MAHALAKSHMI
ENGINEERING COLLEGE
TIRUCHIRAPALLI – 621213

DEPARTMENT: CIVIL **SEMESTER: VII**

SUB.CODE/ NAME: CE2403/ BASICS OF DYNAMICS AND ASEISMIC DESIGN

UNIT – V
DESIGN METHODOLOGY

IS 1893, IS 13920 and IS 4326 – Codal provisions – Design as per the codes – Base isolation techniques – Vibration control measures – Important points in mitigating effects of earthquake on structures.

Two Marks Questions and Answers

1. What is the formula to find the load factors for plastic design of steel structures?

In plastic design of steel structures, the following load combinations shall be accounted for

1. 1.7(DL+IL)
2. 1.7(DL+EL)
3. 1.3(DL+IL+EL)

When Earthquake forces are considered on a structure, these shall be combined as per Load combination for plastic design of steel structures and partial safety factor for limit state deign of RC and PSC structures.

2. What are the methods of improving element level Ductility?

Ductility in element level is generally with reference to the displacement and moment curvature relationship of a section. This can be generally improved by

i. Decreasing the tension steel area, yield stress and strain of the tension steel increasing the ultimate compressive strain of concrete.
ii. Increasing the area of compression steel.
iii. Reduction in the axial compression on the section.
iv. Provision of effective confinement stirrups, hoops or ties such that

compressive steel does not buckle and concrete is led into three dimensional state of stress such that its ultimate compressive strain increases.

3. Write the IS 13920 provisions for flexural members.

The provisions apply to frame members resisting earthquake induced forces and designed to resist flexure. These members shall satisfy the following provisions

(a) The factored axial stress on the member under earthquake loading shall not exceed 0.1fck.

(b) The member shall preferable have a width to depth ratio more than 0.3

(c) Width of the member shall not be less than 200mm.

(d) The depth D of the member shall preferably be not more than ¼ of clear span.

4. What is the formula for finding out the Base shear using seismic co efficient method?

$$V_B = K C \alpha_h W$$

Where, V_B = is base shear, K is performance factor

C is a co – efficient depending on the flexibility of the structure
α_h is design seismic co – efficient.

5. Write a short notes on Review of Indian Code IS 1893 (1984)

IS 1893 (1984) gives the Necessary criteria for the earthquake resistant design of structures. This code states that structures should withstand without structural damage, moderate earthquakes and withstand without total collapse, heavy earthquakes.

This code specifies two methods of analysis

i. Seismic co-efficient method

ii. Modal analysis or Response Spectrum method.

6. What are the structural protective systems?

Modern protective system is based on (i) Seismic base isolation (ii) Passive energy dissipaters (iii) Semi active and active systems. Passive energy dissipaters are classified as hysteric, design seismic co – efficient design seismic co – efficient Visco – elastic and others based on the devices used. Eg yielding of metals through sliding friction

7. Write a short note on Mechanism of Base isolation.

The Mechanism of base isolation subjected to ground motion. The isolation reduces the fundamental lateral frequency of the structure from its fixed base frequency and thus shifts the position of structure in the spectrum from peak plateau region. Also it brings forth additional damping due to the increased damping introduced at the base level and thus reduction in the spectral acceleration is achieved.

8. Write down the steps to improve Global level Ductility?

(a) Increasing the redundancy of the structure

(b) Weak bam and strong column approach.

(c) Avoiding soft first storey effects

(d) Avoiding Non – ductile failure modes like shear, bond and axial compression at the element level

9. Define lateral load analysis of building system.

Earthquake force is an inertia force which is equal to mass times acceleration. Mass of the building is mainly located at its floors. Transferring the horizontal component of seismic force safely to the ground is the major task in seismic design. The floors should transfer the horizontal force to vertical seismic elements viz., columns, frames, walls and subsequently to the foundation finally to the soil.

10. Write a short note on Indian seismic codes.

The codes ensure safety of buildings under earthquake excitation IS 1893 – 1962, recommendations for earthquake resistant design of structures. IS 1893 – 1984 the country has divided into five zones in which one can reasonably forecast the intensity of earthquake shock which will occur in the event of future earthquake.

