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Study of Base Isolation Technique for Earthquake Resistant Structures

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Abstract - *Base Isolation technique is the most commonly used technique to protect a structure from earthquake. The idea behind this technique is to detach the superstructure from ground by introducing flexible isolators between foundation and superstructure. These isolators absorb energy or vibrations and protect structure from an earthquake. The base isolation technique is considered as one of the most suitable methods from last fifteen years because it stops the effect of earthquake attack. The flexible base helps to decouple a superstructure from its substructure built on a seismic ground and results in protecting the structure. This paper highlights the concept, principle of this technique. This paper also summarizes the various types of base isolators, their locations in the structure, comparison of fixed base vs base isolated structure and advantages and disadvantages of the technique.*

Key Words: base isolation technique, isolators, fixed base vs base isolated, advantages, disadvantages.

1. INTRODUCTION

Base isolation is also known as 'seismic base isolation' or 'base isolation system'. If the seismic isolation is provided in the foundation, then it is known as Base Isolation. It is one of the most popular means of protecting a structure against earthquake forces. Base means the part that serves as the foundation for the structure and Isolation means the state of being separated. It decouples a superstructure from its substructure resting on a shaking ground, thus protecting a building or non-building structure's integrity and provides flexibility and energy dissipation capability by inserting the isolated device called isolators between the foundation and the building structure. So the only ground will experience vibrations, when earthquake occurs. The structures with Base Isolation System are known as Base Isolated Structures.

It reduces the effect of an earthquake by essentially isolating the structure from potentially dangerous ground motions. Thus, it increases the fundamental period of the vibration so that the structure is subjected to lower earthquake forces. So the primary use of the Base Isolation is to mitigate the earthquake effects.

1.1 History

The first Base Isolation technique was proposed by Dr. Johannes Calanterients, an English Medical Doctor, in 1909 and introduced by engineers and scientists in early 1923 in New Zealand.

In India, base isolation technique was first demonstrated after the 1993 Killari (Maharashtra) Earthquake. Two single storey buildings (one school building and a shopping complex building) in newly relocated Killari town were built with rubber base isolators resting on hard ground. Both were brick masonry buildings with concrete roof. The four-storey Bhuj Hospital building was built with base isolation technique, after the 2001 Bhuj, (Gujarat) earthquake.

- 1st application in New Zealand in 1974
- 1st US application in 1984
- 1st Japanese application in 1985
- 1st Indian application in 2001

1.2 Applications

- Traditionally, the application of the system is seen in larger buildings and bridges.
- Base isolation techniques have been utilized worldwide for retrofitting historical structures and monuments to reduce any possible destruction.
- On a smaller scale, museums have started to use the system to ensure the security of artifacts.

2. CONCEPT

The concept of base isolation is explained through an example of a building resting on frictionless rollers. When the ground shakes, the rollers freely roll, but the building above does not move. Thus, no force is transferred to the building due to shaking of the ground and therefore, the building does not experience the earthquake. Now, if the same building is rested on flexible pads that offer resistance against the lateral movements due to an earthquake, then some effect of the ground shaking will be transferred to the building above. If the flexible pads are properly chosen, the forces induced in the building by ground shaking can be a few times smaller than that experienced by the building built directly on ground, namely a fixed base building. These flexible pads are known as base isolators and the structures protected by means of these isolators are called as base isolated buildings.

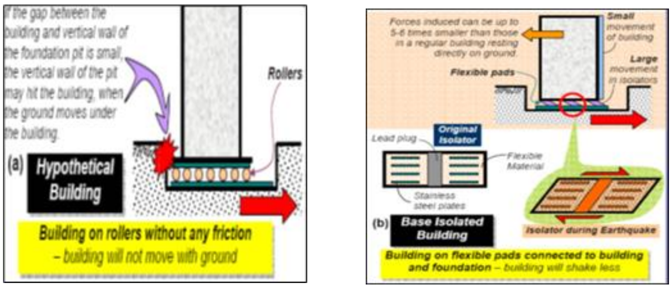

Fig.-1 : Concept of Base Isolation[3]

3. PRINCIPLE

The basic principle of this technique is "to modify the response of the building so that the ground can move below the building without transmitting these motions into the building".

A building that is perfectly rigid will have a zero period. As 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 such type of structure, when the ground below the structure moves, the acceleration induced in the structure will be zero and the relative displacement between the structure and ground will be equal to the ground displacement. All real structures are neither perfectly rigid nor perfectly flexible and so the response to ground motions is between these two extremes. For periods between zero and infinity, the maximum accelerations and displacements relative to the ground are a function of the earthquake.

