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Study on Effect of Different Base Isolation System on Seismic Performance for Multistoried RC Building

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Abstract: An earthquake is the shaking of the surface of earth, which may be able to destroy major buildings, structures. As seen by historical events, Nepal has had a number of devastating earthquakes that have destroyed homes, claimed many lives, and damaged other types of personal property and that have been mostly caused by out dated and inadequately built structures. For protection of these structures from hazardous seismic effects, there is a most widely accepted and modern technique known as base isolation technique. Therefore, in our earthquake-prone nation, base isolation techniques may be advantageous as a safe and cost-effective method for both newly built and retrofitted structures. This study explores the effectiveness of base isolation system for the seismic protection of the buildings. The Lead Rubber Bearing and Friction Pendulum System are mounted beneath the superstructure in base isolation system. In this study, G+5 story regular, plan irregular and geometrically vertical irregular RC Building has been designed and analyzed according to IS: 1893:2002 Code for seismic analysis by (ETABS 20.0) software using response spectrum analysis and time history analysis. Lead rubber bearing and friction pendulum systems were designed as UBC 97 and used for base isolation. The reduction of story drift and story displacement in the building indicates more stability than fixed base constructions because of its isolation. Furthermore, increase in time period indicates that the demand in the building is reduced significantly. Base isolation system can be effectively used for seismic protection of building and enhance the building resilience.

Index Terms— Base Isolation Technique, Lead Rubber Bearing, Friction Pendulum System, Response Spectrum Analysis, Time History Analysis.

1 INTRODUCTION

Nepal is prone to earthquakes because it is located on the Himalayan range, where the Indian and Eurasian tectonic plates intersect. The country has already been subjected to a number of seismic events, some of which have seriously harmed the infrastructure and inhabitants. Structures are extremely vulnerable to earthquakes, which could destroy them. This could result in more expensive design specifications. The best line of action is to isolate the building from the earth via structural isolation measures. To properly use foundation isolation in building design, sufficient analytical, design, and construction expertise is necessary. Base isolation simply lengthens the structural fundamental vibration period to line it with low spectral acceleration, which minimizes building demand during an earthquake Ram & Wang., (2013).

The isolation system also functions as an energy dissipation mechanism, thereby minimizing the transmission of ground acceleration to the superstructure. Instead, then concentrating only on increasing the structure's seismic capability, another approach to seismic isolation is to reduce the seismic demands placed on it. This reduction in seismic demand allows for a controlled structural response during seismic events Zhang et al., (2021).

The introduction of Base Isolation systems in building construction represents a significant advancement in seismic engineering. These systems are designed to decouple the building structure from the potentially damaging effects of earthquake motion, effectively preventing the building's superstructure from absorbing the energy generated by seismic activity.

Base isolation results in a substantial decrease in the horizontal earthquake loads transmitted to the superstructure. Several strategies or combinations of base isolation techniques can be applied to achieve this. These methods include: i) extending the fundamental vibration period of the structure to match low spectral accelerations; and ii) utilizing sliders with specific friction coefficients to lower the maximum force exerted on the superstructure by using sliders with particular friction coefficients Calvi and Calvi., (2018).

