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Design of Base Isolation for Seismic Response Control

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Abstract – Earthquake is one of the natural hazards that occur suddenly due to violent movement of earth's surface which releases energy causing destruction to buildings and structures. Protection of structures against this destruction is of vital importance and decades of research have been carried out focusing on this. This paper discusses one such seismic protection method using base isolation. Base isolation is a technique in which the super structure is isolated from the foundation using special devices which are good in lateral load resisting. Isolators are introduced between super structure and sub structure, under each column. During earthquake, these base isolation devices partially absorb and reflect the input seismic energy before it gets transmitted to the superstructure. This reduces the seismic energy that gets transferred to the structure, thereby increasing its earthquake resistant capacity. Typical base isolator is made of sandwiched layers of materials like rubber, with and without reinforcing steel shims. The design methodology depends on input parameters like fundamental period of structure, damping of the fixed base structure, axial load on the column, seismic zone, type of soil and shear modulus of rubber. In this study, a typical G+5 storey hospital building has been analyzed using SAP2000 and isolators are designed for different column loads. Comparisons of responses were made between fixed base and isolated base structure, in terms of frequencies, and response acceleration.

Index Terms – Base isolator, earthquake resistant, isolation devices, SAP2000.

1. INTRODUCTION

Earthquakes are considered to be dangerous natural hazard which causes damages or collapse in a structure. Earthquake damage of structure relies on the numerous parameters, including force, time period and frequency content of ground movement, geological and soil condition, nature of the development etc. As per IS 1893 (Part 1): 2002 [1], the seismic zones of India become more defenseless and diminished in to four zones. So it is vital to design the structures with seismic resistance. Reinforced concrete framed structures require special detailing techniques to enhance ductility in the structure. Lack of appropriate detailing practice or adoption of only those required for gravity load design may lead to severe damage. Load bearing structures require special reinforcement in their structural elements to contain the damage or collapse of the structure. The main types of earthquake control systems are classified in to passive, active, and Hybrid systems [2]. Active control system is one of the most promising alternatives to reduce the demand on structural components. But these systems required huge external energy for operation, which makes them economically higher than other control systems. Passive control systems work without usage of any outside energy source. Accordingly, the cost of setting up these systems is less in comparison with other systems. Passive control systems are more successful in the practical application. These systems depend upon the materials that absorb the energy at a specific level. Base isolation is one of the widely used passive control system in earthquake prone areas to protect the structure from seismic forces. Base Isolation physically uncouples the structure from horizontal component of earthquake ground motion and leads to a substantial reduction of the force generated by the earthquake. Hybrid control systems consolidate elements of both passive and active control systems, where the segment of the control target is accomplished by the passive system and less active control efforts which suggest less power resource, is required in the hybrid control system.

2. CONCEPT OF BASE ISOLATION

Base isolation is a technique to isolate the buildings from the ground motion in which that earthquake motion are not transmitted up through the building or at least greatly reduced. Base isolation concept has been extensively used to control the seismic damage to buildings. Large displacements due to lateral earthquake forces are restricted to the bearing level. The differential displacement between the roof and the bearing is very much reduced, leading to significant reduction in seismic forces encountered in the primary structural elements of the building, and hence, the damage to primary structural elements can be minimized.

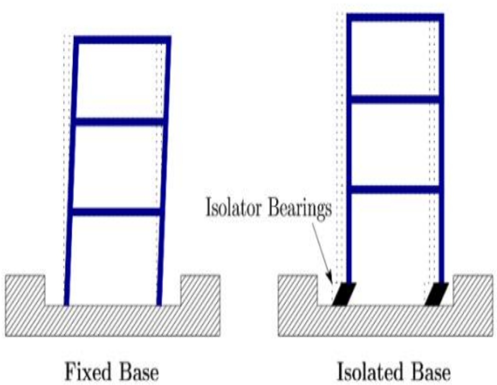

Figure 1: Concept of base isolator

TYPES OF BASE ISOLATORS

The most common types of base isolators used in buildings are [3]

1. Laminated rubber bearing.
2. High damping rubber bearing.
3. Lead rubber bearing.
4. Friction pendulum system bearing.

