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Protection of the Buildings from the Earthquake Risk Using High Damping Rubber Bearing

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Abstract—*In past few years, passive control mechanisms including base isolation systems are gaining large attention as mean to protect structures against seismic hazard. The effectiveness of an isolation system depends upon the dynamic characteristics of earthquake ground motion and the building superstructure. The base isolation system separates the structure from its foundation and primarily moves the natural frequency of the structure away from the dominant frequency range of the excitation via its low stiffness relative to that upper structure. In order to verify the effect of base isolation system, the structure is presented as symmetrical building in which the seismic responses of the 'fixed-base' and 'base-isolated' conditions have been compared using a well-known computer program SAP2000 version 14.*

The aim of this study is to reduce the base shear, story drifts and story acceleration due to earthquake ground excitation, applied to the superstructure of the building by installing base isolation devices at the foundation level and then to compare the different performances between the fixed base condition and base-isolated condition of symmetrical building. The high damping rubber isolation system has been used at the foundation level. Non linear time history analysis has been performed on El-Centro earthquake. Comparing the results of the base -isolated condition with those obtained from the fixed-base condition has shown that the base isolation system reduces the base shear force, story drifts and storey acceleration, also increasing the storey displacement and time period.

Keywords: *Earthquake, Base Isolation, Non Linear Time History Analysis, High Damping Rubber Bearing.*

1. INTRODUCTION

Earthquakes are one of nature's greatest hazards; throughout historic time they have caused significant loss of life and severe damage to property, especially to man-made structures. On the other hand, earthquakes provide architects and engineers with a number of important design criteria foreign to the normal design process. From well established procedures reviewed by many researchers, seismic isolation may be used to provide an effective solution for a wide range of seismic design problems.

The application of the base isolation techniques to protect structures against damage from earthquake attacks has been considered as one of the most effective approaches and has gained increasing acceptance during the last two decades. This is because base isolation limits the effects of the earthquake attack, a flexible base largely decoupling the structure from the ground motion, and the structural response accelerations are usually less than the ground acceleration [1].

Many comparative studies have revealed that the responses of the isolated structure are significantly smaller than the fixed base structure. Most of these studies compared the seismic demands (e.g. inter story drift, floor acceleration and base shear) for the two types of building structures, but only a limited number of studies investigated the responses of the isolated structure using high damping rubber bearing (HDRB) with detailed procedures of the design of HDRB. Nassani and Mustafa [1] presented as two different structures are (symmetrical and non-symmetrical school buildings) in which the seismic responses of the 'fixed-base' and 'base-isolated' conditions using SAP2000. Comparing the results of the base -isolated condition with those obtained from the fixed-base condition has shown that the base isolation system reduces the base shear force and story drifts, whilst also increasing the displacement. Akhare and Wankhade [2] studied to use of High density rubber bearing (HDRB) and friction pendulum system (FPS) as an isolation device and then to compare various parameters between fixed base condition and base isolated condition by using SAP2000v14 software. In this study the (G+12) storey hospital building is used as a test model. Nonlinear time history analysis is carried out for both fixed base and base isolated structure. The result obtained shows the reduction in base shear in both direction and increase in the displacement and time period for the base isolated structure. Gomase & Bakre [4] studied force deformation behaviour of an isolator is modeled as Bi-linear hysteretic behaviour which can be effectively used to model all isolation system in practice. Floor acceleration and inter-story drifts of the subject base isolated building are significantly reduced when compared to its fixed base counterpart. Tourunbalci & Ozpalanlar [3] presented energy approach to the earthquake resistant structure design. They studied the numerical example on six storey structure and analysis is done by using five different seismic protective system i.e. fixed base, rubber bearings, additional isolated storey, viscous damper. A three dimensional nonlinear time history analysis is performed on r/c building model for fixed base case with respect to the seismic isolation and earthquake protection alternatives and the comparative results regarding the total base shear forces, storey shear forces, maximum absolute accelerations and relative story drifts in both x and y directions presented graphically and results are discussed.

Thakare and Jaiswal [5] presented the comparative study of fixed base building and the base isolated building. The isolator used in this study is lead plug bearings and represented by bilinear force deformation behaviour. Response spectrum analysis and linear time history analysis used for both fixed base and base isolated buildings. Author also gives the step by step procedure regarding the properties & modeling of isolator. A result of this study shows the reduction in inter storey drift, base shear.

