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Response of RC Framed Building With Different Isolator Systems

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Abstract

Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. It is a collection of structural elements which should substantially decouple a superstructure from its substructure resting on a shaking ground thus protecting a building or non-building structure's integrity.This research evaluates the applicability of base isolation system for reinforced concrete structure using Lead Plug Bearing (LPB), Friction Pendulum Bearing and High Damping Rubber Bearing. The linear model Time History Analysis of a real RC framed building was performed by using ETABS software for fixed base and isolated base system. Analysis illustrated that the building responses like base shear, roof acceleration and relative displacement between base and roof of the structure decreased while the fundamental time period of the structure increased.

Keywords

RC buildings, Base Isolation, Lead Blug Bearing, Friction Pendulum Bearing, High Damping Rubber Bearing, Time History Analysis

1. Introduction

Base isolation is one of the most popular means of protecting a structure against seismic forces. It is meant to enable a building to survive a potentially devastating seismic impact. It can, in some cases, raise both a structure's seismic performance and its seismic sustainability considerably. Base isolation system involves the addition of a flexible layer (isolator) in between the structure and its foundation with permission for relative deformation at this level. The flexibility of the isolator layer results in the modification of the time period of the superstructure (increase in time period), which results in significant reduction in acceleration and forces transmitted to the structure.

The lead plug bearing (LPB) was first introduced and used in New Zealand in the late 1970s. LPB system provides the combined features of vertical load support, horizontal flexibility, restoring force and damping in a single unit. To provide an additional means of energy dissipation, a central lead core is added which deforms plastically under shear deformation, enhancing the energy dissipation capabilities compared to low damping natural rubber bearings.

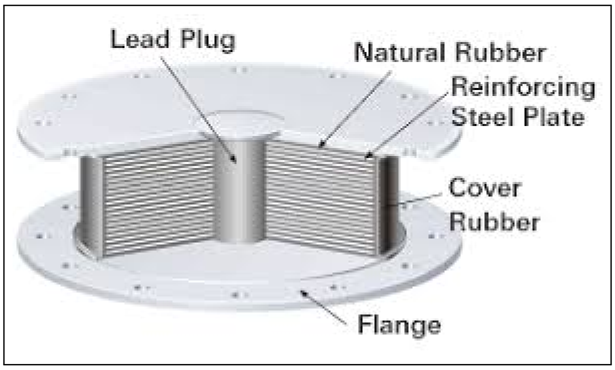

Figure 1: Lead Plug Bearing

Friction Pendulum Bearings (FPB) essentially detach the structures from the ground to help stabilize the building from unstable ground motion. FPBs allow superstructures to rest at the top of two concave surfaces with a ball bearing as a buffer between the two surfaces. During an earthquake, the bearings shift against the direction of earthquake keeping the building stable as a result.

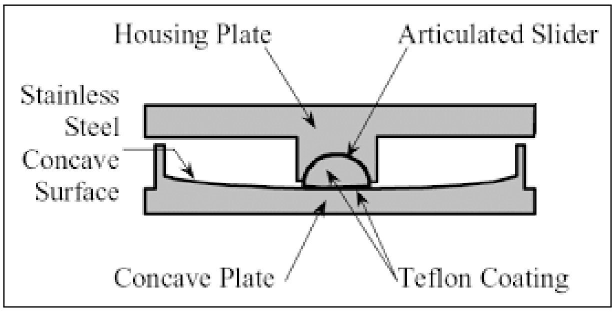

Figure 2: Friction Bearing

A high-damping rubber bearing, also known as HDR, has very similar appearance to lead rubber bearings, but they are totally different in nature. HDR bearing is composed of special rubber with excellent damping attributes, sandwiched together with layers of steel without any lead plugs. HDR bearings are very stiff in nature, however, during earthquake, it becomes very flexible in the horizontal direction so that they can reduce the earthquake force upon the structures by changing its own shape. Most of all, it can spring back to its original shape post-earthquake owing to its high elastomeric property.

