Dynamic behaviour analysis in buildings incorporating Lead Rubber Bearing

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ABSTRACT

Earthquakes are a major threat to human lives and to the integrity of the infrastructures in seismic regions. Structures are the worst hit with the phenomenal damages due to ground motions resulting from earthquakes. Recent researches and studies have led to new techniques to reduce the damages caused by earthquakes on structures and these techniques are applied for innovative structural design. One of the techniques is the base isolation method, which is used to design structures against earthquake damages by using seismic isolators to change the dynamic characteristics of a structure.In this study, three bay 4 and 8-storey reinforced concrete structures are analysed as isolated and fixed-base. Laminated rubber bearing (LRB) is used as an isolation system. Nonlinear behaviour of both isolation system and super-structure are considered in the modelling. The behaviour of designed models under dynamic loads is analysed using ETABS (Extended Three Dimensional Analysis of Building System) computer software. Bhuj Earthquake Data (Gujarat Earthquake) are chosen as the ground motions (i.e. Linear Time History Analysis). At the end of analysis (i.e. Linear Response Spectrum and Linear Time History Analysis), the response quantities are mode period, displacement, storey accelerations and base shear forces are compared and results are drawn for isolated and fixed-base structures.

INTRODUCTION

1.1 GENERAL

In most earthquakes, the collapse of structures like houses, schools, hospitals, historic and public buildings results in the widespread loss of lives and damage. Earthquakes also destroy public infrastructure like roads, dams and bridges, as well as public utilities like power and water supply installations. Past earthquakes show that over 95 per cent of the lives lost were due to the collapse of buildings that were not earthquake-resistant. Though there are building codes and other regulations which make it mandatory that all structures in earthquake-prone areas in the country must be built in accordance with earthquake-resistant construction techniques, new constructions often overlook strict compliance to such regulations and building codes. A large number of buildings in India have been constructed without due consideration to earthquake loads. Further, the earthquake loads are also under continual revision in successive revisions of codes. Buildings also deteriorate with time and get damaged due to earthquake, flood, fire, blast, etc. All these circumstances require evaluation and retrofitting of existing building.

1.2 PAST EARTHQUAKE IN INDIA

India's high earthquake risk and vulnerability is evident from the fact that about 59 per cent of India's land area could face moderate to severe earthquakes. During the period 1990 to 2006, more than 23,000 lives were lost due to 6 major earthquakes in India, which also caused enormous damage to property and public infrastructure. The occurrence of several devastating earthquakes in areas hitherto considered safe from earthquakes indicates that the built environment in the country is extremely fragile and our ability to prepare ourselves and effectively respond to earthquakes is inadequate. During the International Decade for Natural Disaster Reduction (IDNDR) observed by the United Nations (UN) in the 1990s, India witnessed several earthquakes like the Uttarkashi earthquake of 1991, the later earthquake of 1993, the Jabalpur earthquake of 1997, and the Chamoli earthquake of 1999. These were followed by the Bhuj earthquake of 26 January 2001 and the Jammu & Kashmir earthquake of 8 October 2005. In addition to recent earthquake in India, moderate earthquake near the East Nepal/India board (5M), Strong earthquake in Kashmir (5.6M), moderate earthquake near the India/Tibet board (5.1M) Uttaranchal, etc.

THE PURPOSE OF EARTHQUAKE ENGINEERING

The purpose of earthquake engineering is to:

Avoid the loss of lives resulting from the collapse of infrastructure or a building in a major earthquake (a design earthquake or ultimate limit state earthquake)

Limit personal injury and building damage (including contents) in moderate earthquakes (serviceability limit state earthquake). Infrastructure / building should be fully functional after a clean up

Minimize damage and disturbance to residents in moderate and minor earthquakes maintain the key function of the infrastructure / building

Protect the lives of those outside the building Protect other property & the environment.