1. Laminated Rubber Bearing

It consists of alternating rubber layer which provides flexibility, steel reinforcing plates that gives vertical load within certain limit. At the top and bottom of this layer consists of steel laminated plates that distribute the vertical loads and transfer the shear force to the internal rubber layer as shown in figure 2.

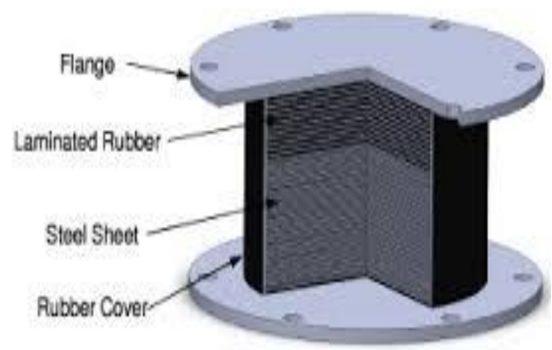

Figure 2: Laminated Rubber Bearing

2. High Damping Rubber Bearing

It is like an elastomeric bearing where the elastomer uses either natural or synthetic rubber which provides the damping as shown in figure 3.

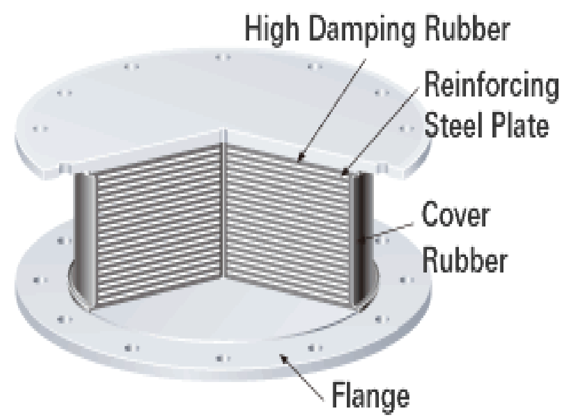

Figure 3: High Damping Rubber Bearing

3. Lead Rubber Bearing

It is a type of lead connect drive fitted to a pre-shaped opening in a low damping elastomeric bearing as shown in figure 4. The lead core provides rigidity under service loads and energy dissipation under a high lateral loads.

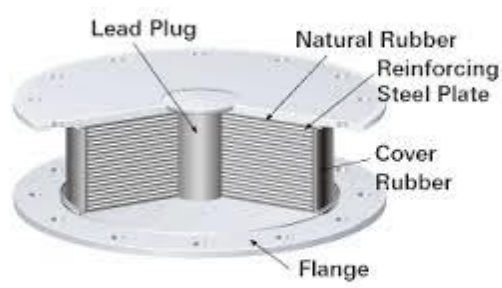

Figure 4: Lead Rubber Bearing

4. Friction Pendulum System

The weight of the structure is supported on spherical sliding surface as shown in figure 5 that slide relative to each other when the ground movement exceeds the threshold.

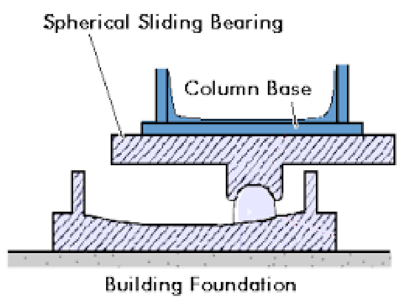

Figure 5: Friction pendulum system

In the present work, laminated natural rubber based isolators are designed for a typical G+5 hospital building and seismic analysis is carried out to study the response reduction in structure.