In this paper, the effect of base isolation system on seismic responses of structures is studied. 9-storey Symmetrical building is presented in which the seismic responses of the fixed-base condition and HDRB isolation condition have been compared using the well known computer program SAP2000 [7]. Time history analysis is performed using El-Centro earthquake.

2. BASE ISOLATION

Seismic Base-isolation of building is an innovative technique used in recent years, for reducing seismic energy transmitted to buildings, in highly seismic prone areas. The basic principle behind the base-isolation system is to introduce a flexible interface between the base of a structure and the foundation. The Basic concept of base isolation is to differentiate the building from its foundation, so during the seismic action, building is stays unaffected from the ground motion. In other words, even though ground moves aggressively, the building will tend to move ideally as a rigid body rather than collapsing. This reduces the floor hastening and storey gliding and so the building components are left less harmed. In the model, separation is total but practically, there is some co-relation between the ground and the building which provides flexibility to the structure. Any stiff structure will have short period. During the ground movement, amount of acceleration entrusted in the structure is the same of ground acceleration that results in zero displacement between the structure and the ground. In other words, ground and structure will move with equal amount.

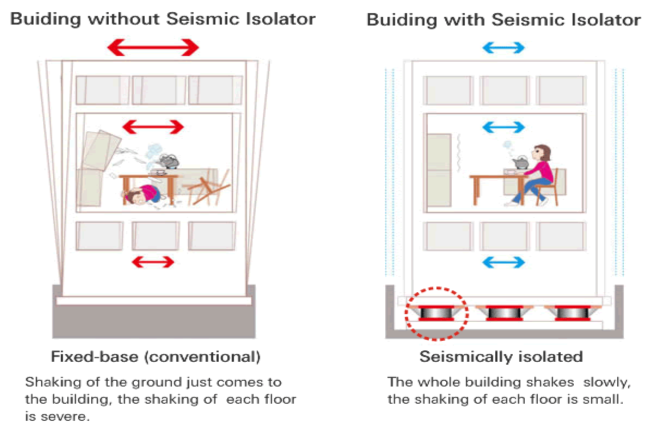

Fig. 1: Behaviour change while using conventional and base-isolated structure.

2.1 Base Isolation Techniques

Successful seismic isolation of a particular structure is strongly dependent on the appropriate choice of the isolation system. The isolation system should essentially be

- Able to support the structure
- Provide horizontal flexibility
- Able to dissipate energy

These three functions could be concentrated into a single device or could be provided by means of different components. In addition to these basic requirements, it is desirable that isolation system should be rigid for low lateral loads so as to avoid perceptible vibration during frequent minor earthquakes or wind loads. Different types of devices have been developed to achieve these properties.

Presently earthquake protective techniques are mainly categorized into three types

1. Passive Protective Systems

2. Hybrid Protective Systems

3. Active Protective Systems

Passive control system includes tuned mass dampers, isolation system, and mechanical dissipaters. These systems have significant application to building, bridges and industrial plants. The basic concept of seismic isolation is to reduce the response to earthquake motion by

i. Reducing the stiffness
ii. Increasing the natural period of system
iii. Provision of increase damping to increase the energy dissipation in the system

2.2. Types of Base Isolators

The most common types of base isolators used in buildings are;

1. Laminated rubber bearing
2. High damping rubber bearing (HDRB)
3. Lead rubber bearing (LRB)
4. Friction pendulum system (FPS)

Laminated Rubber Bearing

It is composed of alternating layers of rubber that provide flexibility and steel reinforcing plates that provide vertical load-carrying capacity. At the top and bottom of these layers are steel laminated plates that distribute the vertical loads and transfer the shear force to the internal rubber layer. On the top and bottom of the steel laminated plate is a rubber cover that provides protection for the steel laminated plates.

High Damping Rubber Bearing

It is similar to elastomeric bearings where the elastomer used (either natural or synthetic rubber) provides a significant amount of damping.