2 Literature Review

1. In this paper researcher considered LRB as a base isolator for 4- story, 8- story and 12-story reinforced concrete buildings. Dynamic response of the multistory base isolated and base fixed buildings are investigated under 3- near fault ground motion and 3-far fault ground motion. Story drift, acceleration of each story, base shear and base displacement are examined after the nonlinear time history analysis was carried out. The result after the analysis show that the isolator absorbs the seismic energy well enough such that there is a considerable reduction in the majority of the dynamic response. Also, inter-story drift of each floor considerably decreases in base-isolated models compared with base-fixed ones Desai et al., (2015).
2. Studied on dynamic assessment of base isolation systems for irregular in plan structures: Response spectrum analysis vs nonlinear analysis. In this paper, researchers analyze the dynamic behavior of base isolated multi-storey structures characterized by high irregularity in plan. The results of the research are illustrated in terms of calculations of the deformations and the stresses of the base isolated structure Cancellara et al., (2019).
3. Researchers presented studies on comparison of Lead Rubber Bearings and laminated rubber bearings. Analysis of both laminated and Lead Rubber Bearings and comparison of the hysteresis of both the bearings is presented. The study has concluded that the damping in laminated rubber bearing is very less whereas the damping in Lead Rubber Bearing is much higher than laminated rubber bearings. The study did not considered damage of rubber material hence the damping in laminated rubber bearing resulted less Mathai et al., (2017).
4. Studied on Base Isolation and Damage-Resistant Technologies for Improved Seismic Performance of where Buildings Modern methods of seismic design (since the 1970s) allow structural engineers to design new buildings with the aim of predictable and ductile behavior in severe earthquakes, in order to prevent collapse and loss of life. If not already the case, damage-resistant design will soon become no more expensive than conventional design for new buildings Buchanan et al.,(2011).

3 Statements of Problem

Because Nepal is located in a seismically active region, it is prone to earthquakes. Buildings and infrastructure need to be designed and constructed to withstand both vertical and horizontal ground motion. When there is an increase in structures as a result of global urbanization, the impact of frequent earthquakes cannot be overstated Wang and Ram (2013). Research has been conducted to determine whether base isolation systems for different building types in seismically prone areas can benefit from the use of sliding or flexible bearings, LRBs, and FPS. These techniques have been shown to be effective in lessening the effects of seismic loads Shaaban & Ahmed (2012); Melkumyan (2019); Ferraioli & Mandara (2017). To lessen the transmission of seismic energy into the structure, isolaters are used to create an interface that reroutes the energy back to the earth. Grabbing the aforementioned facts into account, study is necessary to determine whether using base separation techniques in Nepal could increase building resilience.

4 Objectives of Study

The aim of this research is to study effect of different base isolation system for seismic performance in multi storied RC building.

5 Dimensions and Models

The buildings modelled for this study feature G+5 storey buildings with 4x4 bay having 5m and 4m in X and Y direction recpectively, which are mostly constructed and to be constructed in near future in our research area of Surkhet were drafted i.e. Regular shape, mostly found plan irregular shape of L-shape and geometrical irregular in vertical direction.

Parameters	Details
Type of the structure	Multi-story RC building
No of storey	G+5
Typical story height	3m
Shape of building	Regular, plan irregular:L-shaped, vertical irregular
Grade of concrete	M25
Rebar grade	Fe 500
Column size	500x500mm
Beam size	300x500mm
Slab thickness	125mm
Wall Thickness	Ext-230mm, Int-115mm
Importance factor	1
Seismic zone	V
Seismic zone factor (Z)	0.36
Damping ratio	5%

Soil type	Medium Soil
LL, floor	3 kN/m2
LL, roof	1.5 kN/m2
Floor finish	1 kN/m2

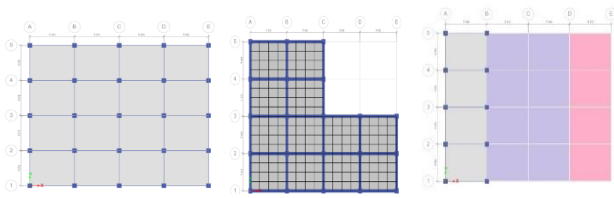

Figure 1: Different Shaped Buildings Plans

Then after analysis of above model having Lead Rubber Bearing & Friction Pendulum System base isolators at different models along with was modeled for analysis for Regular, L-shape and geometrically vertical irregular buildings.

5 DATA PROCESSING PROCEDURES

For Data Processing ETABS software and IS 1896:2016 code is used for Response Spectrum analysis and Time History Analysis is done for different selected models and Isolators can be modelled in analysis software such as SAP2000, ETABS, etc. In this study, LRB and FPS were modelled as spring system with the linear and nonlinear stiffness parameter of isolator.
Data analysis is done by the following steps
Step 1: Preparation of 2-D and 3-D model of building frame, using different irregular plan geometry, and material properties.
Step 2: Assigning of Different load to the model
Step 3: Estimation of design lateral force on building using IS 1896:2016.
Step 4: Analysis of the models with and without base isolation systems by Response Spectrum Method and Non-linear Time History Analysis.