3. MODELING OF THE STRUCTURE

Six story regular reinforced concrete building [4] is modeled in the SAP 2000 software. The beam length in (x) transverse direction are 3m (four numbers), 6.75m (two numbers), and 6.25m and beams in (z) longitudinal direction are 3 x 3m (three numbers), 2m (two numbers), and 6.25m. Figure 6 shows the plan of the six story Hospital building having 7 bays in x-direction and six bays in z-direction. Story height of each building is assumed 4m. Beam cross section is 300x600 mm and Column cross section is 500x500 mm.

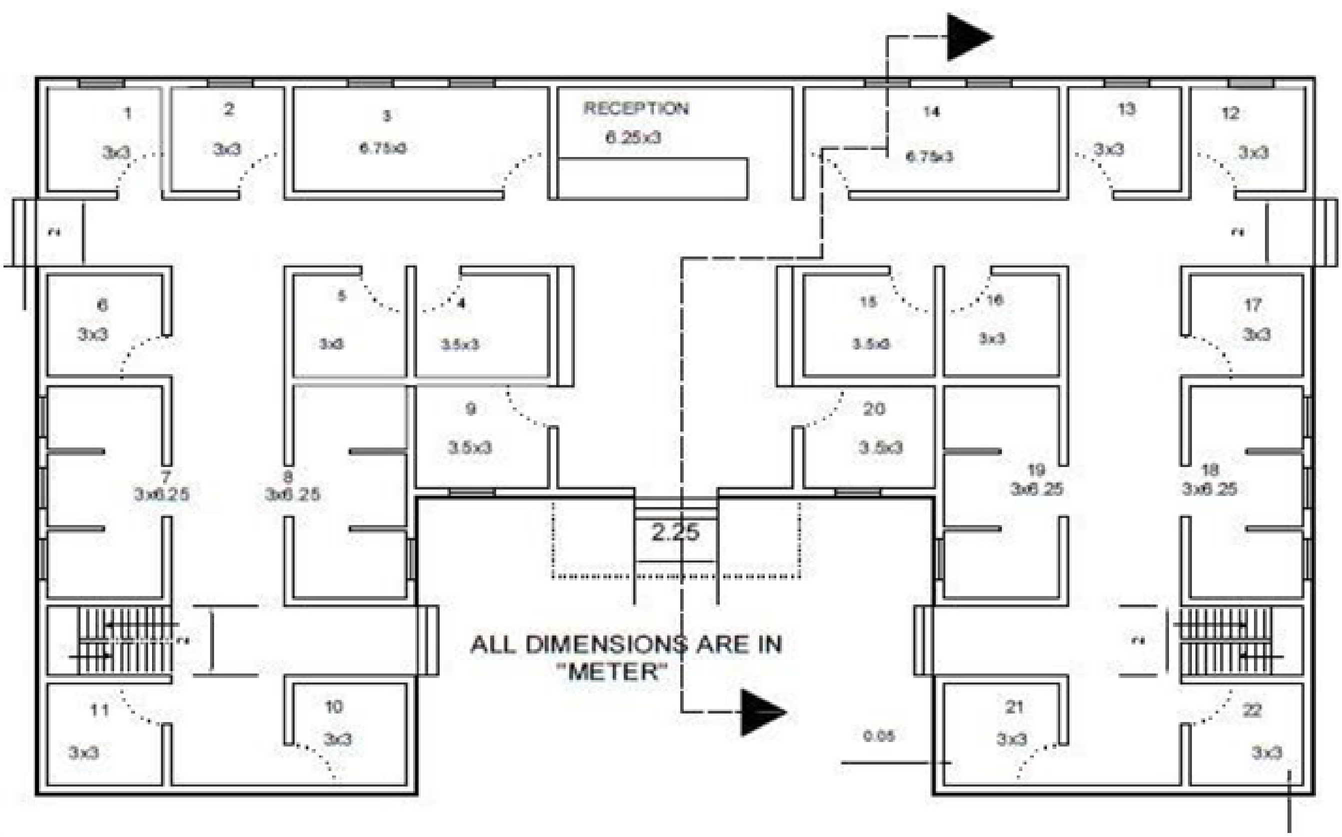

Figure: 6 Plan of six-story Hospital building

The support condition at the bottom is fixed and the analysis is performed for different load conditions. The axial loads are computed for all the columns at their base, where the base isolation is to be installed. The structure is assumed to be in Zone III, built on medium soil. The time period for the fixed base is identified. Then the calculated rubber properties are given as link/ support properties in the SAP software and the base-isolation model performance is analyzed [5]. The acceleration and displacement of the structure with the rubber isolator is determined. Figure 7 shows the SAP model of the building.