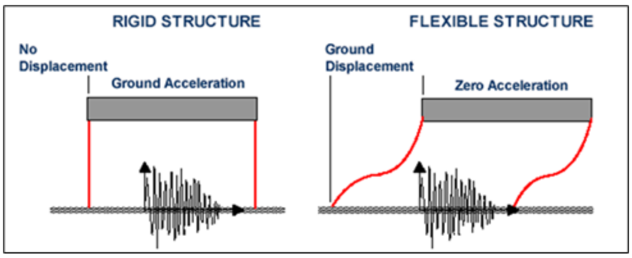

Fig.-2 : Principle of Base Isolation[5]

4. TYPES OF BASE ISOLATORS

4.1 Elastomeric Bearings

Elastomeric Bearings consist of horizontal layers of natural or synthetic rubber in thin layers bonded between the steel plates. These steel plates prevent the rubber layers from blown up or busting. The bearing is capable to support higher vertical loads with only very small deflection (typically 1 to 3 mm under full gravity load).

The internal steel layers also do not restrict horizontal deformations of the rubber layers in shear. Therefore, the bearings are much more flexible under lateral loads than vertical loads. Thus, the bearing works as a flexible unit.

4.1.1 Lead Rubber Bearings (LRB)

These elastomeric bearings consist of thin layers of low damping natural rubber and steel plates built in alternate layers and a lead cylinder plug firmly fitted in a hole at its center. The LRB was invented in New Zealand 1975 and has been used extensively in New Zealand and all over the world. These are the most commonly used base isolators. These bearings provide an elastic restoring force and also produces required amount of damping by selection of the appropriate size of lead plug.

These LRBs convert earthquake vibration to low speed motion. As horizontal stiffness of the multi-layer rubber bearing is low, strong earthquake vibration is lightened and the oscillation period of the building is increased. After an earthquake this restoring force returns the building to the original position. LRB mainly are of two shapes. One is conventional round and the other type is square.

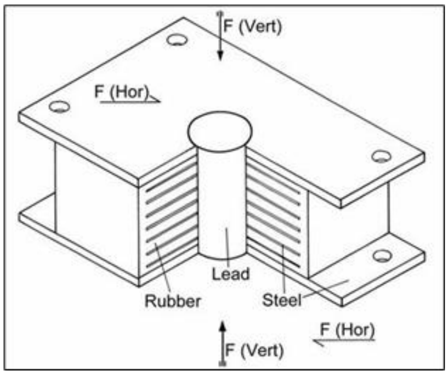

Fig.-3 (a) : Cross-section of LRB [4]

4.1.2 High Damping Rubber Bearings (HDRB)

These consist of thin layers of high damping rubber and steel plates in alternate layers. Like LRB this type of bearing does not contain any lead at the center of it. The rubber used in the bearings is either natural rubber or synthetic rubber which provide a sufficient amount of damping. The damping in the bearing is increased by adding an extra-fine carbon block, oils or resins and other proprietary fillers.

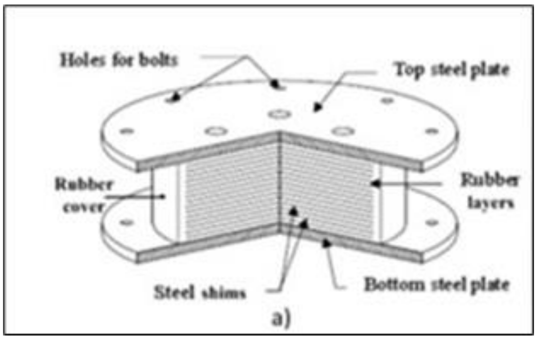

Fig.-3 (b) : Cross-section of HDRB [4]

4.2 Sliding Base Isolators

4.2.1. Flat Sliding Base Isolators

These type of isolators consist of a concave sliding plate. Due to geometry, each horizontal displacement results in a vertical movement of the isolator. They remain horizontally flexible, dissipate energy and reenter the superstructure into neutral position.

First use of sliding these bearings dates back to antique Persia (today Iran). There are evidences of pouring sand between the ground and the bearing walls of some historical structures in Iran. This would create a sliding mechanism for the structure during earthquakes. Current devices are mainly based on friction between stainless steel and Teflon.

