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Seismic Response Control Using Base Isolation Strategy

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***Abstract*- Earthquakes are one of the natural hazards that occur due to sudden violent movement of earth's surface which releases energy and has destructive power in many parts of the world. The development of recent technologies for the control of seismic hazards catches the attention of structural engineers to make the structures seismically resistant. The seismic base isolation technique is a passive protective system. It limits the effects of the earthquake attack through a flexible base which decouples the structure from the ground motion, and the structural response accelerations are usually less than that of the ground acceleration. This technique has been incorporated and studied practically in many multi-storey structures. In the present work, a laminated rubber bearing isolator has been designed and the properties of the isolator are obtained. Then the dynamic analysis of the structure has been carried out and the performance of the building with and without isolator is studied. A parametric study has also been conducted and the results can be used in the implementation of a real time structure to improve its seismic performance.**

***Keywords*- base isolation, flexible base, laminated rubber bearing, parametric study, passive system**

I. INTRODUCTION

Natural hazards bring many damages to man-made interventions such as habitat and infrastructural facilities causing loss to life and property. Earthquakes are one of those hazards with the sudden violent movement of earth's surface with the release of energy. These energy travels in the form of seismic waves which affects the structures. According to the revised provisions of IS 1893 (Part 1): 2002 Code [3], the seismic zones of India become more vulnerable and reduced to four zones. So it is important to design the structures with seismic resistance. The two main design concepts adopted for the structures are as follows.

In the first concept, plastic hinges are allowed to form only in some parts of the structure and the other parts of the structure are in their elastic range. These hinges are designed for high ductility for the global stability of the structure. This may result in an economical design. In the second design concept, some additional mechanical devices may be placed in the structure making it seismically safe. In this approach, the earthquake protective systems are considered. The control of structures to improve their performance during earthquakes was first proposed more than a century ago. But it has only been in the last 25 years that structures have been successfully designed and built using earthquake protective systems [2]. It is uneconomical to use the earthquake protective systems in all places. It can be adopted in the earthquake prone regions to safeguard the lives.

The main types of earthquake protective systems include passive, active and semi-active systems [5]. In *passive control* systems the devices do not require additional energy source to operate and are activated by the earthquake input. *Active control* systems require additional power source, which has to remain operational during an earthquake and a controller to determine the actuator output. *Hybrid control* systems combine features of both passive and active control systems. Since a portion of the control objective is accomplished by the passive system, less active control effort, implying less power resource, is required in the hybrid control system.

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Many concepts are used worldwide for the control and reduction of effects due to the earthquake forces. The new inventions in the design field and the use of control devices are largely developing these days. The structural response control mainly relies on the stiffness (i.e., energy storage) and damping (i.e., energy absorption/dissipation) elements/devices in a structure to control its undesirable response due to excitations caused by winds and moderate earthquakes [8]. In most cases, the bracing systems and shear walls are used as passive protective systems. Modern passive systems include tuned mass dampers and base isolation systems which do not require any additional energy input.

A. Concept of Base Isolation

The basic concept in seismic isolation is to protect the structure from the damaging effects of an earthquake by introducing a flexible support isolating the building from the shaking ground [1]. In the literal sense, the structure is separated from its foundations. In practice, a full separation of the structure from its foundations is impossible, as large relative horizontal displacements have to be avoided either during the earthquakes or when other horizontal loads such as wind are present. Hence, the common solution is to use a layer, usually between foundation and superstructure, which is more flexible than the other structural elements and is able to transmit the vertical load when undergoing lateral displacements without critical damages.

An isolated system does not absorb the vibrating energy, but rather deflects it through the dynamics of the system. It lengthens the natural period of vibration of the structure so that the responses are greatly reduced. In some cases a passive damper may also use to control excessive displacement [6] Figure 1 represents the shifting of period by the isolator and the resulting reduction in the acceleration response.

