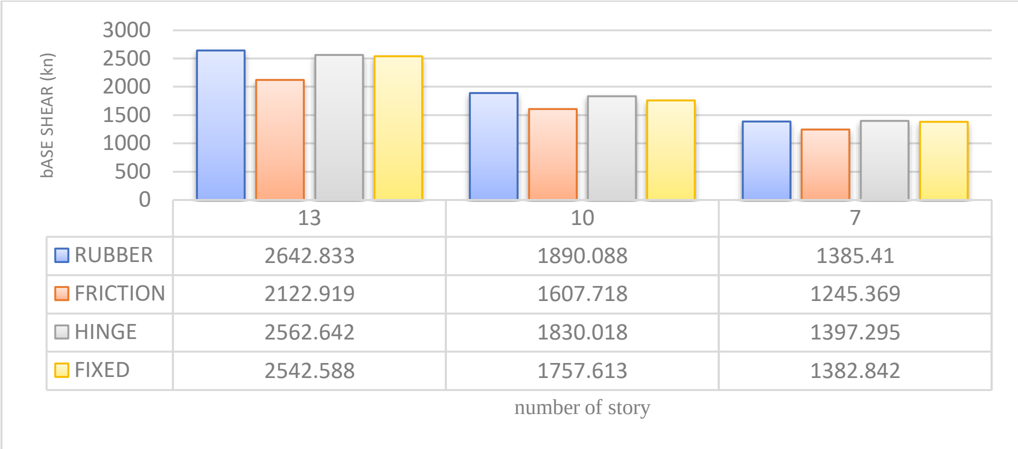

Figure 9: Maximum base shear with different types of isolators, first model.

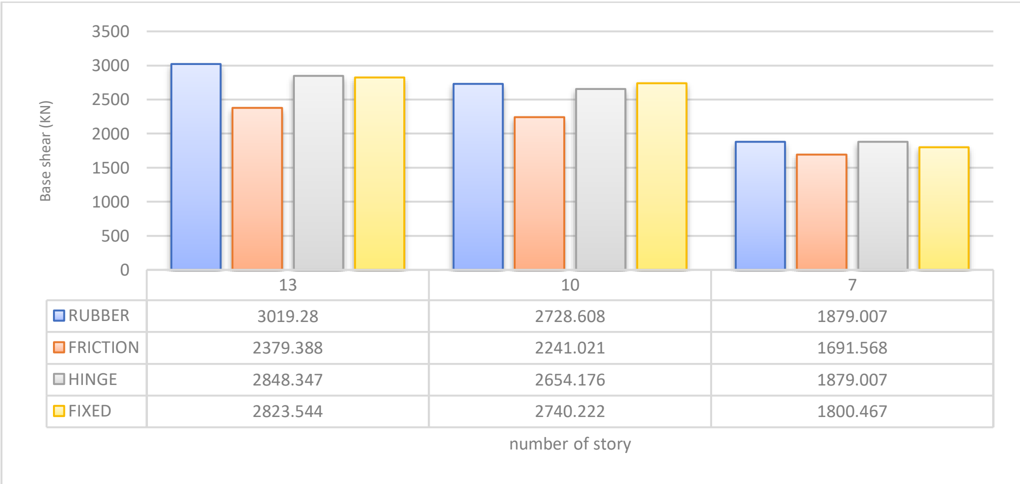

Figure 10: maximum base shear with different types of isolators, second model.