6 RESULTS

For this study, the seismic effect on medium rise regular, plan irregular, and geometrically vertical irregular buildings was rigorously investigated in this research work, with and without base isolation. The formulation and modeling were carried out in ETABS v20. The Response Spectrum and Non-Linear Time History analysis approach were used to model and assess the base isolation building, in which the superstructure was supposed to be linearly elastic and the link or spring system was non-linear.
In this section, the analysis results in terms of fundamental modal time period, storey displacement, and inter-storey drift were discussed. All parameters of a regular and irregular medium-rise RC structure with and without base isolation systems were compared.

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6.1 Seismic Parameters Results of Regular, plan & vertical Irregular Models Due to RSA and THA

6.1.1 Maximum storey Displacement

Figure 2 shows the variation of the story displacement of the given model in three different shape in ground motion due to response spectrum analysis and time history Analysis. The charts show story displacement in plan regular building model is less as compared to other. According to this graph, by RSA and THA method: maximum story displacement is increased by 11%&10% and 17%&15% in case of vertical irregular and L-shaped building model respectively.

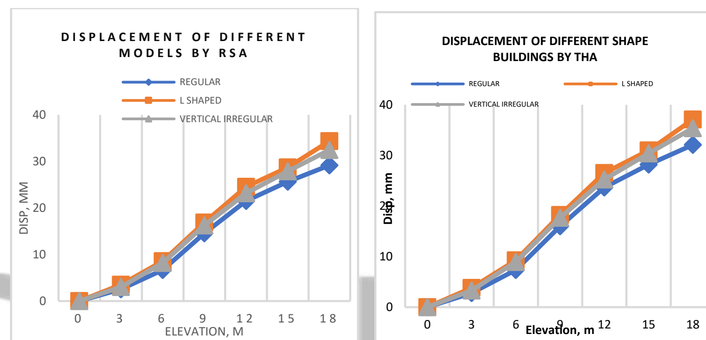

Figure 2: Storey Displacement for different buildings

6.1.2 Maximum Storey Drift

Figure 3 shows the variation of the story drift of the given model in three different shape in ground motion due to response spectrum analysis and time history analysis. The charts show story drift in plan regular building model is less as compared to other. According to this graph, by RSA and THA method: maximum story drift is increased by 5%& 6% and 7% & 8%in case of vertical irregular and L-shaped building model respectively.

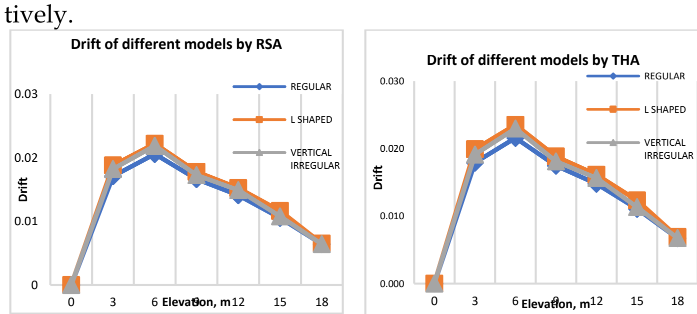

Figure 3: Storey Drift for different buildings

6.1.3 Maximum Modal Time Period

Figure 4 shows the variation of the modal time period of the given model in three different shape in ground motion due to response spectrum analysis and time history analysis. The charts show modal time period in plan regular building model is highest as compared to other. According to this graph, by RSA and THA method: maximum modal time period is decreased by 16%&17% and 20%&21% in case of vertical irregular and L-

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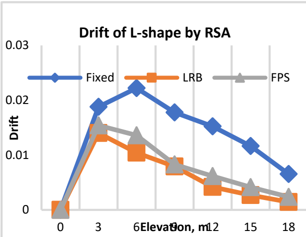
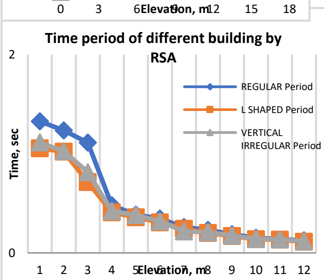
shaped building model respectively.





