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Performance of RC Building with Base Isolation Systems

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ABSTRACT

Copious attempts are made on structures that can withstand seismic hazards but haven't generated adequate conclusions. These seismic hazards are principal matter of concern in Earthquake prone zones all over the world. Over the period of time detailed research on dynamic analysis and design of structure by means of varying the earthquake intensity is carried out on fixed based structures. However it can also be performed on isolated structures with nonaligned isolator elements. This paper aims at developing a methodology and strategy for reducing lateral load imposing on structure thereby reducing the effect of seismic forces. Base isolation has turned out to be a trending design over past few years; here we take a detailed glance at the different types of isolators and their effect on structure. Seismic base isolation can reduce the seismic effects and floor accelerations, joint displacements, inter story drifts, and base shear by lengthening the natural period of vibration of a structure by use of rubber isolation pads between columns and foundation. However, in case the deformation capacity of the isolators exceeded, isolators may rupture or buckle. An exhaustive study has been performed on the performance of base isolated structures on G+3 and G+9 building using SAP 2000. The behavior of building structure resting on friction isolator and rubber bearing is compared with fixed base structure under maximum capable earthquake. Finally, Parameter such as storey displacement, storey drift, storey shear and base shear are compared and obtained results were presented in both graphically and tabular format.

Keywords: Base Isolation, Friction Isolator, Non-linear Time History Analysis, Rubber Bearing, SAP 2000.

1. INTRODUCTION

The earthquake resistant structures can be categorized into rigid and flexible structures. In rigid structures, the control methods that are applied to withstand extreme loads are basically reducing the interstorey displacement with the help of diagonal bracing, the installation of shear walls and the use of composite materials. In flexible structures, such as base isolated buildings, the main control approach is to decrease the excitation input with the use of isolators and dampers isolators. The control strategies of rigid structures were preferred to be earthquake hazard mitigations alternatives due to long lasting established knowledge and the maturity of technologies pertinent to structural stiffening. However, significant interstorey drift and floor accelerations of highly stiffening structures raise risk of severe devastation of the building, especially under large scale of earthquake. Flexible structures such as high rise buildings can avoid resonant conditions and effectively reduce structural responses. When structures are built according to the code specifications, they are expected to be damaged during strong earthquake but to remain standing. This approach to seismic design is not suitable for critical structures such as hospitals, fire stations and telecommunication centers. The effective reduction of interstorey drift in the floor of base isolation system can ensure the lowest damage to facilities and also human safety. To achieve the performance of base isolation system, various passive devices, including dampers and isolators, can be incorporated into buildings. Isolation systems provide the lateral stability and damping necessary for proficient isolation and develops the proper stiffness that is required for service load. In the category of structural control, base isolation system is classified as passive control. Isolators are the major devices that are implemented in the structural system for the purpose of isolation. Base isolation is an anti seismic design strategy that can reduce the effect of earthquake ground motion by

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disconnecting the superstructure from the foundation. The structure can be decoupled by providing structural element with low stiffness between superstructure and foundation from horizontal components of the ground motions. The concept of isolating the superstructure from the substructure has always been an elegant idea in theory, but only recently has it become a viable solution. The goal is to have a flexible material in the horizontal plane that is capable of preventing energy flow into superstructure. This flexibility increases the superstructures period, which in turn, reduces the induced acceleration.

2. MATHEMATICAL MODEL AND ANALYTICAL PARAMETER

2.1 MODELING AND PROBLEM STATEMENT FOR G+3 BUILDING

In present study, G+3 and G+9 building is considered with different base systems and modelling is done using SAP2000.

Building details are as follows:

1. Grade of concrete used is M 20 and grade of steel used is Fe 415.
2. Floor to floor height is 3.1 m
3. Plinth height above GL is 0.55 m.
4. Depth of Foundation is 0.65 m below GL
5. Parapet height is 1.5 m.
6. Slab Thickness is 150 mm.
7. External wall thickness is 230 mm and internal wall thickness is 150 mm.
8. Size of columns is 300mm X 450 mm and size of beams 300mm X 450 mm.
9. Live load on floor is 3kN/m2 and Live load on roof is 1.5kN/m2.
10. Floor finishes is 1 kN/m2 and roof treatment is 1.5 kN/m2
11. Site located in Seismic Zone IV.
12. Building is resting on medium soil.
13. Take Importance Factor as 1.
14. Building frame type is Special Moment Resting Frame (SMRF).
15. Density of concrete is 25 kN/m3and Density of masonry wall is 20 kN/m3