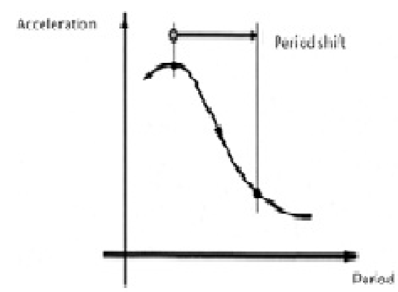

Fig 1. Period shift induced by an isolator

In this study a multi-storey structure is taken and its performance with and without isolators and the time period differences are studied.

B. Objective and scope

The main objective of this work is

- To illustrate the basic concept and behavior of the base isolated structures.
- To design a laminated rubber bearing isolator for the given building specifications.
- To study the free vibration response of the multi-storey building with and without base isolator.

II. MODELLING OF THE STRUCTURE

A three-storied half scale building is modeled in the SAP 2000 software [7]. An open frame building model with 2 bays in each X and Y directions, the bay width as 1.5m and the height of each storey as 1.8m are modeled. The material properties of the frame elements and the area element are defined and M30 concrete grade is used. The rebar material properties are also given. The beams and columns of dimensions 150X200 mm are given as frame elements. The slab in the building is assigned as a shell element with a thickness of 100mm. The rigidity of the beam column joints are given by end length offsets. No additional live loads are given to the model. The support condition at the bottom is made as fixed and the fixed-base analysis is performed considering the dead load mass.

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The period for the fixed base is identified. Then the calculated rubber properties are given as link/ support properties in the software and the base-isolation model analysis is performed. The response of the structure with the rubber isolator is determined. The SAP model of the building is shown in Figure 2.

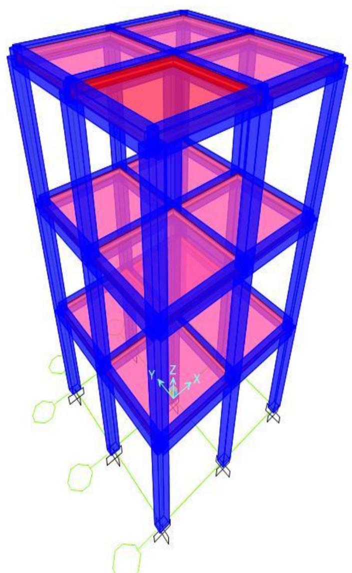


Fig 2. 3D view of the SAP model with fixed base

III. DESIGN OF THE RUBBER 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 [4],

$$d = \frac{T^2}{4\pi^2} \times a \times z \quad (3.1)$$

$$K = m\omega^2 \quad (3.2)$$

$$t = \frac{d}{\gamma}$$

$$A = \frac{K \times t}{G}$$

$$I = \frac{M}{12}\left(l^2 + t^2\right)$$

Where, d=displacement of the rubber

T= period of isolator

a= spectral acceleration

z = zone factor

K= Stiffness of the isolator

m= mass of the column

t= thickness of the rubber layer

γ= shear strain

A= area of the isolator

G= shear modulus

I= rotational inertia

These formulas are given in UBC 97 [9] and IS 1893 (Part 1): 2002. The above properties are incorporated in the SAP 2000 model as a link rubber isolator. The deflection of the isolator below the building can be clearly seen in the model. The period of the building is increased significantly from its fixed-base period. Figure 3 shows the SAP model with isolator at its base and Figure 4 shows the deflection of the isolator after placing the rubber isolator. It can be seen that the entire structure essentially moves as a rigid body above the isolators.