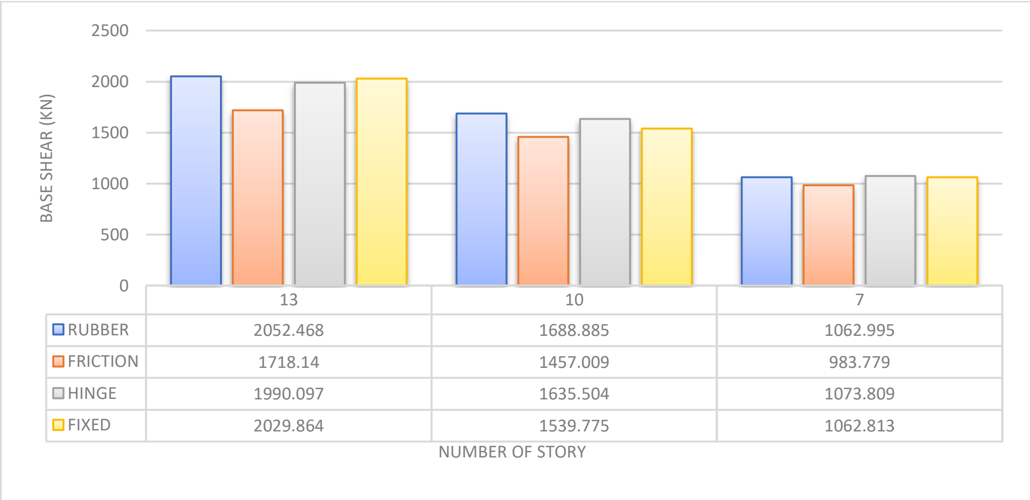

Fig 11: Maximum base shear with different types of isolators, third model

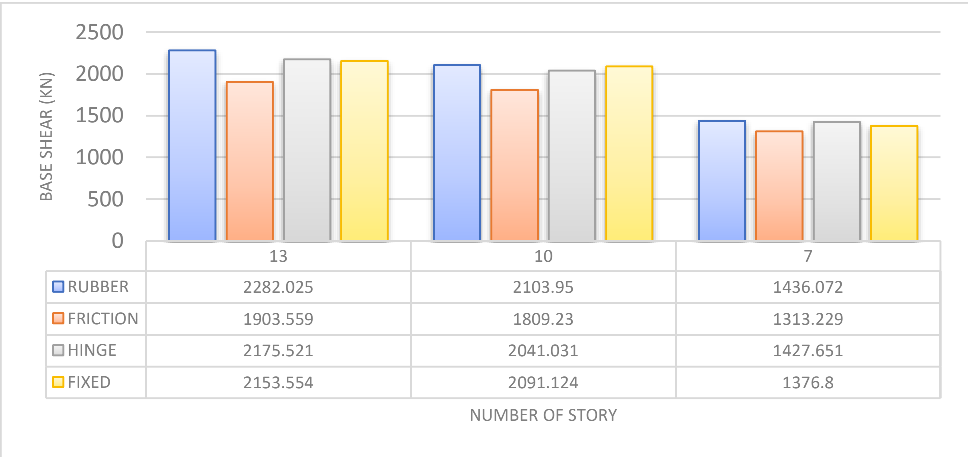

Figure 12: Maximum base shear with different types of isolators, fourth model.

4.2 Time Period Results:

1. Figure 13 show the result of first model story height =3.1 m, bay width =4 m, number of bays= 4 and 13 floors.
   - The time period value decreased as the number of floors increased with all different types of isolators, as shown in Fig.13, 14, 15, 17, and 18.
2. Figure 14 show the result of second model story height =3.1 m, bay width =5 m, number of bays= 4 and 13 floors. The value of the time period increased significantly (LRB= +14%, FPB= +2%, Hinge= +28%, Fix=+20) when increased the bay width from (4-5m), as shown in Fig.14.
3. Figure 15 show the result of third model story height =3.1 m, bay width =6 m, number of bays= 4 and 13 floors. The value of the time period increased significantly (LRB= +24%, FPB= +32%, Hinge= 35%, Fix=+35) when increased the bay width from (4-6m), as shown in Fig.15.
4. Figure 16 show the result of fourth model story height =3.1 m, bay width =4 m, number of bays= 3 and 13 floors.
5. The value of the time period decreased significantly when decreased the number of bays from (4) to (3), as shown in Fig.16, 17, and 18.
6. Figure 17 show the result of fifth model story height =3.1 m, bay width =5 m, number of bays= 3 and 13 floors.
7. Figure 18 show the result of sixth model story height =3.1 m, bay width =6 m, number of bays= 3 and 13 floors.