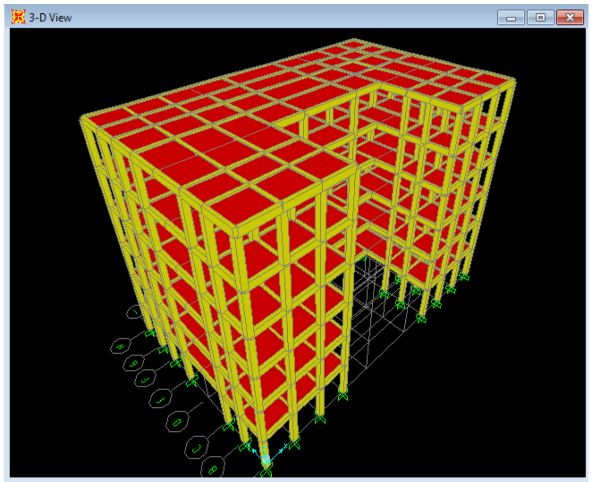

Figure 7:3D view of the SAP model

4. DESIGN OF THE BASE ISOLATOR

The isolators are designed for the axial loads from the columns as they are placed below them. For the given building model from the axial loads, the rubber isolator properties are calculated as follows [6]

Spectral Displacement:

Table 1: Axial load on column and dimensions of base isolator

Maximum axial load (kN)	Thickness of the rubber isolator (mm)	Size of the rubber isolator (mm)	No.of laminated layer	No.of steel shims
593.931	175	410	15	13
981.930	175	530	15	13
1436.57	175	640	15	13

$$S_D = \frac{T^2}{4\pi^2} \times S_a \times z$$

Where,

T = Time period of the isolator

S_a = Spectral acceleration

Z = zone factor

Thickness of the rubber:

$t = S_D / \gamma$

Where,

γ = shear strain

Horizontal stiffness:

$K_H = m\omega^2$

Where,

m=mass of the structure

ω =Natural frequency

Area of the isolator:

$A = K_H \times t / G$

Where,

K_H = Horizontal stiffness

t= thickness of the rubber,

G = Shear modulus

Area ratio:

S = B/4t

Where,

S = Area ratio, B = Breadth of the rubber

t= thickness of the single layer of the laminated rubber isolator

Three isolators are designed for the different range of column loads. These formulas are given in UBC 97 [7] and IS 1893 (Part 1): 2002. The above properties are incorporated in the SAP 2000 model as a link rubber isolator. Time history analysis of the frame is carried out using SAP-2000 software. NS compound of El Centro earthquake is used in the time history analysis. The time period and frequency of the building before the installation of rubber isolator is 0.54390sec and 1.83Hz respectively and after the installation the value of time period is 2.5sec and the value of frequency is 0.4Hz.Figure 8&9 show the acceleration and displacement of the fixed base structure.