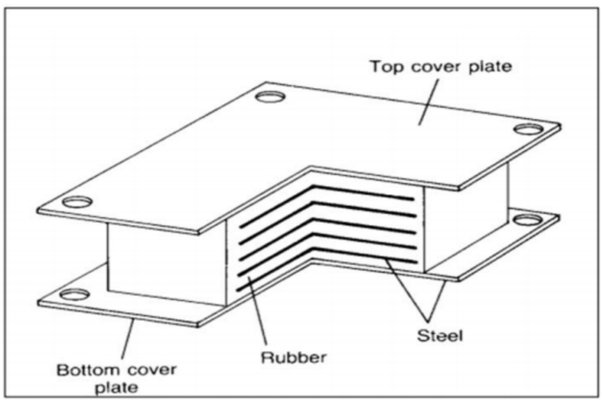

Fig. 2: High damping rubber bearing [1].

Lead Rubber Bearing

It is formed of a lead plug force-fitted into a pre-formed hole in a low damping elastomeric bearing. The lead core provides rigidity under service loads and energy dissipation under high lateral loads.

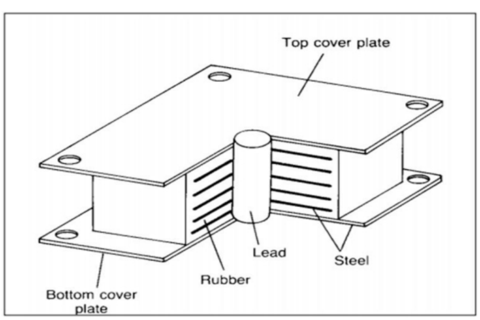

Fig. 3: Lead Rubber Bearing [1].

Friction Pendulum System

Although a number of curved shapes are possible, the only curved sliding which has been extensive used in which the sliding surface is spherical in shape, termed the Friction Pendulum System (FPS). The FPS bearing allows the supported structure to return to its original position, rather than a flat sliding surface, thereby conquering the problem of recentering.

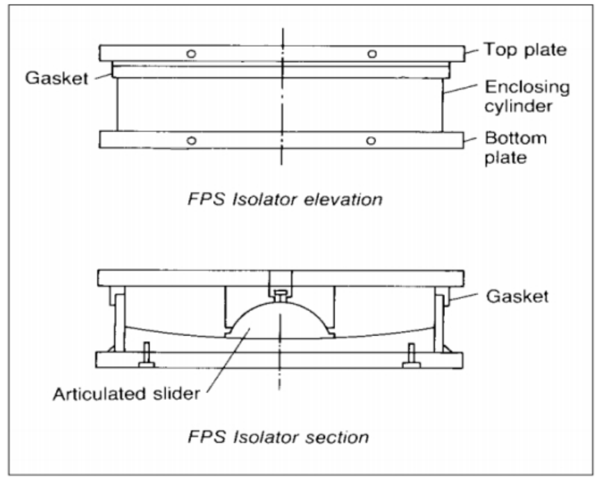

Fig. 4: Friction pendulum system [1].

3. ANALYTICAL MODELING

In this research, the evaluation and comparison of seismic responses of base isolated structures with those of fixed base are performed. 9 storey symmetric R.C.C. building is modeled and nonlinear dynamic analysis (i.e. Time-history analysis) is carried out and response of the buildings are calculated.

3.1. Modeling Approach

Three dimensional non-linear time history analysis is carried out with the SAP2000 v.14 software program. The building sits on a 36 x 12 m^2 area and it is assumed to be located in zone IV. The model building is analyzed by considering Earthquake El-Centro time history data both for fixed base situation and also by earthquake protection alternatives such as HDRB at the base. Comparison between the fixed base and the base isolated structure is carried out and the parameters such as base shear, time period, storey displacement, storey drift and storey acceleration are compared.

3.2. Building details and plan

The symmetric structure consists of 9-storey RCC building with regular plan. The building is consisting of columns with dimension 350x650 mm, all beams with dimension 350x450 mm. The floor slabs are taken as 160 mm thick. The height of all 9 stories is 3m. The building plan and 3D view are shown in Fig. 5 and Fig. 6.

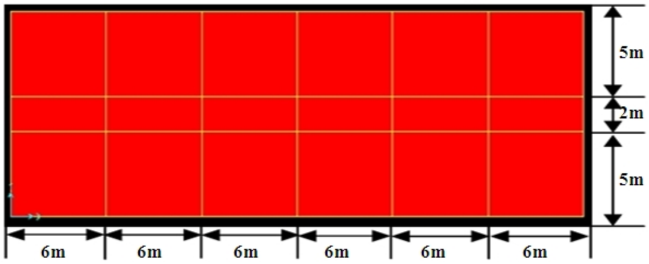

Fig. 5: Plan view of symmetric Building.