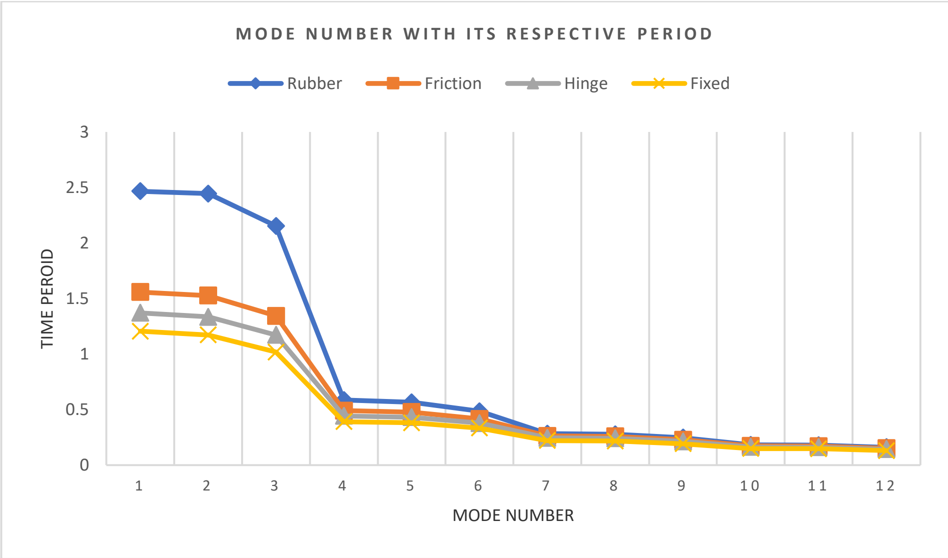

Figure 13: Time period for first model

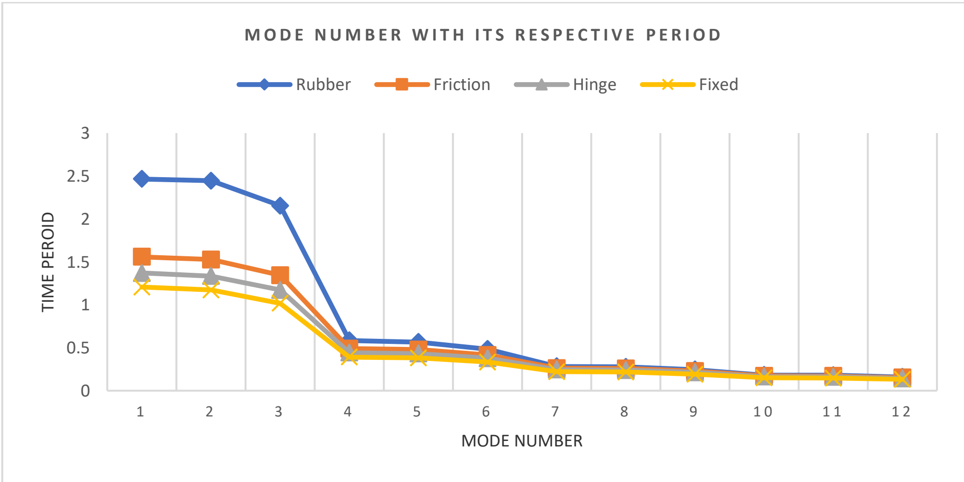

Figure 14: Time period for second model

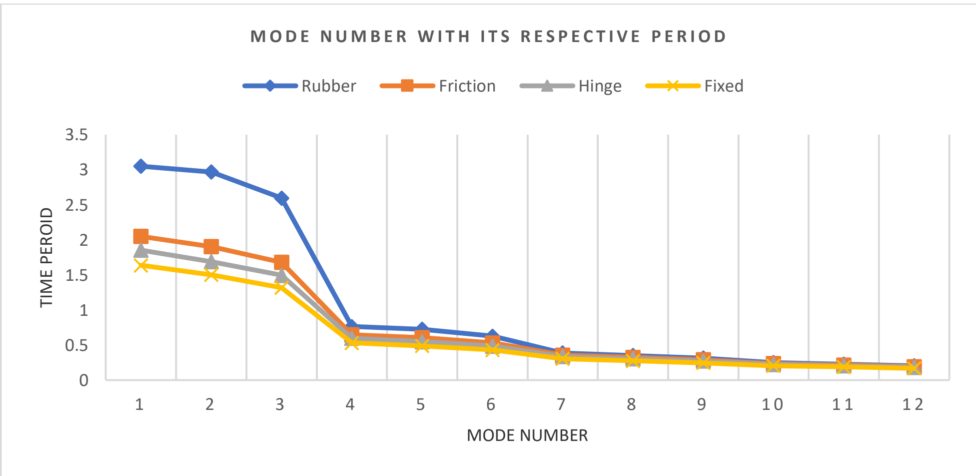

Figure 15: Time period for third model

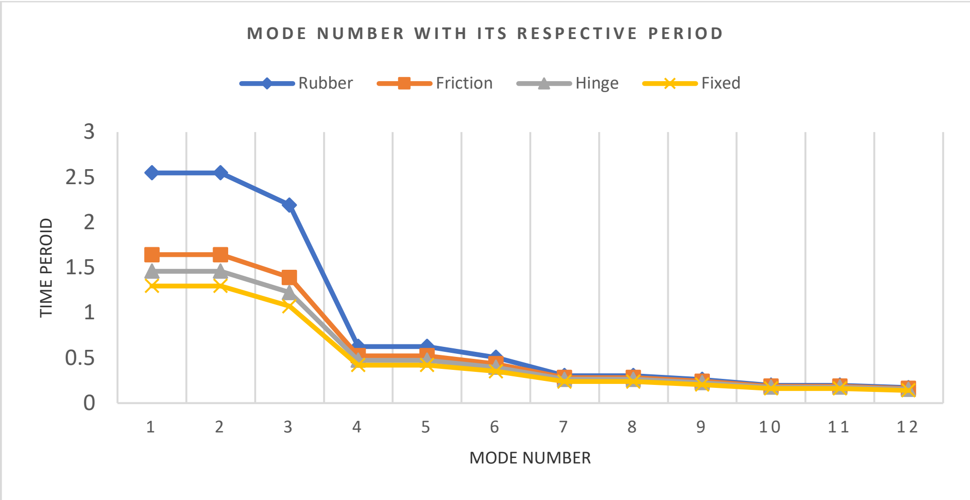

Figure 16: Time period for fourth model

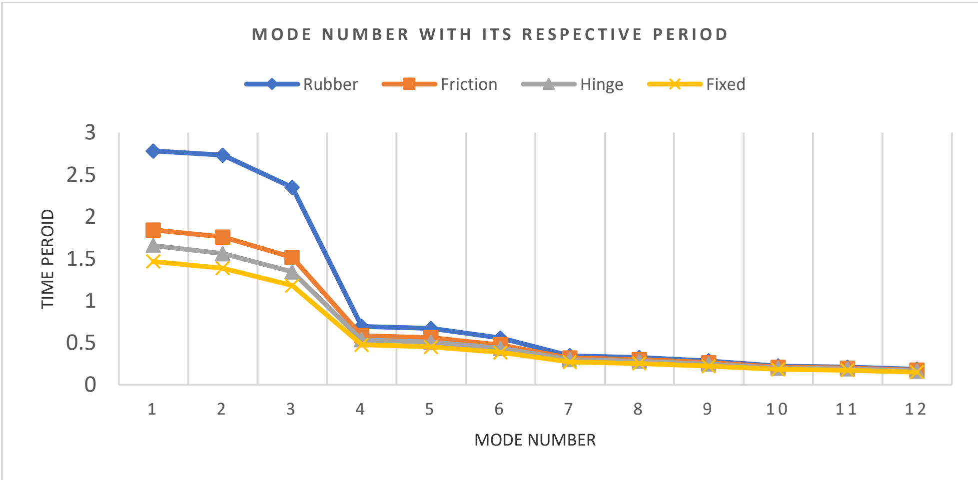

Figure 17: Time period for fifth model

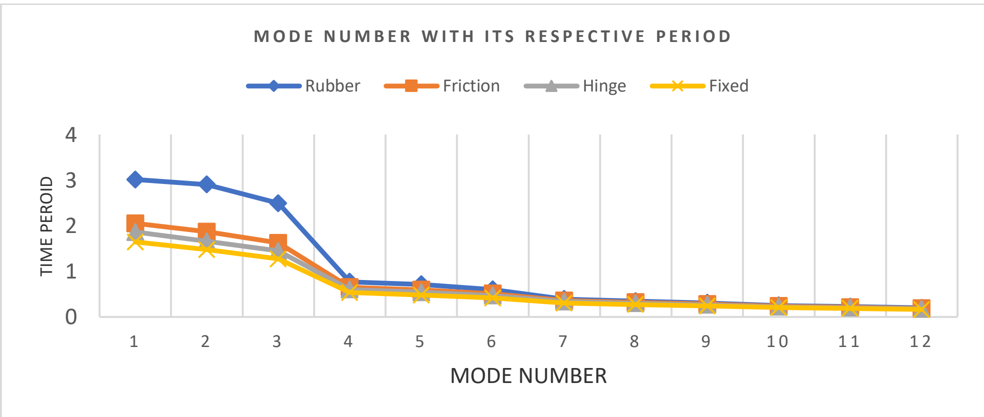

Figure 18: Time period for sixth model

4.3 Displacement Results:

- The value of the displacement increased significantly when the number of bays to (4), as shown in Fig. (19 and 20). But the displacement is smaller when the number of bays 3, as shown in fig. (21 and 22), and the value of the displacement increased significantly when the bays width (6 m), as shown in Fig. (20, and 22). But the displacement is smaller when the bays width (4 m), as shown in fig.20

- In terms of displacement, the Friction Pendulum Bearing technique beat other methods of insulation, since the displacement was always greater when using Friction Pendulum Bearing, and the Lead Rubber Bearings method was superior to the fixed and hinged approaches. as shown in Fig. (19, 20, 21, and 22)
- Figure 19 show the result of first model story height =3.1 m, bay width =4 m, number of bays= 4 and 13 floors, Figure 20 show the result of second model story height =3.1 m, bay width =6 m, number of bays= 4 and 13 floors, Figure 21 show the result of third model story height =3.1 m, bay width =4 m, number of bays= 3 and 13 floors, and Figure 22 show the result of first model story height =3.1 m, bay width =6 m, number of bays= 3 and 13 floors.