11. Define the term DBE, MCE and MMI.

DBE: Design Basics Earthquake

MCE: Maximum Considered Earthquake

MMI: Mercalli Intensity Scale

12. What is the design philosophy adopted for earthquake resistant structure?

The extreme loading condition caused by an earthquake and also the low probability of such an event occurring within the expected life of a structure, the following dual design philosophy is usually adopted

i. The structure is designed to resist the expected intensity of ground motion due to a moderate earthquake so that no significant damage is caused to the basic structure and

ii. The structure should also be able to withstand and resist total collapse in the unlikely event of a severe earthquake occurring during its lifetime. The designer is economically justified in this case to allow some marginal damage but total collapse and loss of life must be avoided.

13. Write down the formula to find out the Magnitude as per the IS code.

The amount of strain energy released at the source is indicated by the magnitude of the earthquake.

Magnitude = Log_{10} (A_{max})

Where A is the maximum aptitude in microns (10^{-3}m) recorded by Wood – Anderson seismograph. If E is the energy released, then

Log E = 11.8 + 1.5 M

14. What do you understand by response spectrum?

A Response spectrum is the plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified load function X_a (t) for all possible SDOF systems (having different natural frequencies or time periods T and a constant damping ratio).

15. Why is base isolation effective?

The base isolation systems reduce the base shear primarily because the natural vibration period of the isolation mode, providing most of the response, is much longer than the fundamental period of the fixed base structure, leading to a much smaller spectral ordinate. The higher modes are essentially not excited by the ground motion; although their pseudo acceleration is large their modal static responses are very small.

The primary reason for effectiveness of base isolation in reducing earthquake induced forces in a building is the lengthening of the first mode period. The damping is the isolation system and associated energy dissipation is only a secondary factor in reducing structural response.

16. Explain two cases of design horizontal earthquake load.

(a) When the lateral resisting elements are oriented along orthogonal horizontal direction, the structure shall be designed for the effects due to full design earthquake load in one horizontal direction at time.

(b) When the lateral load resisting elements are not oriented along the orthogonal horizontal directions, the structure shall be designed for the effect due to full design earthquake load in one horizontal direction plus 30% of the design earthquake load in the other direction.

17. Write the formula for modal mass (M_k).

The modal mass $\mathbf{M_k}$ of mode k is given by:

$$M_k = \frac{\left[\sum_{i=1}^{n} W_i \, \phi_{ik}\right]^2}{g \sum_{i=1}^{n} W_i \, (\phi_{ik})^2}$$

18. Explain design eccentricity.

The design eccentricity, to be used at floor I shall be taken as:

$$e_{di} = \begin{cases} 1.5\, e_{si} + 0.05 b_i \\ or\ e_{si} - 0.05 b_i \end{cases}$$

Whichever of these gives the more severe effect in the shear of any frame

Where = Static eccentricity

= defined as the distance between centre of mass and centre of rigidity

b_i = floor plan dimension of floor

19. What is additive shear?

Additive shear will be super-imposed for a statically applied eccentricity of ± 0.0 with respect to centre of rigidity.

