Seismic Isolation Devices to Mitigate the Devastating Effect of Earthquake: A Theoretical Approach

Subhro Chakraborty[1], Pritha Naskar[2], Anwesha Banerjee[3], Debjyoty Kundu[4], Bishal Biswas[5], Soumik Roy[6] and Khokan Bari[7]

[1,2]University of Engineering and Management, Jaipur
[3,4,5,6]B Tech Civil Engineering, University of Engineering and Management, Jaipur
[7]B Tech Mechanical Engineering, University of Engineering and Management, Jaipur

Abstract—*Natural disasters like floods, avalanche, landslides, drought and earthquakes have historically been the biggest retarding factors in the socio-economic progress of human civilizations. Various branches of science and engineering have been dedicated to look for disaster management and mitigations.*

Earthquake, primarily caused by the tectonic movements of plates, results in huge loss of infrastructure and lives. The branch of Civil and Structural engineering have long faced the challenge of devising earthquake-resistant buildings. Damage caused to built-up structures like buildings, bridges, dams, nuclear and thermal power plants during an earthquake have been found to be caused due to the disturbances and waves generated in the lithosphere.

This paper does a theoretical study of the role and method of working of seismic isolation devices which primarily works on the principle of shock absorption. The foundation of the structures absorb the waves generated during an earthquake, providing stability to the structure and ensuring safety and security of its inhabitants and surrounding structures.

The conclusion drawn from this paper is that the base isolation techniques is an effective tool against the devastating dynamic seismic waves, especially in highly active seismic zone.

Keywords: *Tectonic movement, seismic waves, highly active seismic zones, base isolation, damping, bearing system, algorithm, computer simulation*

1. INTRODUCTION

With the general scenario of the modern world, it is being gradually recognized the importance of seismic resistant structure. They are not only helpful to mitigate the devastating effects of Earthquakes, but also provide an effective means to reduce the vibration of structures due to the undesirable excitations of wind and other dynamic forces, so as to maintain the stability and integrity of structures. The seismic control of structures including flexibility of the structural systems, increased safety levels, stringent performance level and economic consideration. As a result of this development, research in the area of structural control has intensified. Since the 1980's many structural methodologies have been developed, with some other structural mitigation system being implemented in the practical reality. The method of structural control can broadly be categorized into passive and active control methods. In passive control the mass or the damping or stiffness or a combination of any two or all are modified by adding same components into structures. These components are actuated by the movements of the structures and provide control forces according to their dynamic characteristics. More external sources of energy is required to activate the system.

In the active control, an external source of energy is used to activate the control system by providing an analog signal to it. The required signal is generated by the computer following a control algorithm that uses major responses of the structure.

Combination of these methods of structural control has between used to evolve semi active and hybrid control methods.

Base Isolation Methodology

Base Isolation of structures is one of the most popular means of protecting structures against earthquake force. It is the passive control device that is installed between the foundation and the base of the building. For the case of the bridges, the base isolators are installed between the deck and the pier, as with the bridge bearings. In buildings the base isolators protects the structure from earthquake forces in two ways.

a) By deflecting the seismic energy

b) By absorbing the seismic energy

The seismic energy can be deflected by making the base of the building flexible in lateral directions, thereby increasing the fundamental time period of the structure. The seismic energy is absorbed by the isolator because of its non-linear response to earthquake excitations. The (internal) force displacement curve of the isolator is lost in the hysteresis loop. Due to this two properties of the isolators, they have become very attractive passive control devices to be used in the control of seismic response of the structures, especially the multi storied building structures. Generally the base isolators can be grouped under the following:

a) Laminated Bearing

b) Friction bearings

Among the laminated bearings, Laminated Rubber bearing (LRB) and New Zealand rubber bearing (NZ) are extensively used in practice of the friction type, elastic sliding bearings, friction systems (FPS), resilient friction systems(R-FBI) and the Pure Friction System are popular.

The characteristics of the isolators are briefly discussed below.

a) Laminated Rubber Bearing

The basic components of LRB are Steel and Rubber plated built into alternate layers. Generally, an LRB system exhibits high damping capacity, horizontal flexibility, and high vertical stiffness. For low damping rubber bearing, a lateral force deformation relationship is modelled as linear.
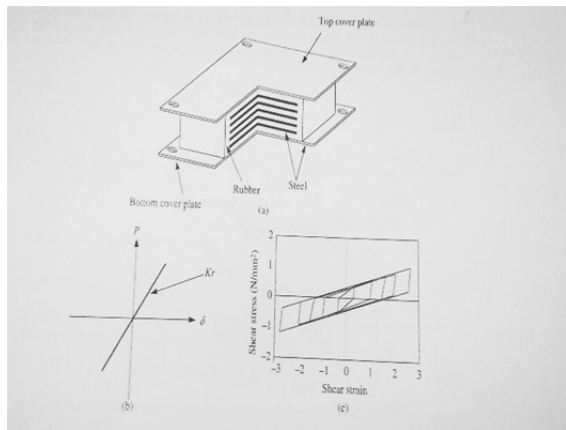
A temperature independent model for the lateral stiffness is given by that at 15^0C, i.e.