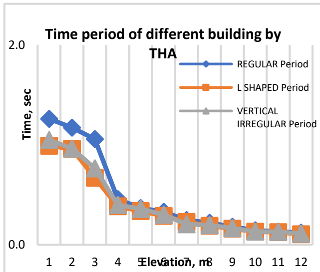
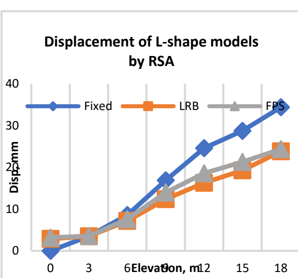


Figure 4: Modal Time Period for different buildings

6.2 Seismic Parameter Results of L-shaped Models with LRB and FPS base isolators due to RSA and THA

6.2.1 Maximum storey Displacement

Figure 5 shows the variation of the story displacement of the given L-shape building with different configuration of base isolators in ground motion due to response spectrum analysis and time history analysis. The charts show story displacement in fixed base L-shaped building model is highest as compared to other. According to this graph, by RSA and THA method: maximum story displacement is decreased by 35%&37% and 29%&30% in case of LRB base isolated and FPS base isolated-shaped building model respectively.



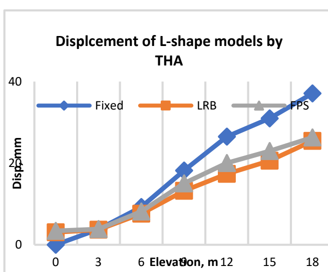


Figure 5: Storey Displacement for L-shaped buildings

6.2.2 Maximum Storey Drift

Figure 6 shows the variation of the story drift of the given L-shape building with different configuration of base isolators in ground motion due to RSA and THA. The charts show story drift in fixed base L-shaped building model is highest as compared to other. According to this graph, by RSA and THA method: maximum story drift is decreased by 45%&44% and 38%&37% in case of LRB base isolated and FPS base isolated L-shaped building model respectively.

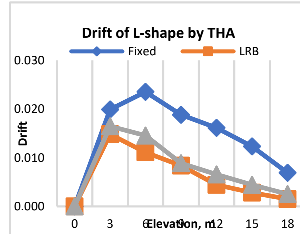
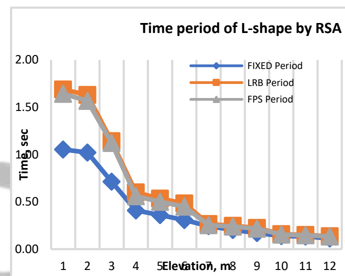


Figure 6: Storey Drift for L-shaped building

6.2.3 Modal Time Period

Figure 7 shows the variation of the modal time period of the given L-shaped building with different configuration of base isolators in ground motion due to RSA and THA. The charts show modal time period in fixed base L-shaped building model is lowest as compared to other. According to this graph, by RSA and THA method: maximum modal time period is increased by 60%&59% and 56%&57%in case of LRB base isolated and FPS base isolated L-shaped building model respectively.