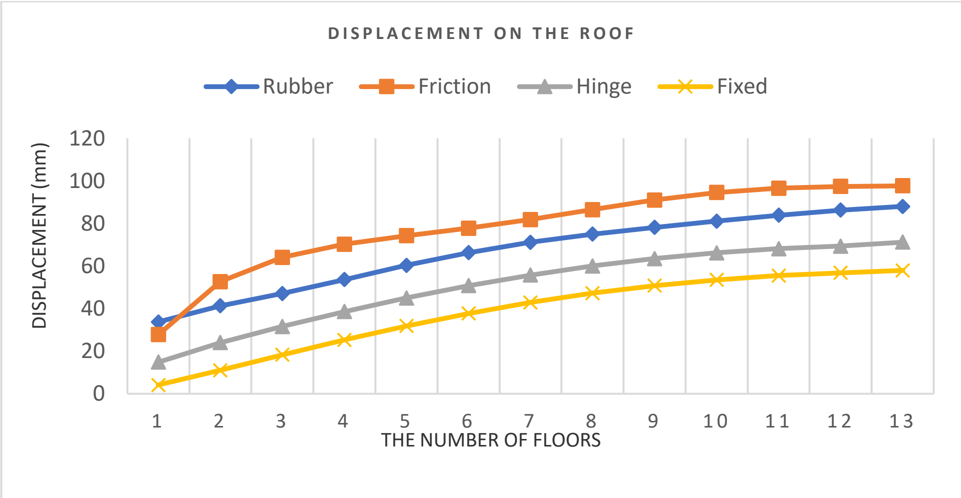

Figure 19: Displacement for first model

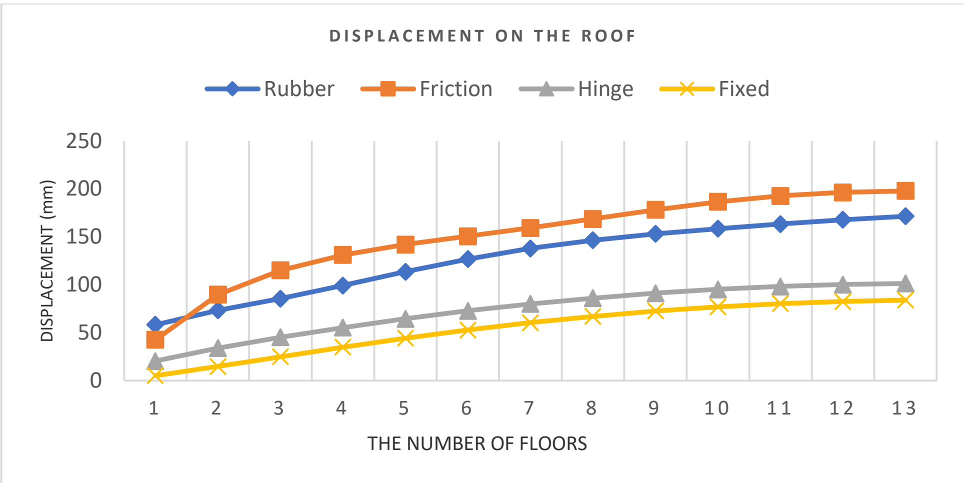

Figure 20: Displacement for second model

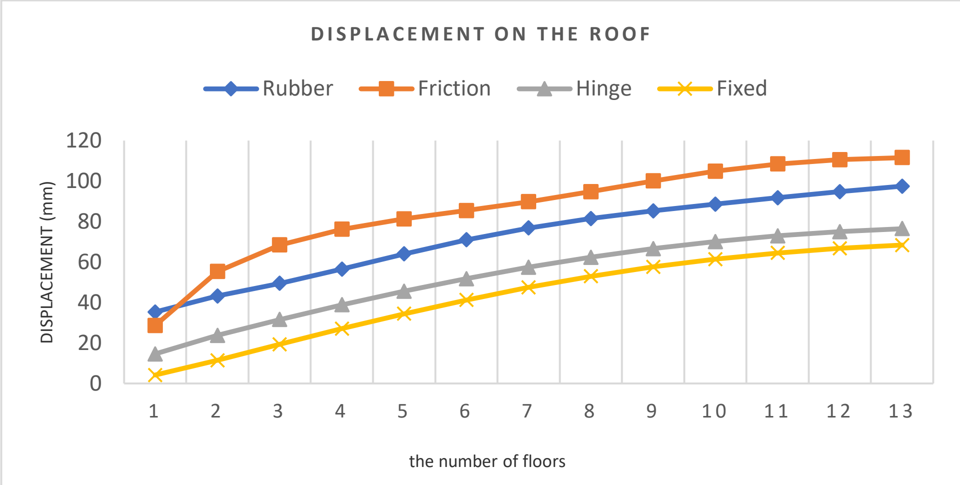

Figure 21: Displacement for third model

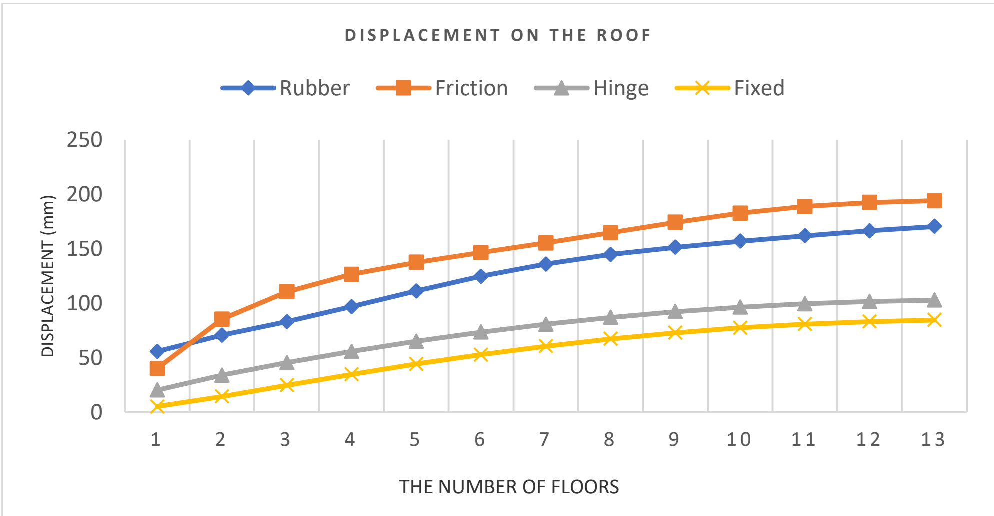

Figure 22: Displacement for fourth model

5. Conclusions

This study attempts to comprehend the sufficiency of the base disconnecting component for a quake. This study deals with the dynamic response of multistory buildings with different types of isolators. A nonlinear, time-history analysis has been done using the finite element method with SAP2000 software. This study yielded numerous calculations, which can be summarized as follows:

- The percentage of error in the results obtained from the applied models did not exceed 3%, and fixed support system is not preferred for seismic loadings due to the story drifts are more than other bearing support types.
- The formed building system having many support systems such as fixed, pinned, rubber isolator and friction pendulum isolator whichever, the friction pendulum support has been preferred type due to the lowest drift story of building when it compared with other support system.
- The value of the base isolated structures reduces compared with that of fixed base structures 17 % when use Friction, and The value of the base isolated structures increases 25% when increased bay width from (4-6 m), and the value of the time period increased significantly (LRB=+14%,FPB=+2%, Hinge= +28%, Fix=+20) when increased the bay width from (4-5m)