20. Name types of damper's.

(i) Metallic dampers or yielding dampers

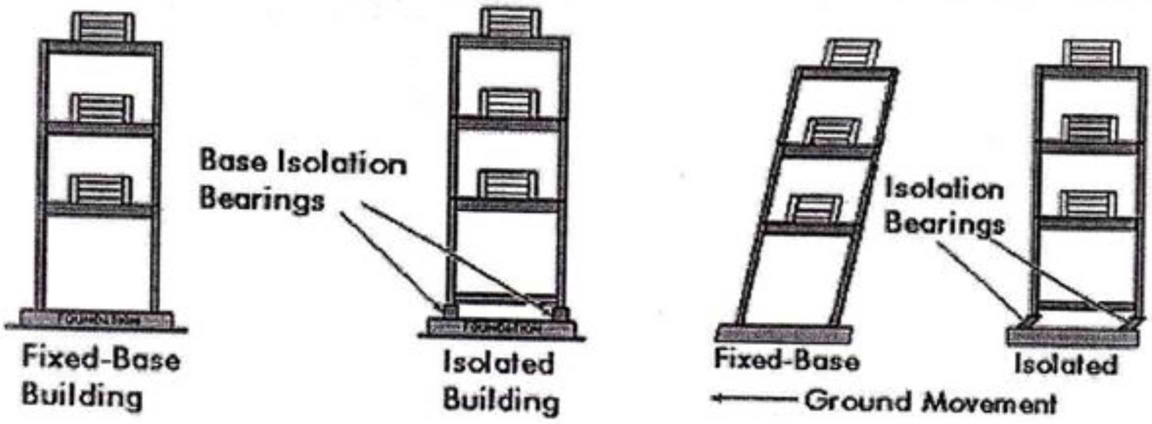
(ii) Friction dampers

(iii) Viscous dampers.

16 MARKS

1. Explain the Concept of Base Isolation Technique? May | June 2009

It is easiest to see the principle at work by referring directly to the most widely used of these advanced techniques, known as base isolation. A base isolated structure is supported by series of bearing pads, which are placed between the buildings and building foundation.



Base Isolation Technique

Concept of Base Isolation

One of the most widely implemented and accepted seismic protection systems is base isolation. Seismic base isolation is a technique that mitigates the effects of an earthquake by essentially isolating the structure and its contents from potentially dangerous ground motion, especially in the frequency range where the building is most affected. The objective is to simultaneously reduce inter-storey drifts and floor accelerations to limit or avoid damage, not only to the structure but also to its contents, in a cost-effective manner.

Seismic base isolation is emerging as on alternative approach for earthquake protection of structures. The basic concept in this approach is to uncouple a structure from the ground by interposing a flexible element bearing between the structure and foundation. Many buildings have been constructed on some type of rubber bearings, and such structures have shown superior performance in earthquakes.

The aim of base isolation is to minimize the energy that is transferred from ground motion to the structure by buffering it with a bearing layer at the foundation which has relatively low stiffness. The bearing level has a longer period than the superstructure, which reduces the force and displacement demands on the superstructure, allowing it to remain elastic and generally undamaged. As a result of flexibilization, the natural period of the past fixed-base structures undergo a jump and the new base isolation structure has a new natural period. The flexibility of the interposing layers between structure and its foundation lead to a bigger fundamental period for structural ensemble.

Need for Base Isolation

Base isolation technique is necessary for the following situations:

- Building is located in a high seismic intensity zone
- Building should be operational in post-earthquake period such as hospital, school, wate tank, etc.
- Limitations exist with lateral force restraining system or due to construction scheme suc as precast construction scheme or masonry construction scheme.
- Existing structure is unsafe
- Minimise the damage to primary and secondary structural members and
- Cost economics of the structure with and without isolators

Mechanism of Base Isolation

The isolation reduces the fundamental lateral frequency of the structure from its fixe base frequency (or increases the time period of the structure) and thus shifts the position (structure in the spectrum from the peak-plateau region to the lower regions. Also it brings fort additional damping due to the increased damping introduced at the base level and thus furth reduction in the spectral acceleration is achieved.