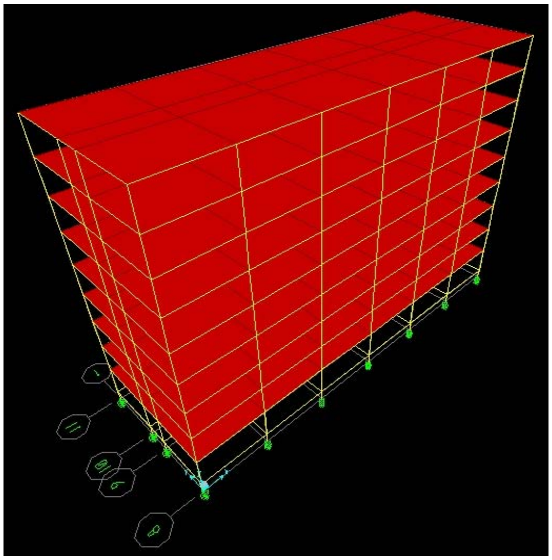

Fig. 6: 3D view of symmetric Building.

3.3. Design example for HDRB

As a design example we consider a G+9 story structure. While designing the high damping rubber bearing, we consider the site to be situated in zone IV with S_D soil type & assume that site is not less than 15 km from a known active fault. Using Uniform Building Code (UBC) 97 Appendix Chapter 16 requirements, the parameters associated with location are seismic zone factor, Z= 0.4, Soil type= $S_{D,}$ near source factor, N_v=1.

3.4. Parameters for Rubber isolators

Nonlinear Link Type: Rubber, U1 Linear Effective Stiffness: 1809557.369 kN/m, U2 and U3 Linear Effective Stiffness: 1665.45 kN/m, U2 and U3 Nonlinear Stiffness: 1403.874 kN/m, U2 and U3 Yield Strength: 88.49 kN, U2 and U3 Post Yield Stiffness Ratio: 0.1

4. RESULTS AND DISCUSSION

In this section the results of analytical studies are briefly described.

4.1. Base Shear

From Fig. 7., it is shown that the base shear in X-Direction is reduced by 69% and in Y-Direction by 71% for the case of HDRB when compared with fixed base.

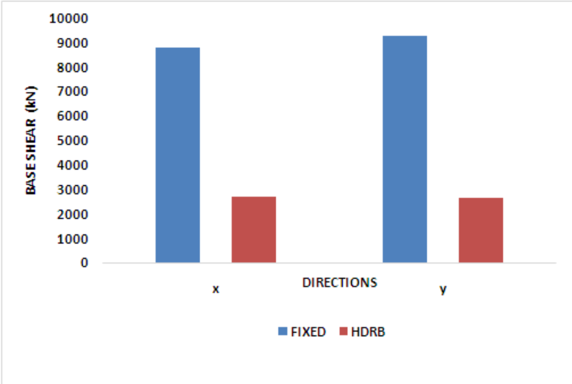

Fig. 7: Base shear in X & Y-Direction (in kN)

4.2. Time period

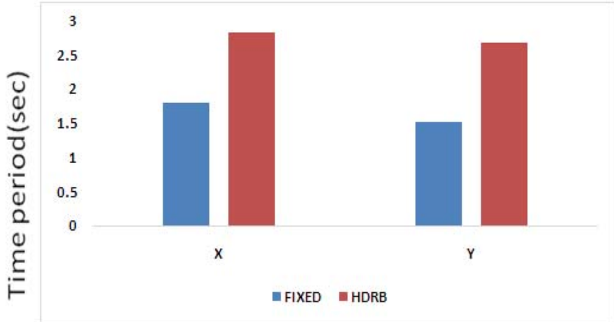

Fig. 8: Time Period in X & Y Directions

From Fig. 8., it is shown that the Time Period in X-Direction is increased by 36% and in Y-Direction by 43% for the case of HDRB when compared with fixed base.