- The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings, and The increases in time period due to decrease the stiffness of RC building and it have more displacements at tip of buildings.

- As the span length increased, the values for the base shear, time period, and roof displacements all rose. The internal forces may need to be redistributed, and the position of the plastic hinges may need to be adjusted as a result. This effect can be attributed to the fact that lengthening beams in the RC building under study causes their lateral stiffness to decrease.

References

[1] A. Islam, M. Jameel, and M. Z. Jumaat, "Seismic isolation in buildings to be a practical reality: Behavior of structure and installation technique," *J. Eng. Technol. Res*, vol. 3, no. 4, pp. 99–117, 2011, [Online]. Available: http://www.academicjournals.org/JETR/PDF/pdf 2011/Apr/Islam.pdf

[2] B. D. Prajapati and D. R. Panchal, "STUDY OF SEISMIC AND WIND EFFECT ON MULTI STOREY R.C.C., STEEL AND COMPOSITE BUILDING," 2013.

[3] J. S. G. Sambhav, "Assessment of Seismic Response Analysis of Base Isolated RC Building frame," *Int. J. Sci. Res.*, vol. 6, no. 4, pp. 1396–1402, 2017, [Online]. Available: https://www.ijsr.net/archive/v6i4/ART20172625.pdf

[4] M. Yurdakul and M. B. Yıldız, "A study on seismic isolation of building used LRB," *Chall. J. Struct. Mech.*, vol. 6, no. 2, p. 52, 2020, https://doi.org/10.20528/cjsmec.2020.02.001.

[5] A. Farqaleet, "Dynamic Analysis of Multi-storey RCC Building," 2016.

[6] A. Verma, P. Pal, and Y. K. Gupta, "Non-linear Dynamic Analysis of a Multi-storey Building Subjected to Earthquakes," in *Recent Trends in Civil Engineering*, 2021, pp. 231–242.