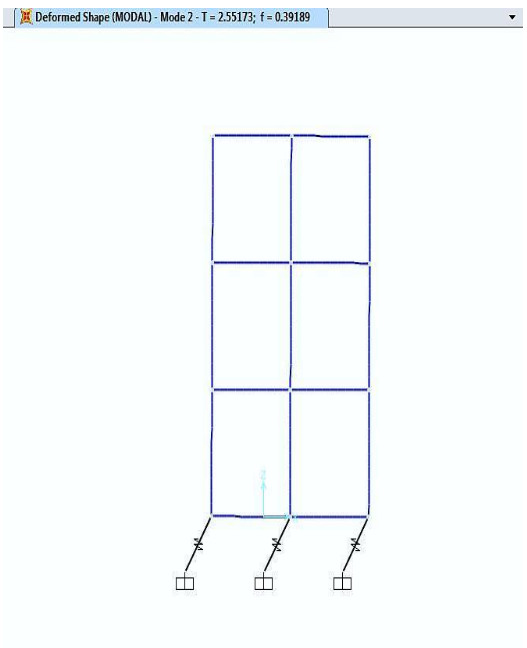


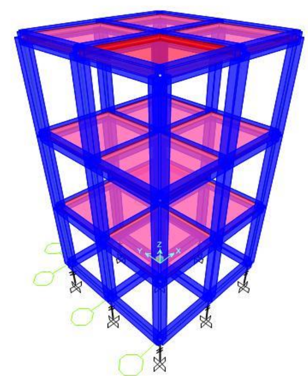
Fig 3. 3Dview of the rubber isolated model

Fig 4. Deflected shape of the model

IV. RESULTS AND DISCUSSIONS

From the analysis results of the fixed base and the rubber isolated structuremodels, the increase in the period of the structure is clearly defined. The rubber isolator period usually ranges from 2 to 3 seconds which is muchgreater than the natural period of the structure. So the isolator used in the modelwas designed for a period of 2.5 seconds and the results obtained from the analysis shows the same result as 2.55 seconds for the three storey structure.

The analysis is done for different storey heights of the building for the same building plan, i.e., for 3, 5, 7 and 10 storeys. The isolator in each case varies in its total height and its single layer thickness depends on the vertical loads on the columns. The corresponding increase in period can be seen in all the different storeys. The time period comparison between different storeys is represented in Figure 5 and the displacements in the storeys are indicated in Figure 6 ,Table I shows the time period for various modes in both fixed-base and base-isolated structures.



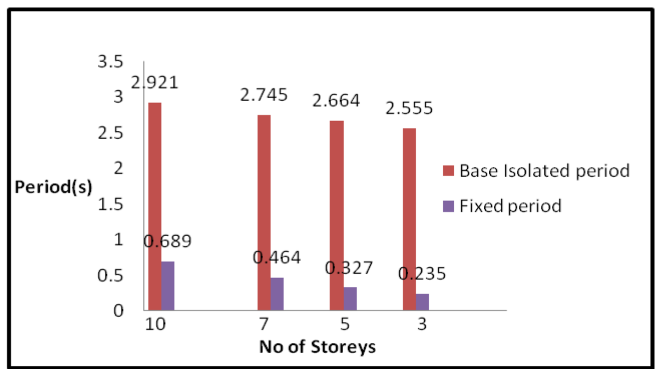


Fig 5. Comparison of time period for different storeys

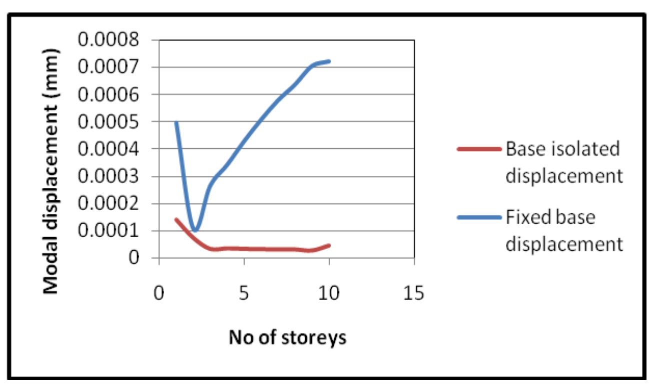


Fig 6. Comparison of displacements of different storeys

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TABLE I

COMPARISON OF FIXED-BASE AND BASE-ISOLATED TIME PERIODS

Mode number	Fixed base period(s)	Isolated base period (s)
1	0.235	2.554
2	0.196	2.551
3	0.181	2.487
4	0.078	0.231
5	0.063	0.225
6	0.060	0.125
7	0.050	0.088
8	0.038	0.061
9	0.038	0.056

A. Conclusions

Base isolation systems are adopted in many places in the world but still not much awareness and usage is available in India. In India, this passive technology can be adopted for many structures located in high seismicity zones to make them seismically safe. The damages can be greatly reduced due to the increase of time period resulting in reduced response.

Acknowledgement

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