4.3. Storey Displacement

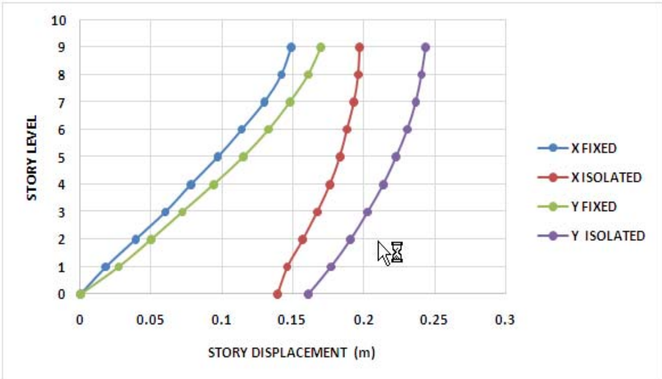

Fig. 9: Storey Displacement in X & Y Directions

From Fig. 9., it is shown that the storey displacement in X & Y-Direction is increased for the case of HDRB when compared with fixed base.

4.4. Storey Drift

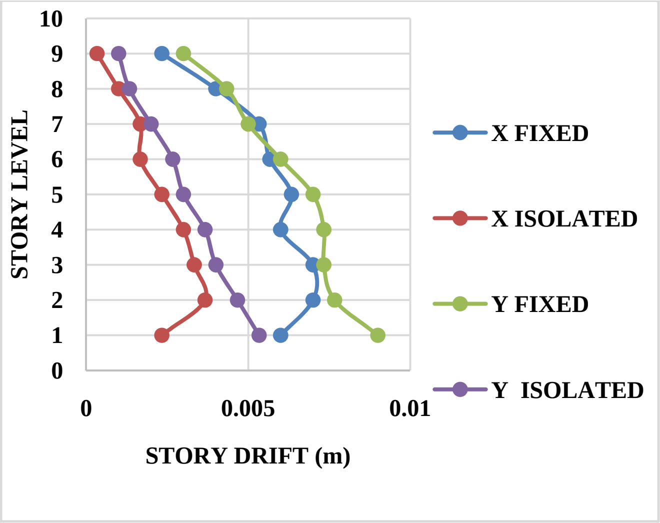

Fig. 10: Storey Drift in X & Y Directions

From Fig. 10., it is shown that the storey drift in X & Y-Direction is reduced for the case of HDRB when compared with fixed base.

4.5. Storey Acceleration

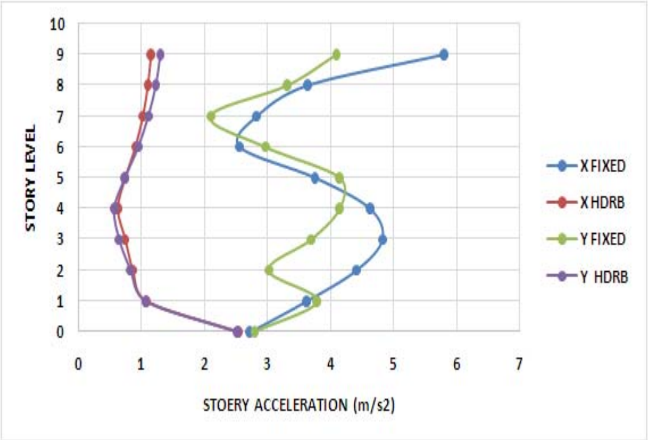

Fig. 11: Storey Acceleration in X & Y Directions

From Fig. 11., it is shown that the story acceleration in X & Y-Direction is reduced for the case of HDRB when compared with fixed base.

5. CONCLUSIONS

The response of base isolation building was investigated using the non linear time history analysis. As a result of the work that was completed in this research, the following conclusions are made:

1. The results of the study shows that the response of the structure can be reduced by using base isolation system.
2. Comparing the results of the base-isolated condition with those obtained from the fixed-base condition has shown that the base isolation system reduced the base shear force and story drifts, whilst also increasing the displacement and time period.
3. Base shear is reduced in X & Y Direction for the base isolated condition as compare to fixed base condition in symmetric building.
4. Time Period is increased in X & Y Direction for the base isolated condition as compare to fixed base condition in symmetric building.
5. Storey Accelerations is reduced in X & Y Direction for the base isolated condition as compare to fixed base condition in symmetric building.

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