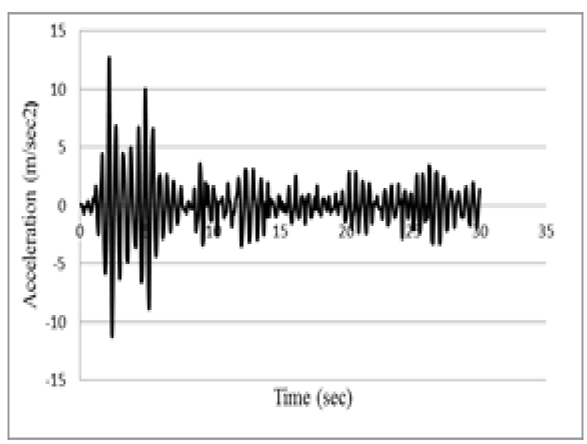

Figure 8: Acceleration of building with fixed base structure

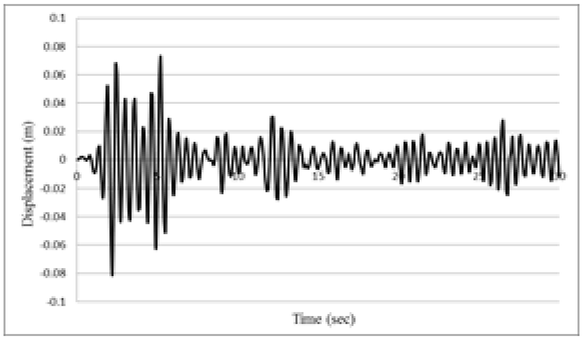

Figure 9: Displacement of building with fixed base structure

Figure: 10&11 shows the acceleration and displacement of the building with base isolated structure.

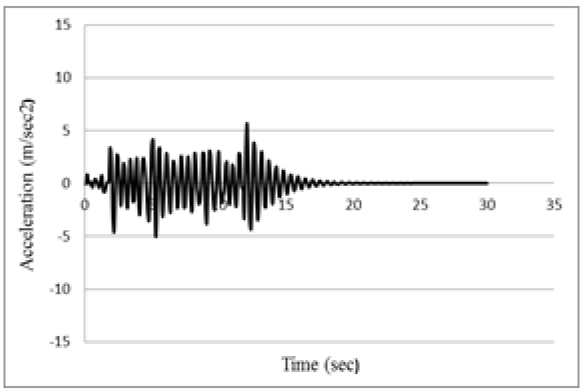

Figure 10: Acceleration of building with base isolated structure

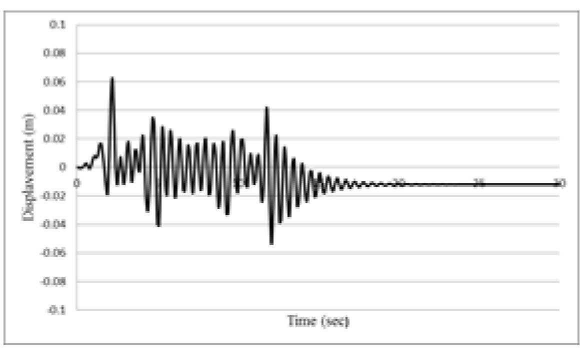

Figure 11: Displacement of building with base isolated structure

5. RESULTS AND DISCUSSION

In this study a G+5 hospital building model is considered and seismic analysis using the SAP 2000 software is done. Depending upon the seismic region, the period of the structure lying in the response spectrum in IS 1893 (Part II) : 2002 is observed and the isolator period is chosen in such a way to avoid the resonance condition and for that time period the building can be designed. Modal analysis has been performed using SAP2000 software and the results show the lengthening in the period after the installation of the rubber isolator compared to the fixed base structure. Time history acceleration data of the El-Centro earthquake is given in the X direction for the building model and the responses observed are compared to the fixed base structure. The reduction of the response is considerable in case of response acceleration, up to a 55.32%. In this study, it is observed that base isolation is effective in reducing the peak response as compared to the fixed base system.

6. CONCLUSION

Base Isolation controls the response in which the structure is decoupled from the horizontal component of the earthquake ground motion. The primary aim of the study was to understand the behavior of the laminated rubber bearings seismic isolated structure. From the seismic analysis carried out for a typical hospital building, it is found that base isolator effectively reduces the peak responses of the structure during an earthquake. This shows the promising effectiveness of the seismic isolation technique as a viable seismic control method.

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