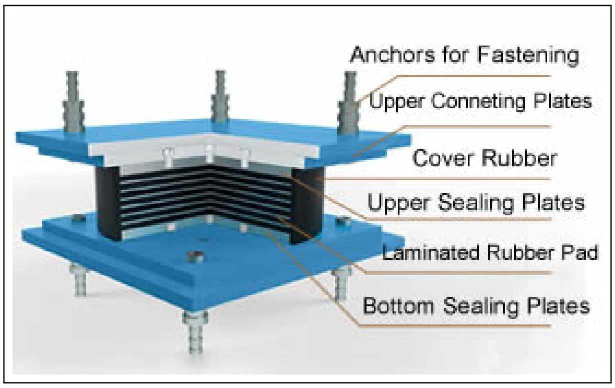

Figure 3: High Damping Rubber Bearing

2. Methodology

In this research, a real hospital building (Five Storied, RC Frame with Basement wall) has been selected and comparative study of time history analysis was carried out for fixed base and isolated building. The 3-D modeling of the building was carried out in ETABS 2016 (version 16.2.1) software considering medium soil condition. The effect of ground motion for both the cases was carried out statically as well as dynamically. Static coefficient method was carried out as per IS 1893:2002. The combination of dead loads and live loads as base force thus obtained was used in the design of the isolators. The type of isolators considered in this research were Lead Plug Bearing, Friction Pendulum Bearing and High Damping Rubber Bearing. The dynamic response of the building was evaluated with the help of linear modal time history analysis which was achieved by matching the time history with the response spectrum from IS 1893:2002 for 5

The target period for isolator was taken such that it is considerably greater than the fundamental time period of the building with fixed base. Linear modal time history analysis was performed in the time domain using Newmark's method for numerical integration to achieve responses in the building under different excitation of earthquake data.

Two different history earthquake data; Imperial Valley-01 (El centro, 1940) and Gorkha Earthquake (2015) were collected to perform the analysis. After time history analysis was performed for both cases, comparative study of responses of both structures was done in different parameters such as story displacement, maximum roof displacement, base shear and story drift.

Methodology Steps:

To accomplish the objectives of the research work, following procedure was adopted:

i. Preliminary Study

- Comprehensive study of previous work and literature review
- Selection of Building
- Collection of required data

ii. Analysis Stage

- Preparation of 3D models of building in ETABS with fixed base and isolation
- Perform linear static analysis and time history analysis

iii. Evaluation Stage

- Identification of Base Shear, Story Drift and story displacement after linear and time history analysis.
- Comparison and evaluation of the result.

2.1 Modelling of Building in ETABS 16.2.1

The 3D model of the RC Framed building was built for both cases i.e., fixed base and isolated system in ETABS software.

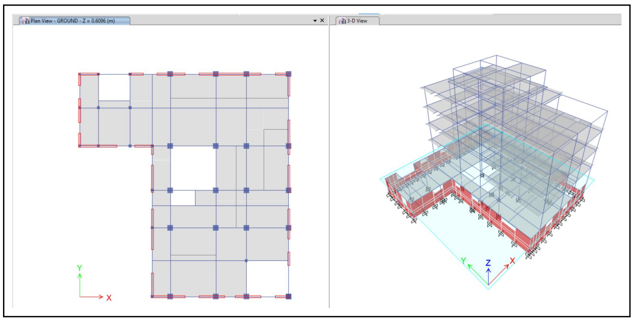

Figure 4: Plan and 3d

2.2 Design of Lead Plug Bearing and assigning to the model

Dutta (2010) presented the design of LPB to find out the design parameters and the size of the isolator based on vertical load, fundamental time period and design displacement.[1]

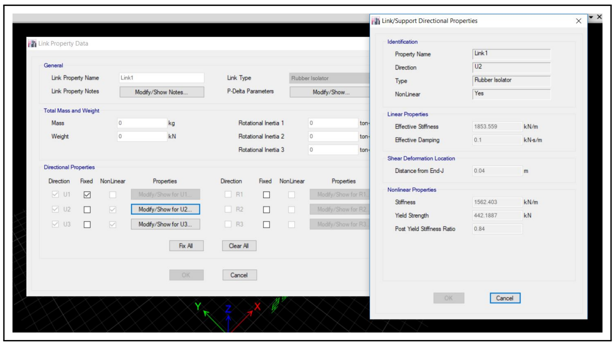

Figure 5: Lead Plug Bearing Properties Assigned to the Building

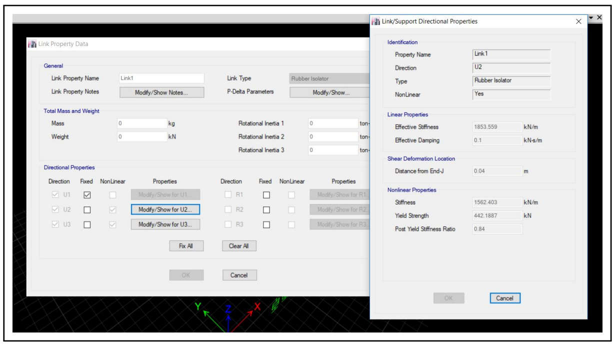

Figure 6: Lead Plug Bearing Properties Assigned to the Building

2.3 Design of Friction Pendulum Bearing and assigning to the model

S. Manohar and S. Madhekar (2000) presented the method of friction pendulum bearing to find out the design parameters and the size of the isolator based on vertical load, fundamental time period and radius of curvature.