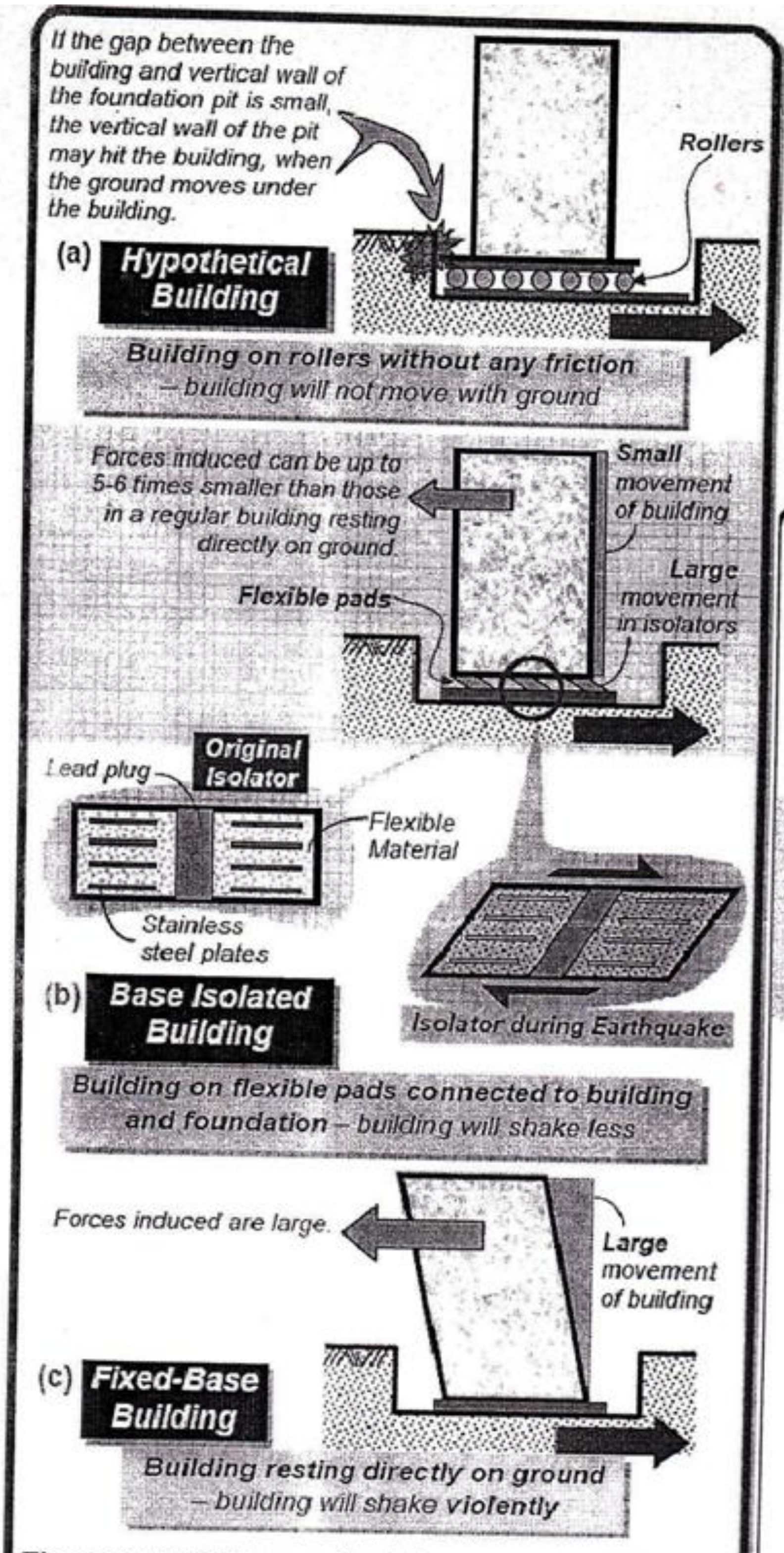
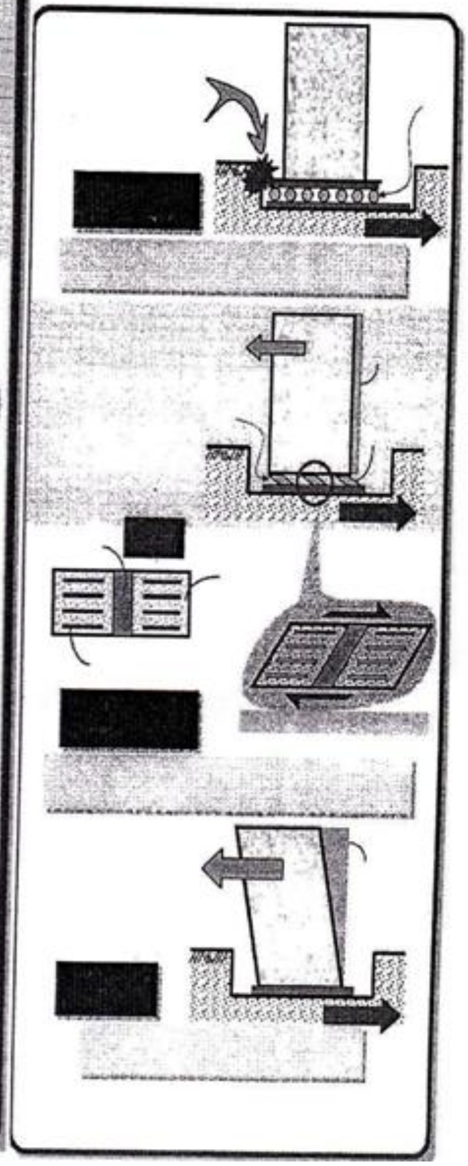