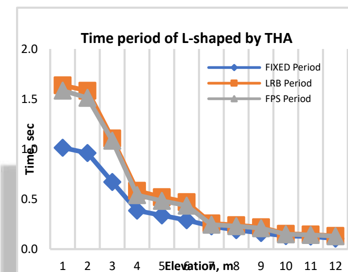
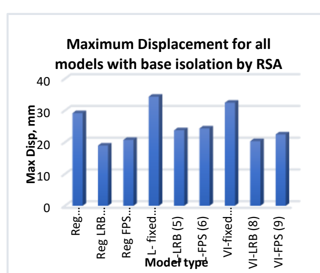


Figure 7: Modal Time Period for L-shaped building

6.3 Seismic Parameters Results of all models Due to RSA and THA

6.3.1 Maximum storey Displacement

Figure 8 shows the variation of the maximum story displacement of the given all nine models in due to response spectrum analysis and time history analysis. The charts show decrement in maximum story displacement in vertical irregular LRB base isolated building model is high as compared to all other models.



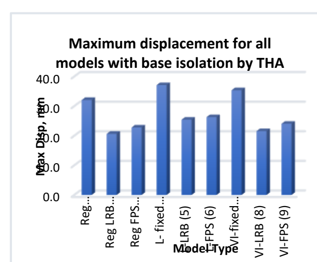


Figure 8: Storey Displacement for all nine models

6.3.2 Maximum Storey Drift

Figure 9 shows the variation of the maximum story drift of the given all nine models in due to RSA and THA. The charts show decrement in maxm story drift in vertical irregular LRB base isolated building model is high as compared to all other models.

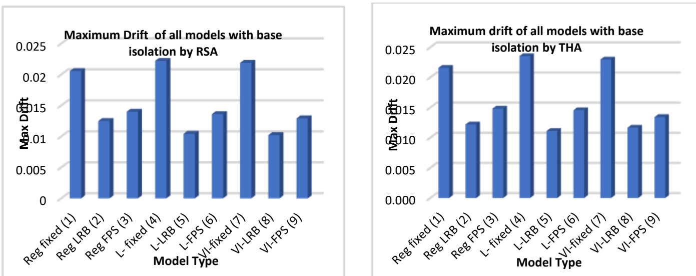


Figure 9: Storey Drift for all nine models

6.3.3 Maximum Modal Time Period

Figure 10 shows the variation of the maximum modal time of the given all nine models in due to response spectrum analysis. The charts show increment in maximum modal time in vertical irregular LRB base isolated building model is high as compared to all other models.

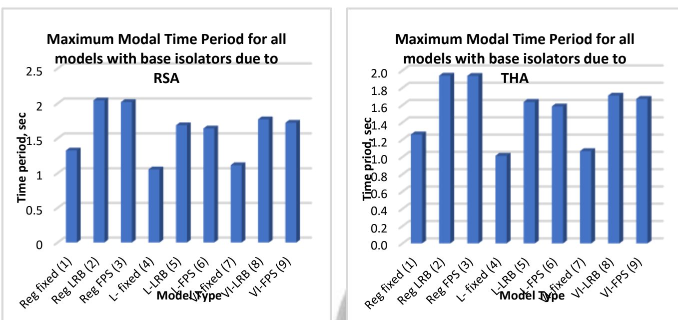


Figure 10: Modal Time Period for all nine models

7 CONCLUSION

Significant insights into the seismic performance of multistoried RC buildings with different base isolators (LRB and FPS) have been obtained through analytical models, employing Response Spectrum and time history analyses. Conclusions drawn from the analysis of G+5 storey buildings with regular, L-shape, and geometrically irregular structures using IS 1896:2016 can be summarized as follows:

1. Regular-shaped buildings exhibit superior seismic performance compared to L-shape and geometrically irregular structures across various parameters. The regular model shows the highest modal time period and the lowest maximum displacement and story drift in both directions.

2. Applying different base isolators to regular and irregular models reveals that irregular shapes demonstrate better efficiency in seismic parameters. Irregular models exhibit a more substantial increase in modal time period and a greater decrease in maximum displacement and story drift when LRB and FPS isolators are used compared to regular models.

3. Comparing the efficiency of LRB and FPS base isolators on different building models, LRB base isolation proves significantly more effective. LRB base-isolated models consistently show better results in modal time period, maximum displacement, and story drift compared to FPS base isolators. This suggests that LRB base isolation is more efficient in enhancing seismic protection and building resilience.

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