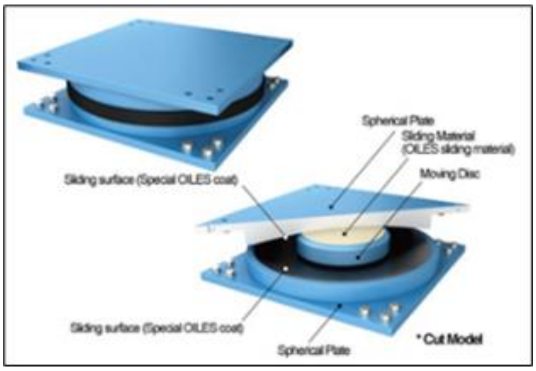

Fig.-4 (a) : Flat Sliding Base Isolator[7]

4.2.2. Friction Pendulum System

The friction pendulum system (FPS) is a sliding type base isolation system and it consists of a spherical stainless steel surface and an articulated slider, covered by Teflon based composite material. It works on the principle of simple pendulum. Friction Pendulum bearings are seismic isolators that are installed between a structure and its foundation to protect the supported structure from ground shakings during an earthquake.

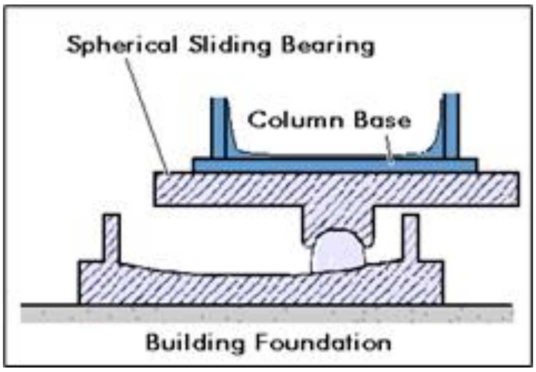

Fig.-4 (b) : Friction Pendulum System[4]

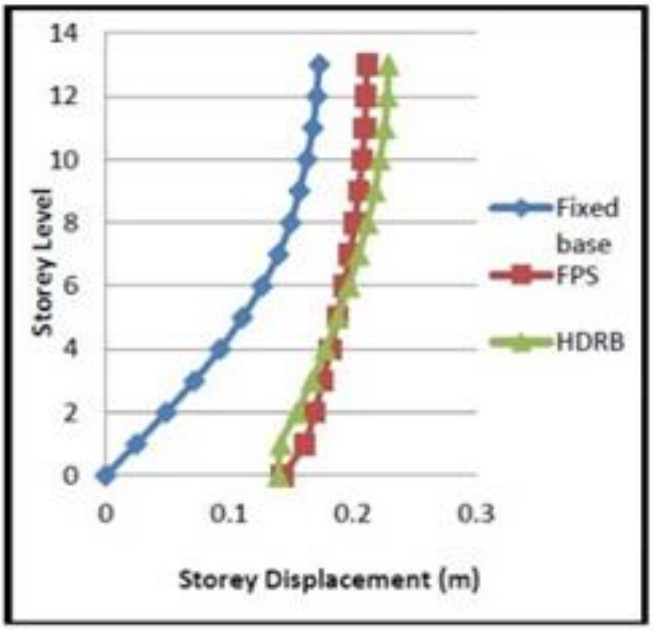

Fig.-4 (c) : Comparative Storey Displacement of a (G+12) building with HDRB and FPS[4]

5. LOCATIONS OF ISOLATORS

The basic requirement for installation of a base isolation system is that the building should be able to move horizontally relative to the ground, usually at least 100 mm or up to 1m. The most common configuration is to install a diaphragm immediately above the isolators. Due to this, earthquake loads are distributed to the isolators according to their stiffness. For a building without a basement, the isolators are installed on foundation pads and the structure is constructed above them. If the building has a basement then the options are to install the isolators at the top, bottom or mid height of the basements, columns and walls.

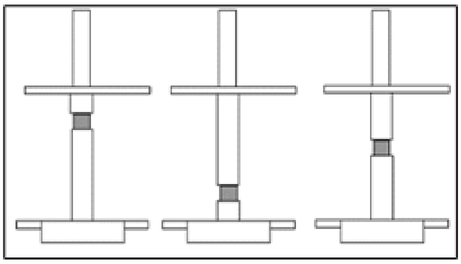

Fig.-5(a) : Locations of Isolators for Building having Basement[1]

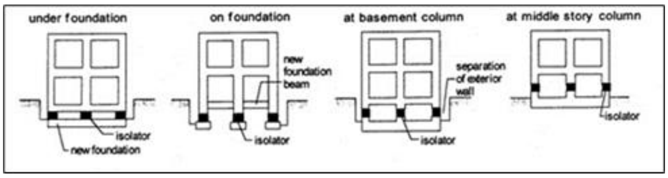

Fig.-5(b) : Locations of Isolators for Building no Basement[1]

6. FIXED BASE STRUCTURE VS BASE ISOLATED STRUCTURE

During an earthquake, the rigid base structure subjects to storey drifts and leads to damage or even collapse. Whereas the isolated base structure vibrates like conventional one with large displacements but regains its original position and does not collapse. The decoupling effect gives this extra advantage to isolated structures. In base isolated building, the lateral forces acting on the building are not only reduced in magnitude but also fairly redistributed over the floors, which further mitigates the overturning moment of the structure.