Figure 1: Building on flexible supports shakes lesser – *this technique is called* **Base Isolation.**



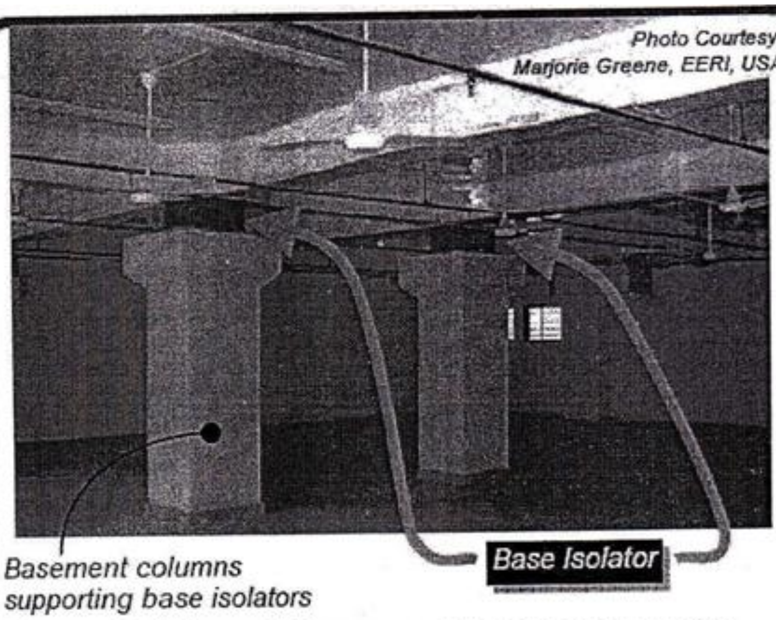


Figure 2: View of Basement in Bhuj Hospital building – *built with base isolators after the original District Hospital building at Bhuj collapsed during the 2001 Bhuj earthquake.*

Concept of Base Isolation

Lead-rubber bearings are the frequently-used types of base isolation bearings. A lead rubber bearing is made from layers of rubber sandwiched together with layers of steel. In the middle of the solid lead "plug". On top and bottom, the bearing is fitted with steel plates which are used to attach the bearing to the building and foundation. The bearing is very stiff and strong in the vertical direction, but flexible in the horizontal direction.

How it Works

To get a basic idea of how base isolation works, first examine the above diagram. This shows an earthquake acting on base isolated building and a conventional, fixed- base, building. As a result of an earthquake, the ground beneath each building begins to move. . Each building responds with movement which tends towards the right. The buildings displacement in the direction opposite the ground motion is actually due to inertia. The inertia forces acting on a building are the most important of all those generated during an earthquake.

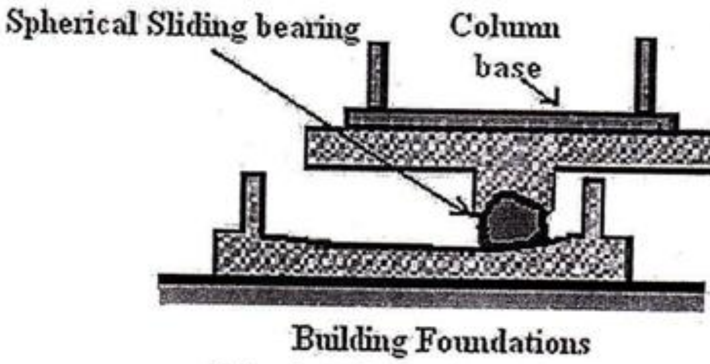
In addition to displacing towards right, the un-isolated building is also shown to be changing its shape from a rectangle to a parallelogram. We say that the building is deforming The primary cause of earthquake damage to buildings is the deformation which the building undergoes as a result of the inertial forces upon it.