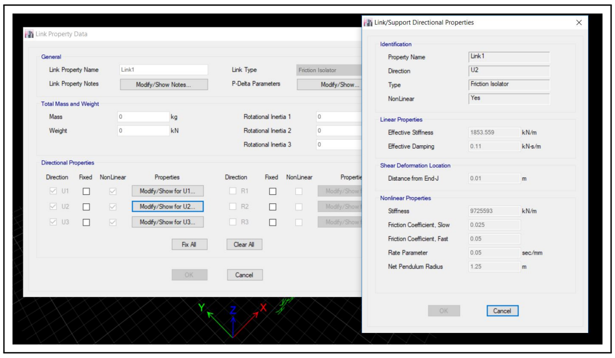

Figure 7: Friction Pendulum Bearing Properties Assigned to the Building

2.4 Spectral Matching Methods

Various methods have been developed to modify a reference time series so that its response spectrum is compatible with a specified target spectrum. Two of the most widely used methods, namely frequency domain method and Time domain method, are available in ETABS 2016

Time domain method was chosen for spectral matching, target response spectrum was set to Indian Standard and reference acceleration time history was chosen as per required time history functions. The uniform unit was set for both functions and the time history was matched. Typical matching method is shown in figure below:

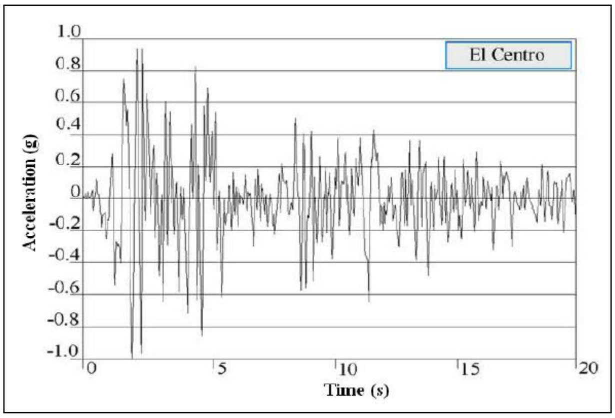

Figure 8: Time History of El-Centro (1940)

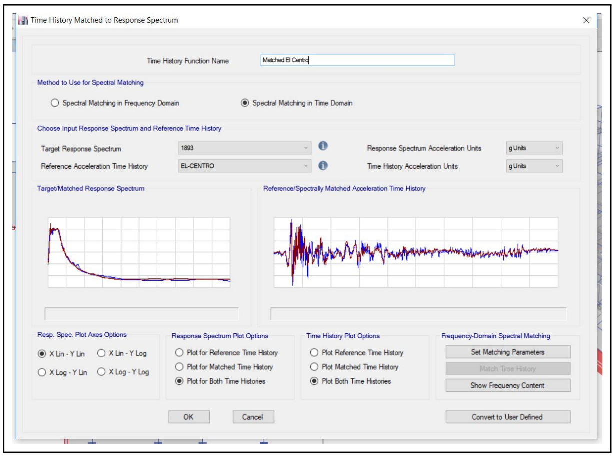

Figure 9: Time History Matched to Response Spectrum

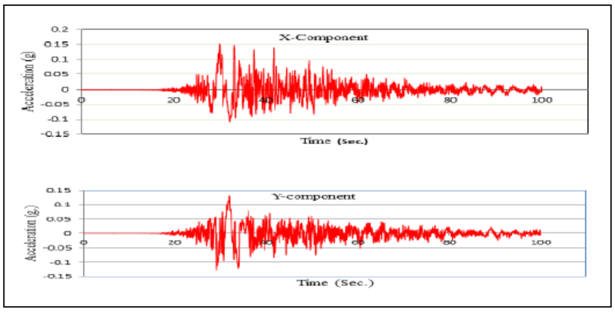

Figure 10: Time History of Gorkha (2015)

3. Results And Discussions

In the present study, Time History Analysis of an RC Framed Building was carried out for two different earthquake motions. The results of time history analysis were interpreted to investigate the effectiveness of different bearing types to minimize the base shear, story drift and displacement.