LITERATURE REVIEW

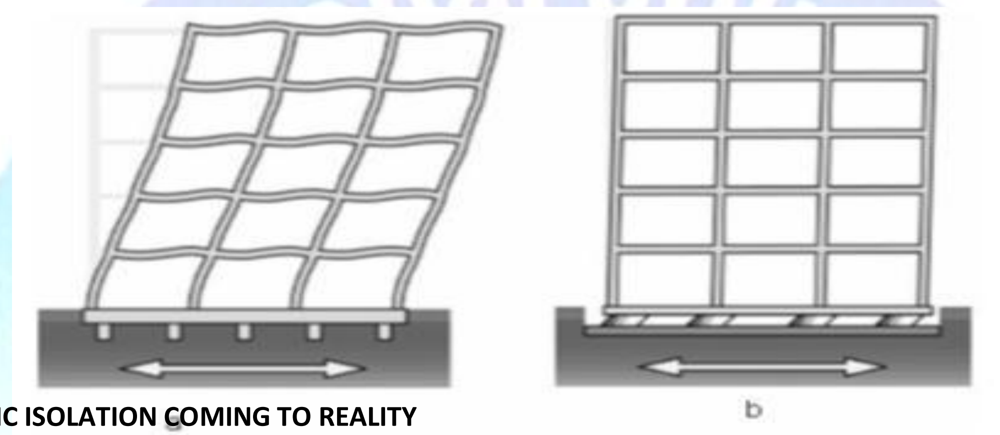
Hirasawa (1988), author present in this paper an actual example of aseismicdesign of a base isolated building and results of verification tests of the isolator and the building loading tests of the isolator indicate that the hysteretic loops are stable under repeated loading and the equipment damping ratio is large. As results of earthquake response analysis, the maximum acceleration response of the isolated building is about one fourth of that of non-isolated one. Results of forced vibration test and earthquake observation of the building has longer period and larger damping and reduces acceleration response as compared with non-isolated one.

Bill Robinson et.al (1993), have written a book called seismic isolation fordesigners and structural engineers. This book gives total insight into the practical methods of construction of seismically isolated buildings. The different types of isolation devices and their properties are discussed here. This book also has information on suitability of an isolator, site conditions, type of soil on while active or passive isolations can be installed are discussed here. This book provides both theory and design aspects of seismic isolation. This will be useful for structural engineers. For other structural components (concrete frames, steel braces etc.) the engineering student is taught the theory [lateral loads, bending moments) but then also the design (how to select sizes, detail reinforcing, bolts). This book will do the same for seismic engineering. The book also provides practical examples of computer applications as well as device design examples so that the structural engineer is able to do a preliminary design that won't specify constraints. The book also addresses the steps that need to be taken to ensure the design is code compliant.

BASE ISOLATION

3.1 INTRODUCTION

To minimize the transmission of potentially damaging earthquake ground motions into a structure is achieved by the introduction of flexibility at the base of the structure in the horizontal direction while at the same time Introducing damping elements to restrict the amplitude or extent of the motion caused by the earthquake somewhat akin to shock absorbers. In recent years this relatively new technology has emerged as a practical and economic alternative to conventional seismic strengthening. This concept has received increasing academic and professional attention and is being applied to a wide range of civil engineering structures. To date there are several hundred buildings in Japan, New Zealand, United States, India which use seismic isolation principles and technology for their seismic design.Seismic isolation is intended to prevent earthquake damage to structures, buildings and building contents. One type of seismic isolation system employs load bearing pads, called isolators. They are located strategically between the foundation and the building structure and are designed to lower the magnitude and frequency of seismic shock permitted to enter the building. They provide both spring and energy absorbing characteristics. Fig 3.1 illustrates the behaviour change of structure isolator and with isolator incorporation.



SEISMIC ISOLATION COMING TO REALITY

The first seismic isolation system was proposed by Dr. Johannes Calantarients, an English medical doctor, in 1909. His diagrams show a building separated from its foundation by a layer of talc which would isolate the main structure from seismic shock. The oldest base isolated structure of the world, Mausoleum of Cyrus, is shown in Fig 3.2