Response of Base Isolated Buildings

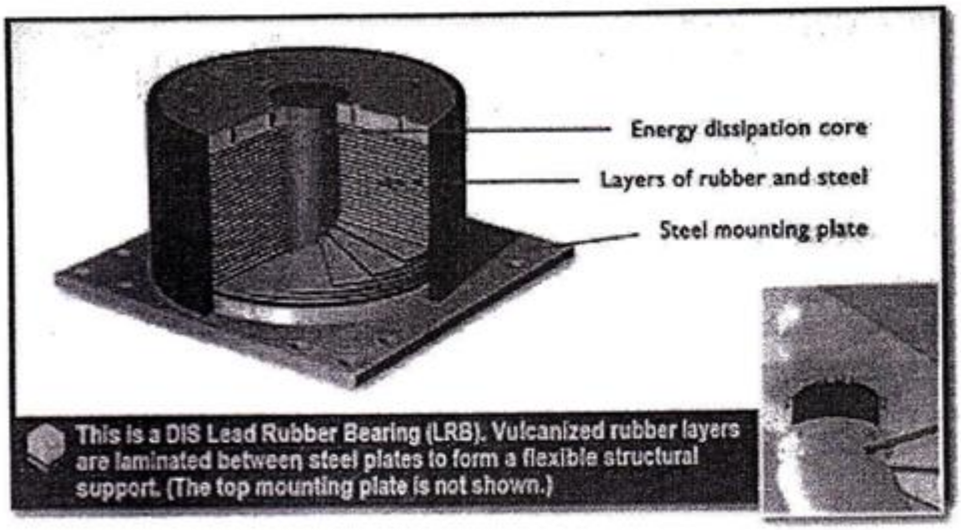
The base-isolated building retains its original, rectangular shape. The base isolated building itself escapes the deformation and damage-which implies that the inertial forces acting on the base isolated building have been reduced. Experiments and observations of base-isolated buildings in earthquakes to as little as ¼ of the acceleration of comparable fixed-base buildings.