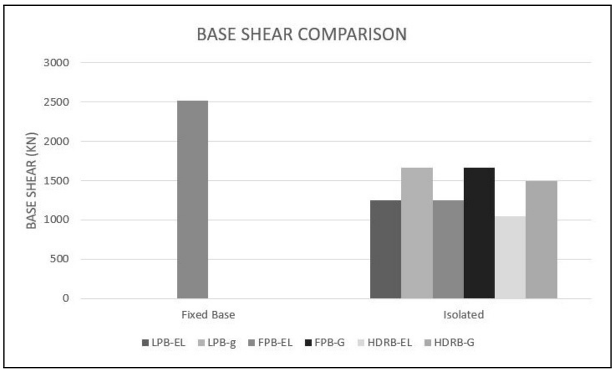

Figure 11: Comparision of Base Shear

The comparison chart shows that base isolation results in decrement of the base shear of the building. Furthermore, the results obtained from LPB and FPB systems are fairly similar while HDRB system shows the most decrease in base shear of the building attributed to the higher damping value of the HDRB bearing. The reduction in base shear under El Centro and Gorkha Earthquakes were found to be vastly difference. One major reason for this discrepancy could be the difference in frequency content of the different earthquake time histories.

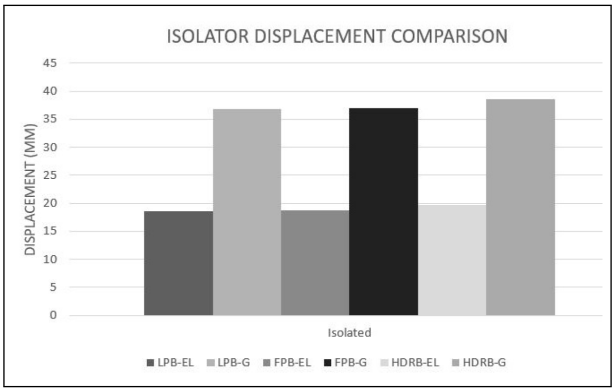

Figure 12: Comparision of Isolator Displacement

Isolator displacement refers to the maximum displacement of the isolator from its original position after the application of lateral forces (seismic forces). The above charts show the comparative isolator displacements for the two different buildings. From the results obtained, it can be reasonably inferred, that for taller buildings, the isolator displacement for gorkha earthquake is much larger and hence base isolation may be difficult with regards to displacement control of the building.

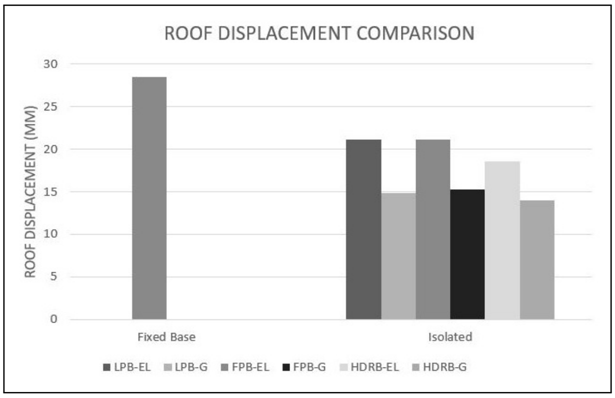

Figure 13: Comparision of Relative Roof Displacement

The table shows the reduction in the relative roof displacement of the structure. While the base displacement of the building is increased due to the displacement of isolators, the roof displacements themselves in comparison were found to have been reduced significantly.

The results show that high damping rubber bearings are more effective in reducing the roof displacement of the structure while FPB and LPB yield almost identical results.

4. Summary and Conclusion

The analysis of an RC framed building with fixed base and three different base isolation has been carried out. The effectiveness of LPB, FPB and HDRB in the buildings using different earthquake excitation under has been discussed. The following conclusions can be drawn from the analysis:

1. The base shear, roof acceleration and relative roof displacement of the structure reduce significantly while the time period increases with the introduction of a base isolation system as compared to fixed base. The response of the structure to FPB and LPB bearings were found to be largely similar while HDR bearings yielded slightly different results (more reduction in base shear)

2. The results show that the response of building to various earthquake excitation can vary significantly.

From the analysis above, it can be reasonably concluded that the isolation system performs well in the sense of reducing structural responses as compared to the fixed base system. The roof accelerations, base shear as well as relative roof displacement were all effectively reduced by adoption of isolator systems with High Damping Rubber Bearings being the most effective.

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