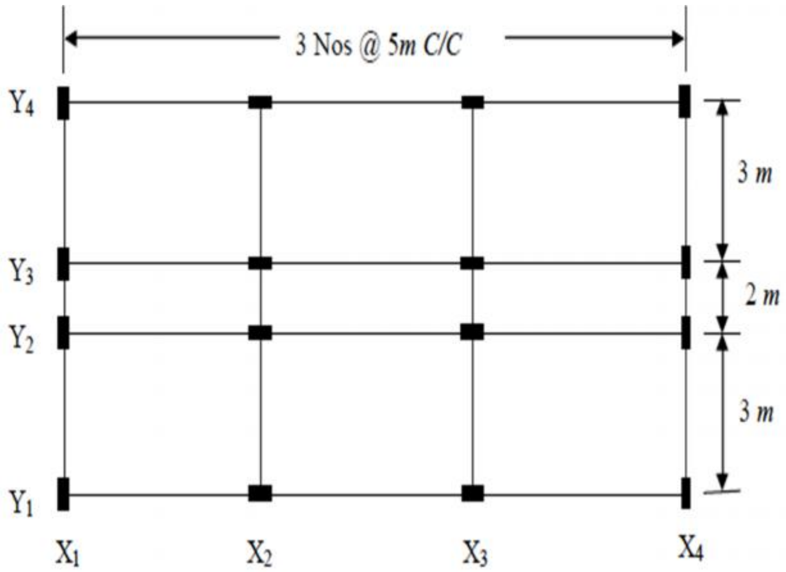

Fig 1: Plan of Residential Building with Fixed Base

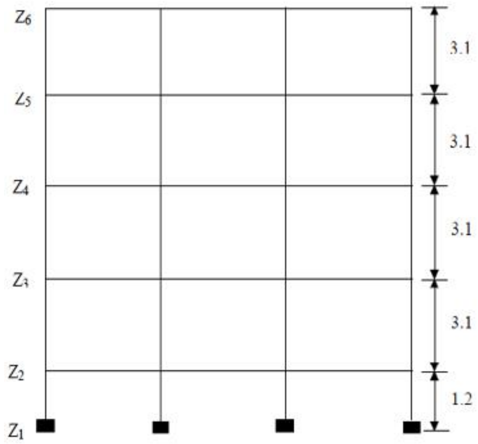

Fig 2: Elevation of Building with Fixed Base

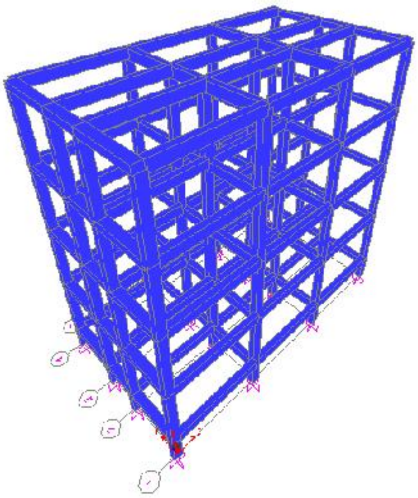

Fig 3: 3D view of fixed base building (G+3) in SAP 2000

2.2. MODELING AND PROBLEM STATEMENT FOR G+9 BUILDING

Building details are as follows

1. Grade of concrete used is M 20 and grade of steel used is Fe 415.
2. Floor to floor height is 3 m
3. Plinth height above GL is 0.55 m.
4. Depth of Foundation is 0.65 m below GL
5. Parapet height is 1.5 m.
6. Slab Thickness is 120 mm.
7. External wall thickness is 230 mm and internal wall thickness is 150 mm.
8. Size of columns is 450mm X 500 mm and size of beams 450mm X 500 mm.
9. Live load on floor is 3kN/m^2 and Live load on roof is 1.5kN/m^2.
10. Floor finishes is 1 kN/m^2 and roof treatment is 1.5 kN/m^2
11. Site located in Seismic Zone IV.
12. Building is resting on medium soil.