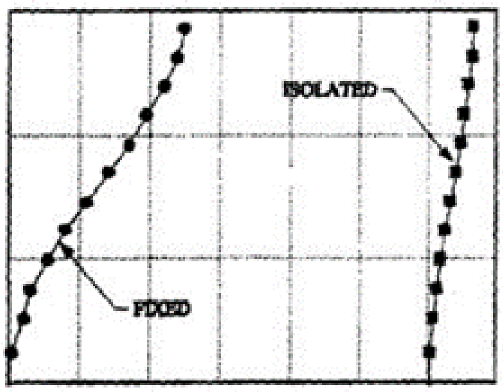

Fig.-6 : Deformation of Fixed Base Structure and Base Isolated Structure During an earthquake[8]

Mr. S. M. Dhawade and Mr. S. M. Harle studied the Seismic Performance of Fixed Based & Base Isolated RC Framed structure using ETABS.

The comparative results of a 13 storied fixed base building with a base isolated building is made. The base isolation system was composed of high damping rubber bearings. Design displacements were estimated using UBC-97 parameter. The comparison was made for the parameters like maximum storey displacements, maximum storey drift, base shear in X as well as in Y direction.

Table -1: Storey Displacement in X & Y Directions [2]

Storey No.	Storey Displacements (m)			
	In X - Direction		In Y - Direction	
	Fixed Base	Base Isolated	Fixed Base	Base Isolated
14	0.2782	0	0.1133	0
10	1.1534	0	0.4617	0
5	1.6643	0	0.6327	0
1	1.7961	0	0.1418	0
Base	0	0	0	0

Table -2: Storey Drift In X & Y Directions[2]

Storey No.	Storey Drift (m)			
	In X - Direction		In Y - Direction	
	Fixed Base	Base Isolated	Fixed Base	Base Isolated
14	0.2782	0.002	0.1133	0
10	1.1534	0.008	0.4617	0.002
5	1.6643	0.014	0.6327	0.003
1	0.2977	0.0031	0.1418	0.001
Base	0	0	0	0

Table -3: Lateral Load to Stories in X & Y Directions [2]

Storey No.	Lateral Load to Stories (kN)			
	In X - Direction		In Y - Direction	
	Fixed Base	Base Isolated	Fixed Base	Base Isolated
14	59.84	0.37	95.74	0.37
10	39.84	0.31	61.92	0.31
5	10.73	0.16	16.65	0.16
1	1.14	0.04	1.56	0.04
Base	0	0	0	0

Table -4: Storey Overturning Moments in X & Y Directions [2]

Storey No.	Storey Overturning Moment (kN-m)			
	In X - Direction		In Y - Direction	
	Fixed Base	Base Isolated	Fixed Base	Base Isolated
14	59.6	0.37	93.14	0.37
10	234.93	1.65	365.81	1.65
5	312.66	2.61	488.64	2.6
1	317.85	2.82	496.74	2.82
Base	317.85	2.82	496.74	2.82

7. ADVANTAGES AND DISADVANTAGES

7.1 Advantages

- Base isolation technique provides a better alternative to the conventional, fixed base design of structures especially for important structures like hospitals, etc.
- Base isolation has the effect of reducing the earthquake force demands on the superstructure upto the $1/4^{th}$ of the demands for a fixed-base structure.
- It restricts the Structural Damages to the building.
- Deflections and stresses generated in the building are lower.
- It protects the contents inside the building.
- Forces induced in a base isolated building can be up to 5-6 times smaller than those in a regular building resting directly on ground.

7.2 Disadvantages

- No national guidelines are available.
- It is challenging to implement in an efficient manner.
- Allowance for building displacements.
- Not suitable for buildings rested on soft soil.
- It cannot be applied partially to structures unlike other retrofitting techniques.
- Not economical.

8. CONCLUSIONS

- Seismic base isolation method has proved to be one of the most reliable methods of earthquake resistant Design.
- This technique protects the content inside the building and also restrict structural damages.
- The success of this technique is largely associated with the development of isolation devices and proper planning.
- The main purpose of the system is to protect people and infrastructures from the danger of seismic activity.
- Applicable isolation systems are required to be effective during a wide range of seismic events.
- There is a need of some more research in India on Base Isolation technique

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