Fig 3.2: Mausoleum of Cyrus, the oldest base-isolated structure in the world

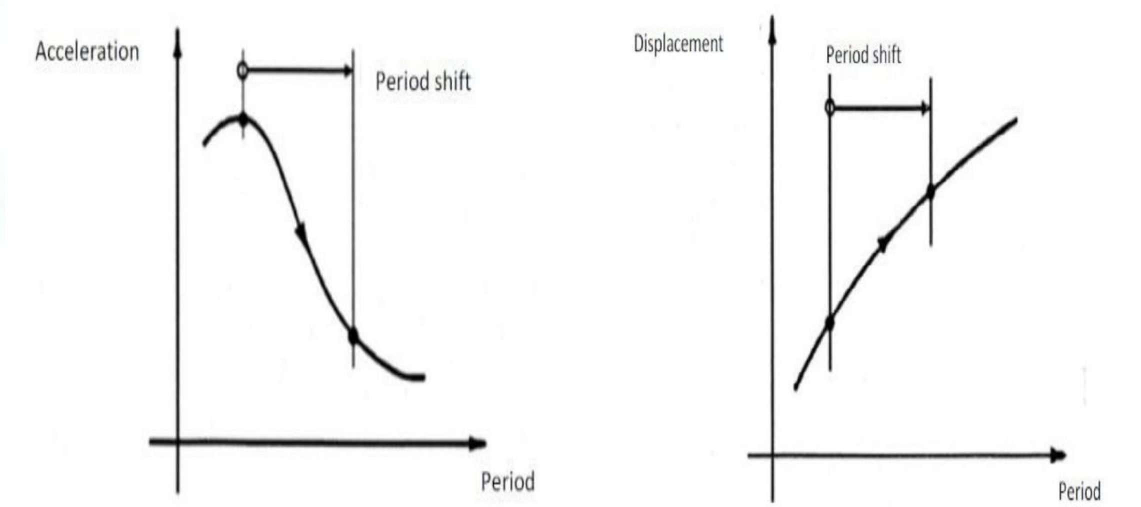
This technology can be used both for new structural design and seismic retrofit. In process of seismic retrofit, some of the most prominent U.S. monuments like Pasadena City Hall, San Francisco City Hall, Salt Lake City and County Building or LA City Hall. The seismic rehabilitation of the Los Angeles City Hall is a landmark event in the City's history. For Los Angeles City Hall (Fig 33a), in process of seismic upgrading, this high rise building was placed atop a mechanical system of isolators, sliders and dampers called base isolation technology. Later on a few famous isolated buildings have also been shown in Bhuj Hospital (Fig 3.3b), New Zealand Assembly Library (Fig 3.3c) and New Zealand Parliament (Fig 3.3d) have been erected on Lead Rubber bearing type base isolator.

BASIC ELEMENTS OF BASE ISOLATION

Seismic Isolation increases the fundamental period of vibration so that the structure is subjected to lower earthquake forces. However, the reduction in force is accompanied by an increase in displacement demand which must be accommodated within the flexible mount, Furthermore, longer period buildings can be lively under service loads. The following are three basic elements in any practical isolation system (Skinner et al., 1993), they are:A flexible mounting so that the period of vibration of the building is lengthened sufficiently to reduce the force response.A damper of energy dissipater so that the relative deflections across the flexible mounting can be limited to a practical design level.A means of providing rigidity under low (service) load levels such as wind and braking force. Isolation system was also inserted at Te Papa Museum of New Zealand (Fig 3.3e).

Flexibility

Due to additional flexibility the period of structure is elongated. From the acceleration response curve shown in Figure 3.4(a), it may be observed that reductions in base shear occur as the period of vibration of the structure is lengthened. The extent to which these forces are reduced is primarily dependent on the nature of the earthquake ground motion and the period of the non-isolated structure.



Impact of period elongation obtained by seismic isolation on accelerations b

(a) **Acceleration response spectrum, (b) displacement response spectrum and displacements of a structure**

COMPONENTS IN AN ISOLATION SYSTEM

The components in a seismic isolation system are specially designed, distinct from the structural members, installed generally at or near the base of the structure. However, in bridges, where the aim is to protect relatively low-mass piers and their foundations, they are more commonly between the top of the piers and the superstructure.The isolator's viscous damping and hysteretic properties can be selected to maintain all components of the superstructure within the elastic range, or at worst so as to require only limited ductile action. The bulk of the overall displacement of the structure can be concentrated in the isolator components, with relatively little deformation within the structure itself, which moves largely as a rigid body mounted on the isolation system. The performance can be further improved by bracing the structure to achieve high stiffness, which increases the detuning between the fundamental period of the superstructure and the effective period of the isolated system and also limits deformations within the structure itself. Both the forces transmitted to the structure and the deformation within the structure are reduced, and this simplifies considerably the seismic design of the superstructure, its contents and services, apart from the need for the service connections to accommodate the large displacements across the isolating layer.