13. Take Importance Factor as 1.
14. Building frame type is Special Moment Resting Frame (SMRF).
15. Density of concrete is 25 kN/$m^3$and Density of masonry wall is 20 kN/m^3

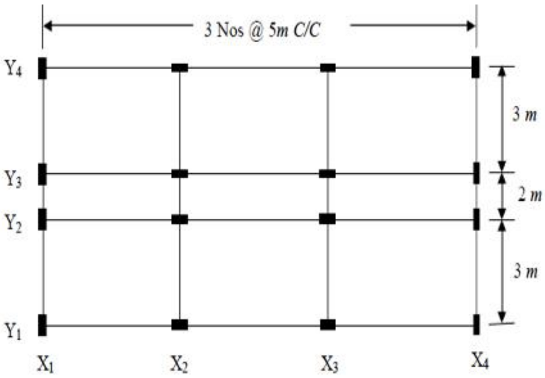

Fig 4: Plan of building

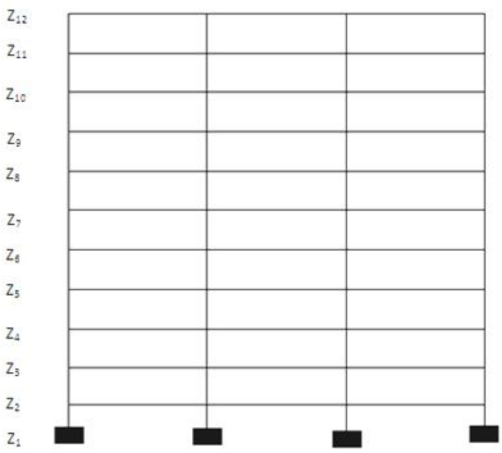

Fig 5 : Elevation of building

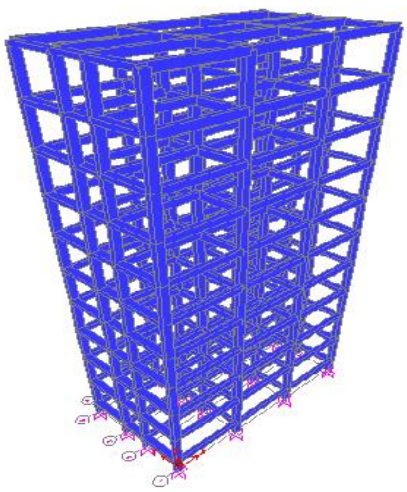

Fig 6: 3D view of fixed base building (G+9) in SAP 2000

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3. MODELING AND ANALYSIS OF MULTI-STOREY RESIDENTIAL BUILDING:

To estimate the seismic response of the building response spectrum method is performed using the computer program SAP2000. The seismic analyses of the buildings are carried out separately in the transverse and the horizontal directions. However, seismic responses only for x-direction are comparatively presented with graphs for the sake of brevity. Degrees of freedom at the base nodes are fixed for base isolation and fixed base, the seismic isolators in the system are defined as Nl-link components 0.5m in length placed between the fixed base and the columns as shown in Figure 9 & 10. The parameters selected to define the utilized rubber isolators in the SAP2000 program are as follows: nonlinear link type: Rubber Bearing, U1 linear stiffness: 1500000 kN/m, U2 and U3 linear stiffness: 800 kN/m, U3 and U2 nonlinear stiffness: 2500 kN/m, U2 and U3 yield strength: 80 kN, U2 and U3 post yield stiffness ratio: 0.1, other nodes are left free. In addition to rubber bearing the building is analyzed with friction pendulum isolator in the system are defined as Nl-link components 0.5m in length placed between the fixed base and the columns. The constraints selected to define the isolators in the program are as follows: Nonlinear link type-friction isolator, U1 linear stiffness 15000000kN/m, U3 and U2 linear stiffness: 750kN/m, U3 and U2 nonlinear stiffness: 15000kN/m, U3 and U2 friction coefficient, slow: 0.03, fast: 0.05, U3 and U2 rate parameter: 40, U3 and U2 radius of sliding surface: 2.23. Slab has been considered as a rigid diaphragm in every story level. The masses of infill walls are also taken into account in the model. In the analysis, Young's modulus and unit weight of concrete are taken to be 28000MPa and 25kN/m3, respectively. The damping ratio is assumed as 5% in all modes. The peak ground acceleration is taken to be 0.4g that is recommended in (IS 1893:2002 Part I/3.11/pg.no.8). Thus, it is assumed that the buildings are sited in high seismicity zone. Seismic analysis of the buildings accounting for the influence of the local ground conditions is carried out with the help of the design spectra for IS 1893:2002 (part I)