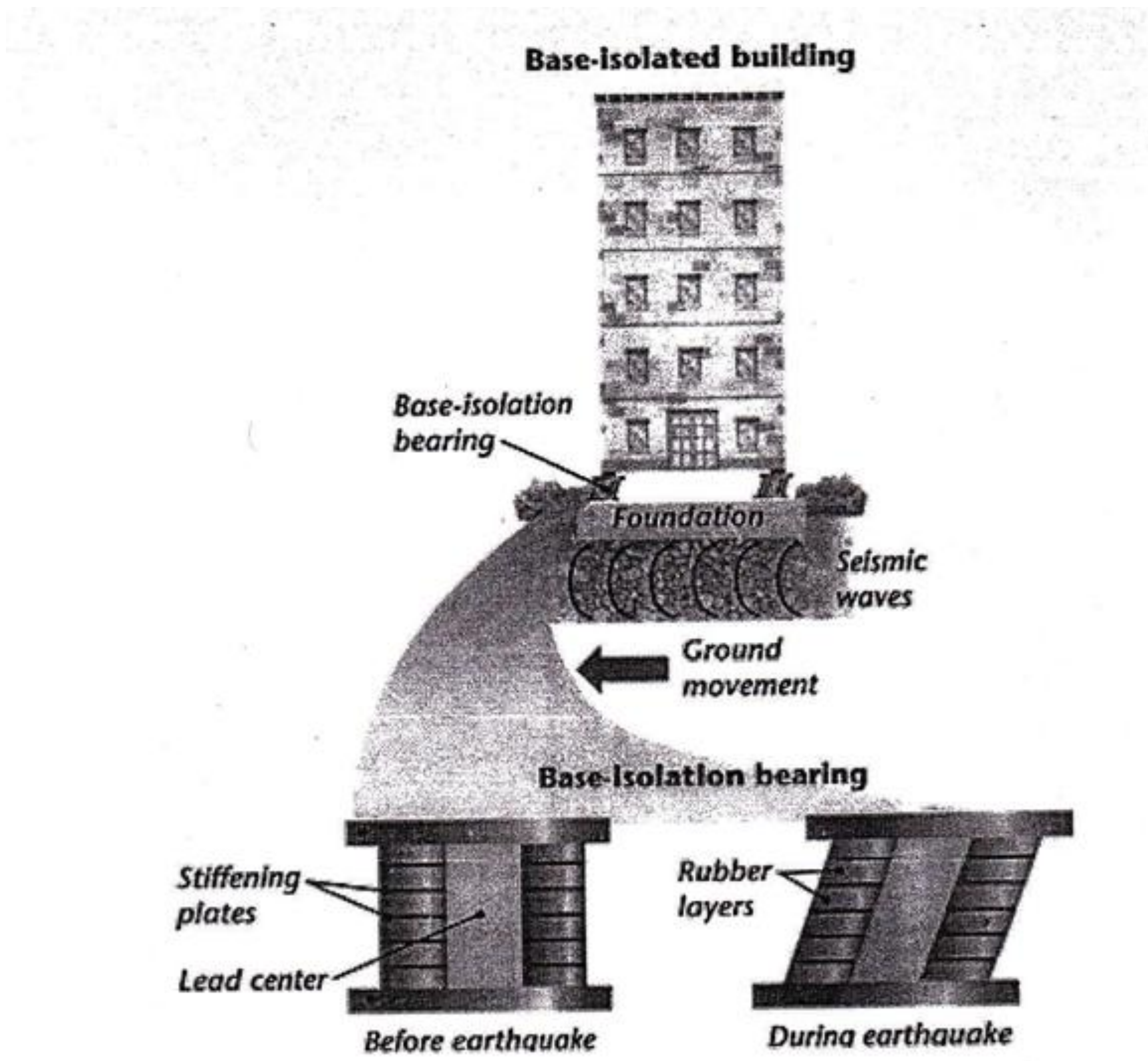
Acceleration is decreased because the base isolation system lengthens a buildings period of vibration, the time it takes for a building to rock back and forth and then back again. And in general, structures with longer periods of vibration tend to reduce acceleration, while those with shorter periods tend to increase or amplify acceleration.