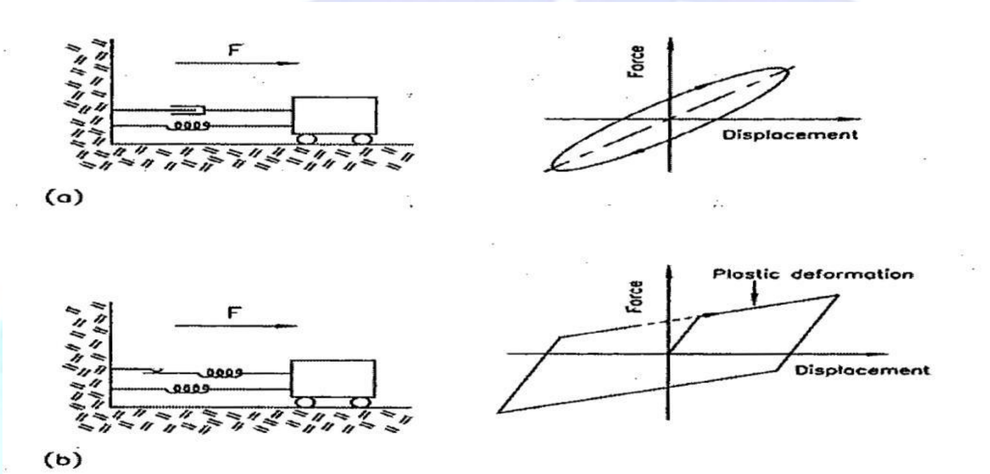


Fig 3.7: Schematic representation of the force-displacement hysteresis loops produced by (a) A linear damped isolator and (b) A bilinear isolator with a coulomb damper [7]

PRINCIPLES OF BASE ISOLATION

The fundamental principle of base isolation is to modify the response of the building so that the ground can move below the building without transmitting these motions into the building. In an ideal system this separation would be total. In the real world, there needs to be some contact between the structure and the ground. A building that is perfectly rigid will have a zero period. When the ground moves the acceleration induced in the structure will be equal to the ground acceleration and there will be zero relative displacement between the structure and the ground. A building that is perfectly flexible will have an infinite period. For this type of structure, when the ground beneath the structure moves there will be zero acceleration induced in the structure and the relative displacement between the structure and ground will be equal to the ground displacement. The structure will not move, the ground will.periods between zero and infinity, the maximum accelerations and displacements relative to the ground are a function of the earthquake, as shown conceptually in Figure 3.9 For most earthquakes there be a range of periods at which the acceleration in the structure will be amplified beyond the maximum ground acceleration. The relative displacements will generally not exceed the peak ground displacement that is the infinite period displacement, but there are some exceptions to this, particularly for soft soil sites and site which are located close to the fault generating the earthquake.