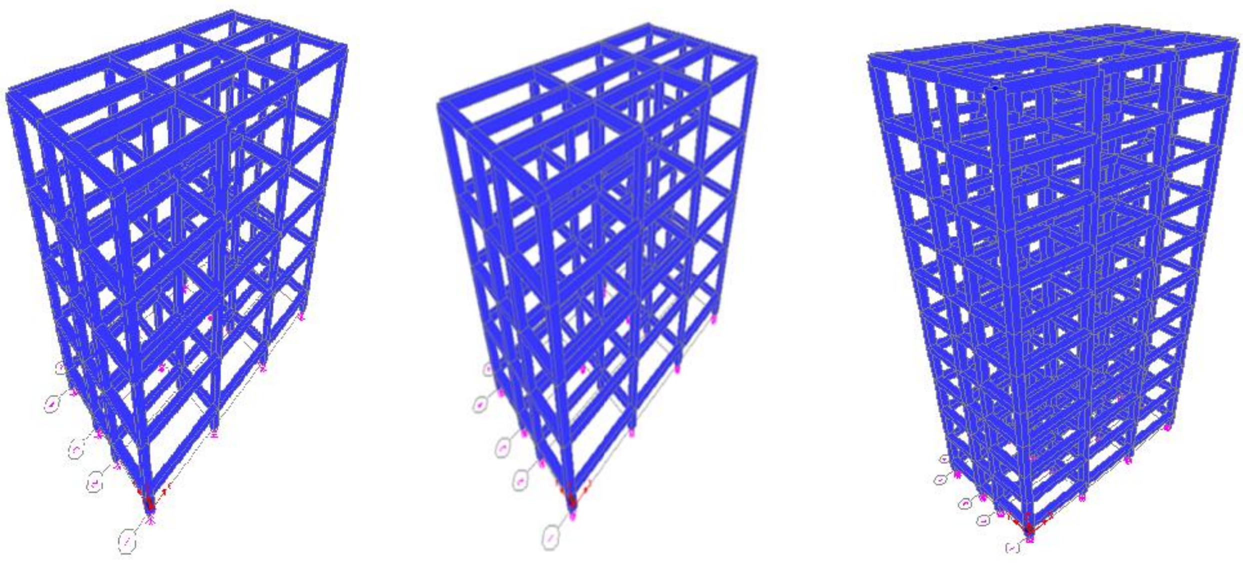


Fig 7: 3D view of rubber bearing building (G+3) in SAP, Fig 8: 3D view of friction isolator building (G+3) in SAP, Fig 9: 3D view of rubber bearing building (G+9) in SAP

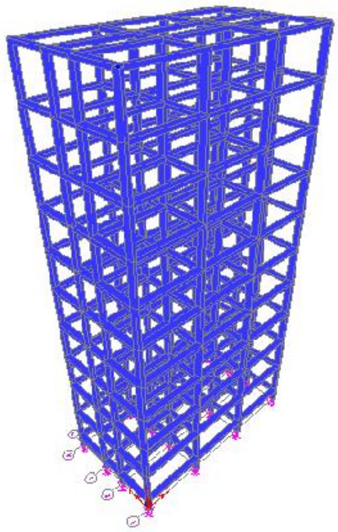
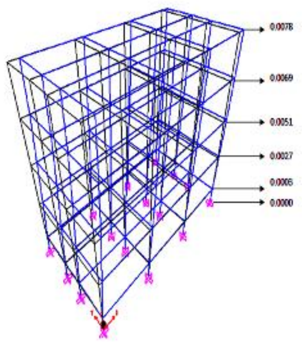


Fig 10: 3D view of friction isolator building (G+9) in SAP

4. ANALYSIS OF G+3 BUILDING



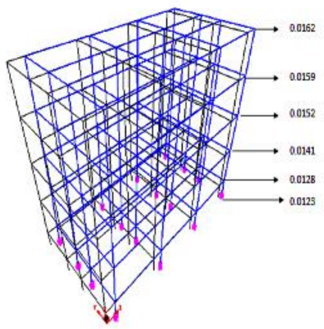


Fig 11: Deflected shape of G+3 building with fixed base, Fig 12: Deflected shape of G+3 building with rubber bearing