$K_r = (GA)/H$

Where, G, A and H are sheer modulus and the cross sectional area and the total thickness of the rubber respectively. The vertical stiffness K_v is given by

$K_v = \alpha/H\{E_0(1+2kS_1^2)E_b/E_0(1+2kS_1^2)+E_b\}$

Where, S_1= Primary shape factor (10-15)

K= Correction modulus of the rubber hardness (1-0.5)

E_o and E_b are the longitudinal and bulk modulus of elasticity respectively

A= Correction modulus for longitudinal elasticity (0.8-1).

The linear damping coefficient maybe taken to be about 10 %. For a high damping rubber bearing, the equivalent damping is considerably increased due to the hysteretic effect. It could be of the order of 15-20%.

b) New Zealand bearing System (NZ)

A New Zealand bearing is similar to a Laminated Rubber Bearing, but with a central lead core or rubber core in order to

increase the size of the hysteresis loop and hence to provide additional dissipation of energy. A typical idealized forced-displacement relationship of lead-rubber bearing is shown in the figure.
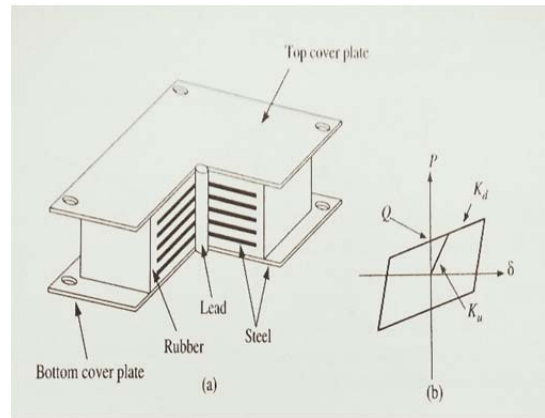
The initial stiffness is given by-

$K_u = \beta K_d$, in which $\beta = K_u/K_d$

And $K_d = C_d(K_r+K_P)$, in which $K_r = GH/A$ and $K_P = \alpha A_p/H$.

A_P= The area of the flow plug, A= Sheer modulus of Lead.

c) Resilient Friction Base Isolation (R-FBI)

The friction base isolator consists of concentric layers of Teflon coated plates that are in friction contact with one-another, and it contains a central core of rubber. It combines the beneficial effect of friction damping with that of resiliency of rubber. The rubber core distributes the sliding displacement and the velocity along the height of the R-FBI bearing. The system provides isolation through the parallel action of the friction, damping and restoring force and is characterized by natural frequency (ω_b), Damping Constant (ξ_{sb}) and coefficient of friction (m). The recommended values of these parameters are $\omega_b = 0.5P$ rad/sec, $\xi_{sb} = 0.1$ and $0.03 \leq m \leq 0.05$. The force deformation behavior of the isolator is shown in the figure.
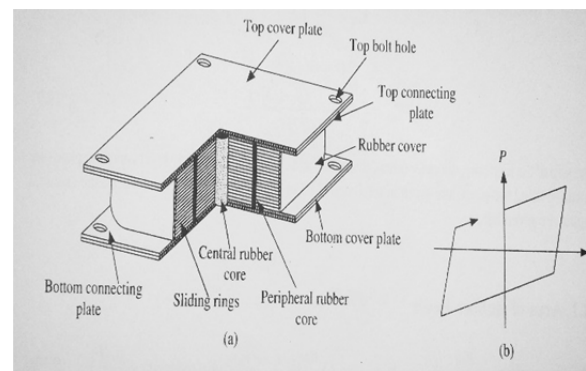
2. CONCLUSION

The base isolation technique is one of the most effective type of seismic isolation technique that can be implemented for

practical applications to prevent or reduce the vibration of the structures against the dynamic seismic waves. Thereby, the seismic isolation technique can be used as an effective tool to mitigate the devastating effect of earthquake.

REFERENCE:

[1] Datta, T.K. (2010) *"Seismic analysis of Structures"*, John Wiley & Sons

[2] Jangid, R.S. and Datta, T.K. (1995) *"Seismic behaviour of base isolated building-a state of art review"*, Journal of Structures and Buildings, Proceedings of *Institute of Civil Engineers (London)*

[3] Higashino, M. and Okamoto, S. (2006) *"Response Control and Seismic Isolation of Building"* (1st Edition), Taylor and Francis, London

[4] Jangid, R.S. and Datta, T.K. (1994) *"Non-linear response of torsionally coupled base isolation structure"*, Journal of Structural Engineering, *ASCE*

[5] Shukla, A.K. and Datta, T.K. (1999) *"Optimal use of viscoplastic dampers in building frames for seismic forces"*, Journal Of Structural Engineering, *ASCE*