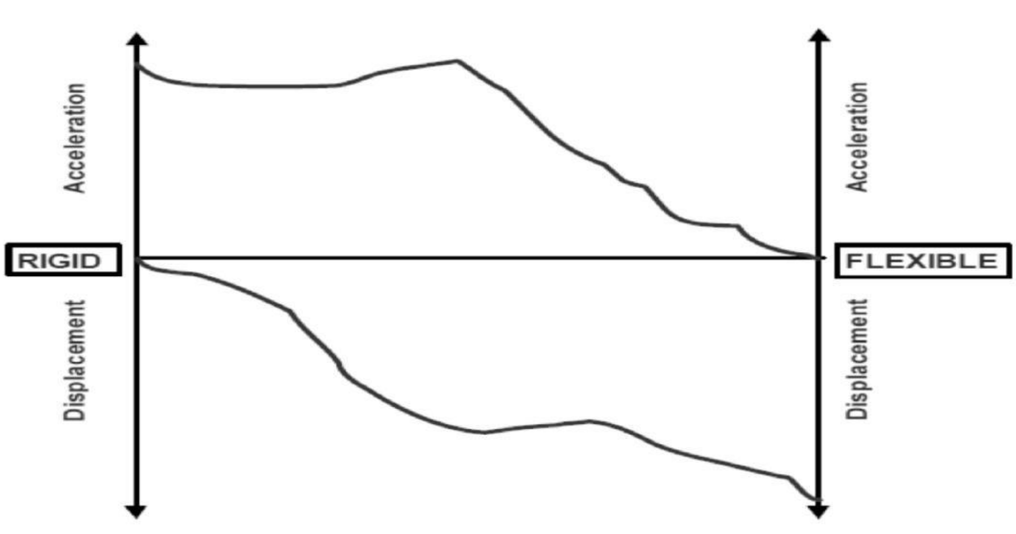


Fig 3.9: Structure acceleration and displacement [8]

TYPES OF BASE ISOLATORS

The most common types of base isolators used in buildings are

1. Elastomeric (rubber) bearings
2. Lead Rubber Bearing (LRB)
3. High Damping Rubber Bearing (HDRB)
4. Friction Pendulum System Bearing (FPSB)

CONCLUSIONS

In the present work the response of multi-storeyed building due to earthquake excitations has been carried out using finite element analysis on 4(G+3) and 8(G+7) types of structures i.e., RC bare frame with fixed base, bare frame with rubber isolator, Based on the studies carried out, the following conclusion may be drawn.

6.1.1

FOR G+4 STRUCTURES

Mode period (first mode or critical mode)

The ratio of mode period of bare frame (BF) with rubber isolator (RI) values was observed as 3.50 respectively. It clearly shows that the mode period for BF with RI is 250% higher value than BF with fixed base (FB) due to BF with RI are flexible.

Base shear

The ratios of base shear of bare frame (BF) with rubber isolator (RI) values were observed as 0.341 in x-direction, 0.344 in y-direction respectively. It clearly shows that the base shear for BF with RI is 66% lesser value than BF with fixed base (FB).

Displacement

The ratios of displacement of BF with RI to BF with FB values were observed as 2.91 in x-direction and 2.80 in y-direction respectively. It clearly shows that the displacement for BF with RI is 191% in x-direction, 180% in y-direction are higher value than BF with FB.The displacement is increased with the period at different storey level for the base isolated building. Increased flexibility of the system led to increase of the total displacement both in BF

Storey Acceleration

The ratios of acceleration at top story for BF with RI were observed as 0.220 in x-direction and 0.222 y-directions respectively. It clearly shows that the acceleration values of BF with RI are 22% and 22% are same BF with FB.In base-isolated structure large reduction in acceleration is observed with respect to fixed base structures (BF).

6.1.2 FOR G+8 STRUCTURES

Mode period (first mode or critical mode)

The ratio of mode period of bare frame (BF) with rubber isolator (RI) values was observed as 2.18 respectively. It clearly shows that the mode period for BF with RI is 118% higher value than BF with fixed base (FB) due to BF with RI are flexible.

Base shear

The ratios of base shear of bare frame (BF) with rubber isolator (RI) values were observed as 0.551 in x-direction, 0.563 in y-direction respectively. It clearly shows that the base shear for BF with RI is 44% lesser value than BF with fixed base (FB).

Displacement

The ratios of displacement of BF with RI to BF with FB values were observed as 1.79 in x-direction, 1.85 in y-direction respectively. It clearly shows that the displacement for BF with RI is 79% in x-direction, 85% in y-direction are higher value than BF with FB.The displacement is increased with the period at different storey level for the base isolated building. Increased flexibility of the system led to increase of the total displacement both in BF.

Storey Acceleration

The ratios of acceleration at top story for BF with RI and FI were observed as 0.32 in x and 0.34 y-directions respectively. It clearly shows that the acceleration values of BF with RI are 32% and 34% higher than BF with FB.

In base-isolated structure large reduction in acceleration is observed with respect to fixed base structures (BF).

SCOPE FOR FUTURE WORK

In this present study, symmetric plan is selected and further study can be carried out for asymmetric plan.Studies can be carried out for providing different types of isolator like elastomeric bearing, friction pendulum isolator, triple pendulum isolators in between column and footing.Studies can be carried out for lateral load resisting system like shear wall, masonry infill and bracings.Studies can be carried out for providing different types of dampers like viscous damper, tune mass dampers etc