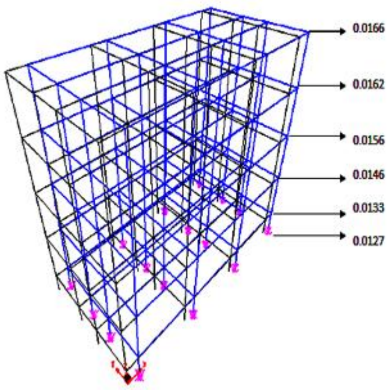


Fig 13: Deflected shape of G+3 building with friction isolator

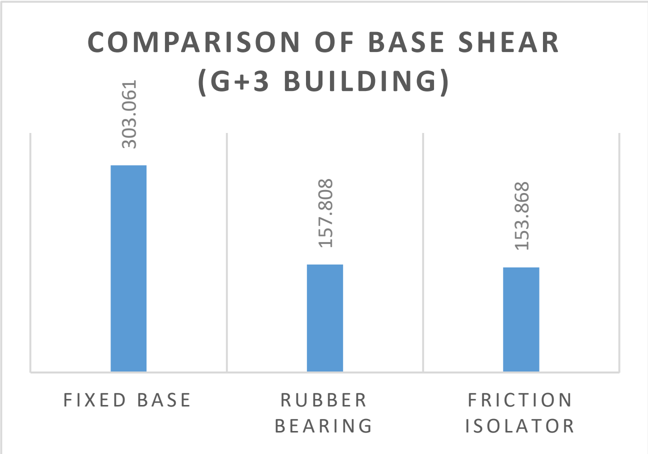


Fig 14: Comparison of Base Shear for Fixed Base, Rubber Bearing and Friction Isolator

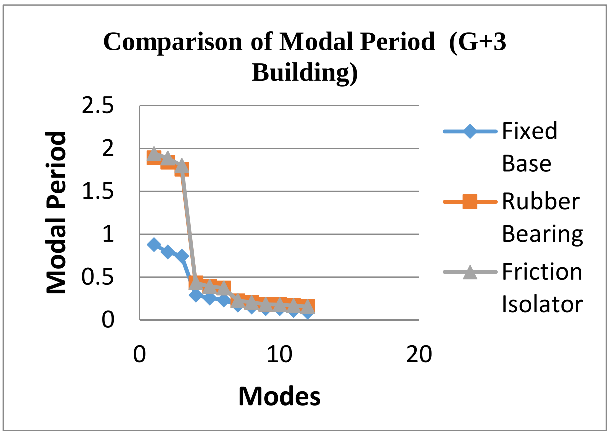


Fig 15: Comparison of Modal Period for Fixed Base, Rubber Bearing and Friction Isolator

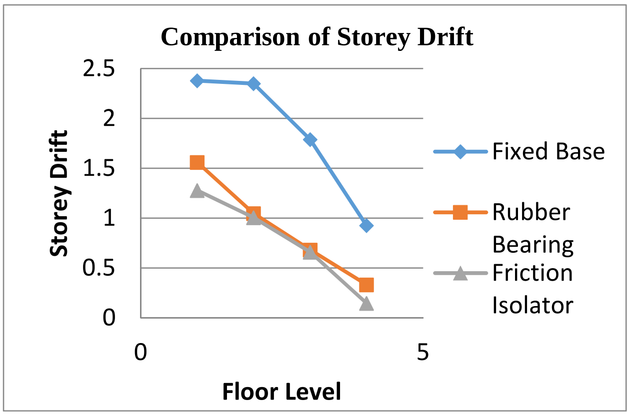


Fig 16: Comparison of Storey Drift for Fixed Base, Rubber Bearing and Friction Isolator

As per IS 1893:2002 (Part I) , the permissible limit of the storey drift is 0.04h= 0.544m and in the present study the maximum storey drift is found to be 0.00238m which is less than the permissible limit , therefore it is found to be ok.

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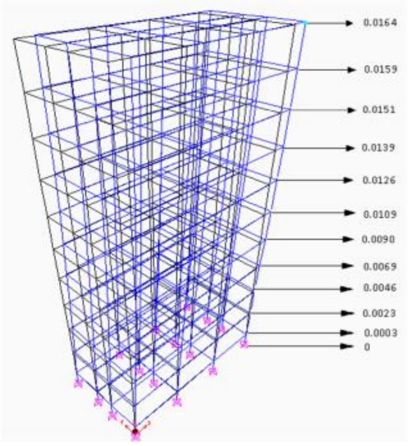
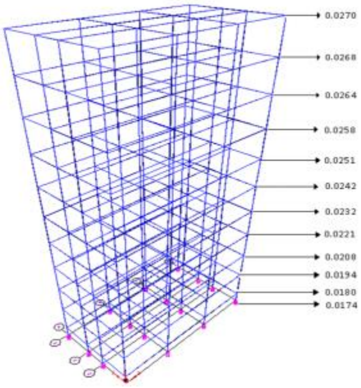
5. ANALYSIS OF G+9 BUILDING





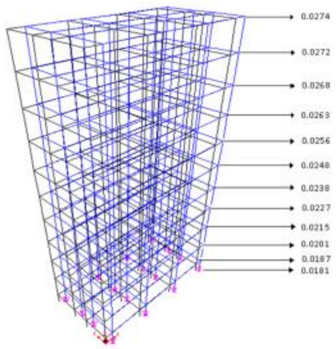


Fig 17: Deflected shape of G+9 building with fixed base, Fig 18: Deflected shape of G+9 building with rubber bearing, Fig 19: Deflected shape of G+9 building with friction isolator

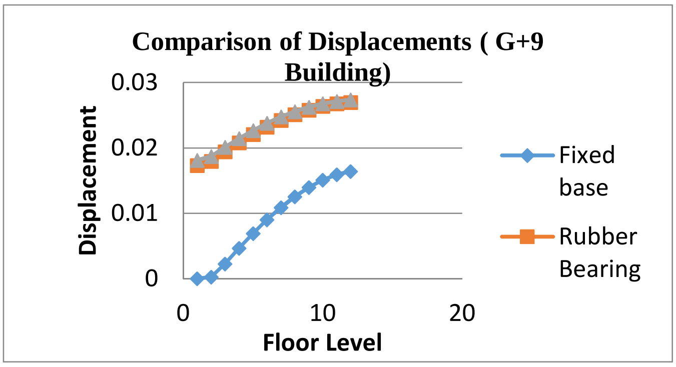


Fig 20: Comparison of Displacements for Fixed Base, Rubber Bearing and Friction Isolator

In case of fixed base building, displacement is zero at the base and increases with the increase in storey height. But in case of base isolated building, there is a small displacement at the base and increases at a moderately slower rate as storey height increases. The reduction in displacement is 4.32% at the base for base isolated building when compared with fixed base building.

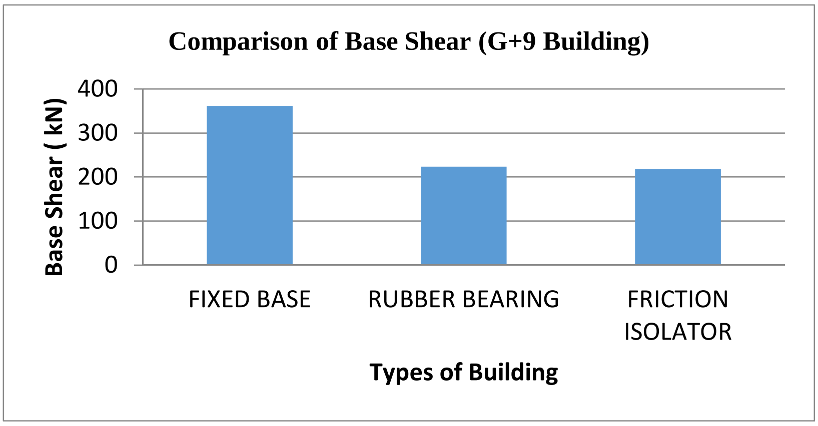


Fig 21: Comparison of Base shear for fixed base, rubber bearing and friction isolator

Base shear is reduced by 61.8% for LRB and 65.39% for FI as compared to fixed base.

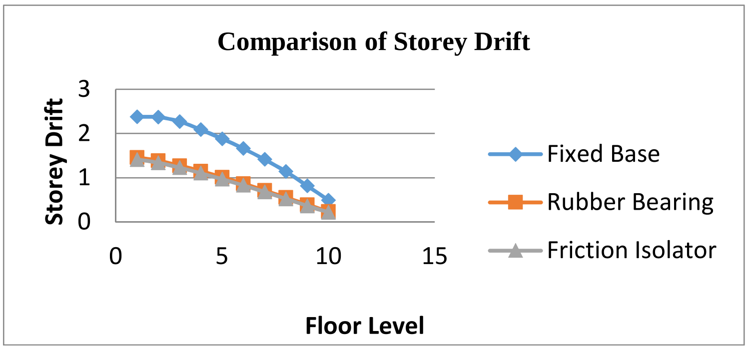


Fig 22: Comparison of storey drifts for fixed base, rubber bearing and friction bearing

In case of fixed base building, storey drift is greater at the lower floors and it decreases extremely as we move to the upper floors. In case of base isolated buildings, storey drift is reasonably lower than fixed base buildings at the lower floors and decreases as we move to the upper floors.

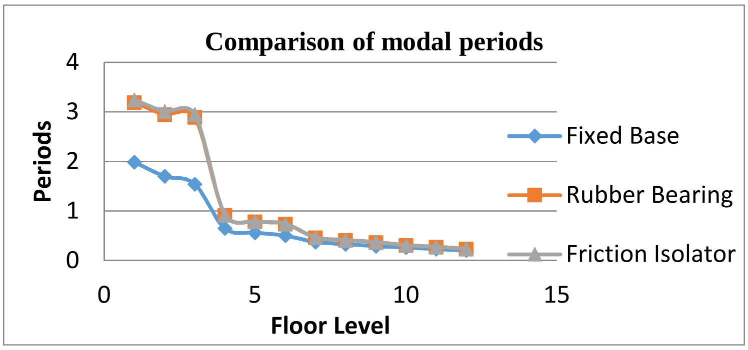


Fig 23: Comparison of Modal Period of Building for Fixed Base, Rubber Bearing, Friction Isolator

The modal period of the fixed base is less than the FI and LRB and it is decreases as the number of modes increases. In case of rubber bearing the modal period is increased by 37.87% and for friction isolator it is increased by 38.78% as compared to fixed base.

CONCLUSION

An exhaustive study has been performed on the performance of structures for G+3 and G+9 building with fixed base and base isolated structure . The behavior of building structure resting on friction isolator and rubber bearing is compared with fixed base structure under maximum capable earthquake. Seismic base isolation can reduce the seismic effects and therefore floor accelerations, joint displacements, interstory drifts, and base shear by lengthening the natural period of vibration of a structure via use of rubber isolation pads between the columns and the foundation. However, if the deformation capacity of the isolators exceeds isolators may rupture or buckle. Therefore, it is extremely important to accurately estimate the peak base displacements in case of foremost earthquakes. Based on the simulations carried out for G+9 building, it is concluded that seismic base isolation is a successful technique that can be used in earthquake resistant design. To check the effectiveness of the isolation system, performance criteria have been carried out for fixed base isolated structure. According to analysis study, following conclusions are as follows:

1. Response spectrum analysis was performed for the G+9 building with base isolation system by Sap2000. It has been found that the base shear is reduced by 61.8% for rubber bearing and 65.39% for friction isolator as compared to fixed base structure.

2. Buildings modeled with fixed base for different storeys have zero displacement at the base but structure with base isolation shows considerable amount of lateral displacement at the base of structure. Also it has been observed that as floor height increases, lateral displacements increases significantly in case of fixed base building. But for base isolated buildings the lateral displacement variation is minor as the height increases.

3. At base of the structure, higher storey drift is observed for base isolated model when compared to fixed base building. As storey height increases, the storey drift in base isolated building decreases drastically as compared to fixed base building.

4. The natural period of the structure being 1.984sec in the fixed base structure is increased to 3.194sec for rubber bearing and 3.24sec for friction isolator.

5. For fixed base structural model, storey accelerations vary substantially from bottom to top storey. But for structure with base isolation the storey accelerations are almost the same from bottom storey to top storey. Almost 66.40% of storey accelerations can be reduced by using base isolation.

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