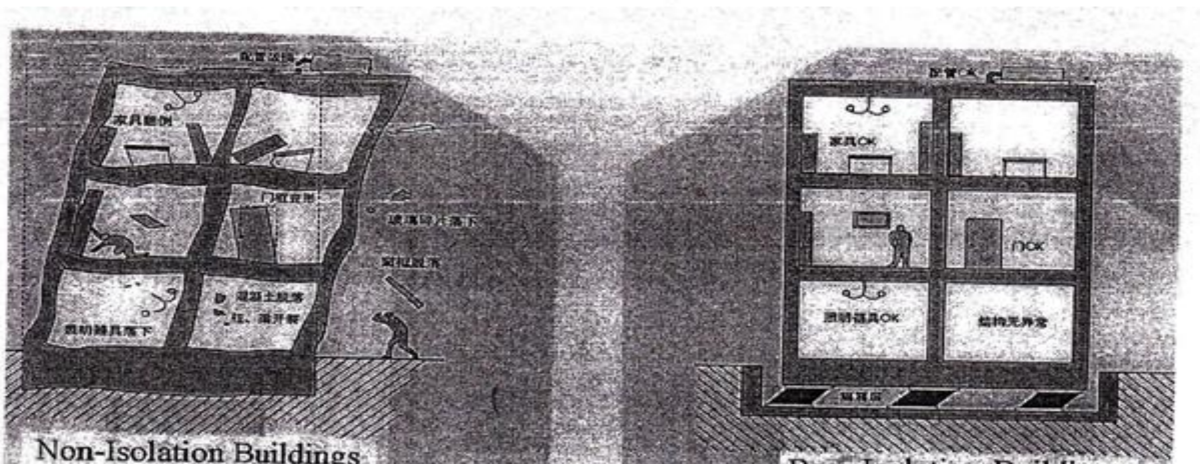
Spherical Sliding Base Isolation



Spherical Sliding Isolation Bearing



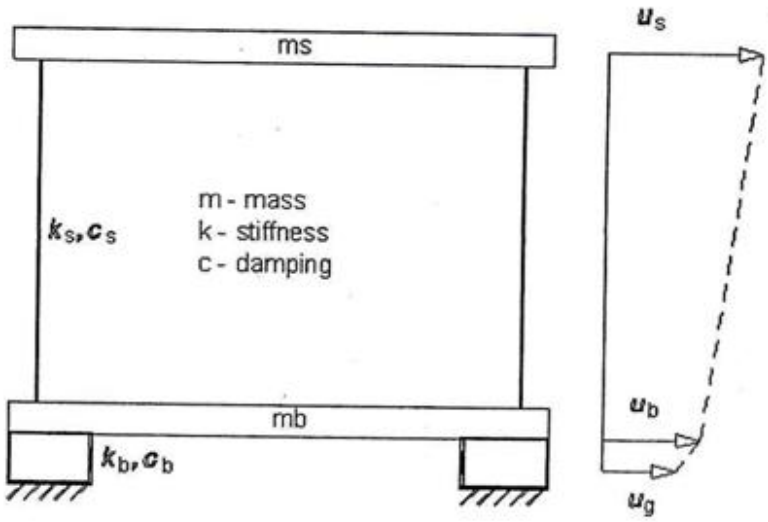

Base-isolated building
Base-isolation bearing
Foundation
Seismic waves
Ground movement
Base-Isolation bearing
Stiffening plates
Lead center
Rubber layers
Before earthquake
During earthquake


Non-Isolation Buildings
Base Isolation Buildings

Spherical Sliding Base Isolation

Spherical sliding isolation systems are another type of base isolation. The building is supported by bearing pads that have a curved surface and low friction. During an earthquake the building is free to slide on the bearings. Since the bearings have a curved surface, the building slides both horizontally and vertically.

The forces needed to move the building upwards limits the horizontal or lateral forces which would otherwise cause building deformations. Also by adjusting the radius of the bearings curved surface, this property can be used to design bearings that also lengthen the buildings period of vibration



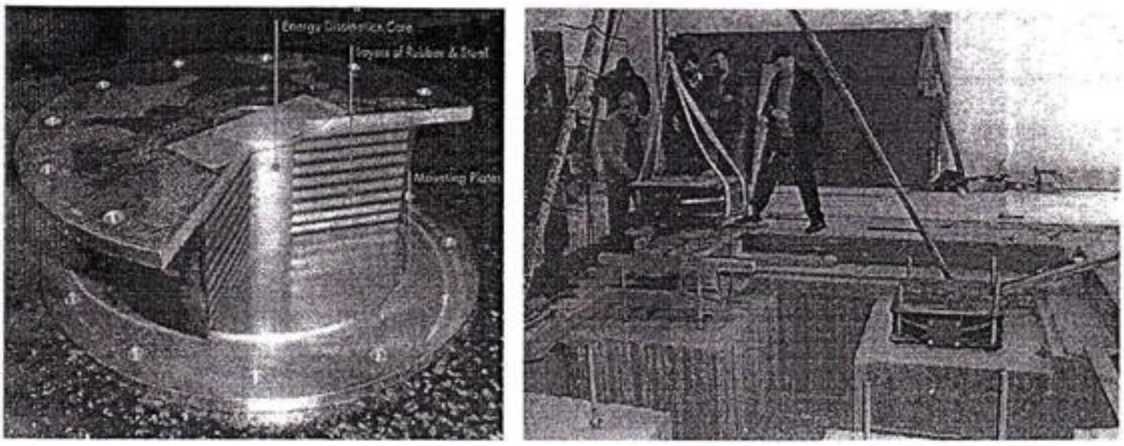


Fig (b) Typical Isolator

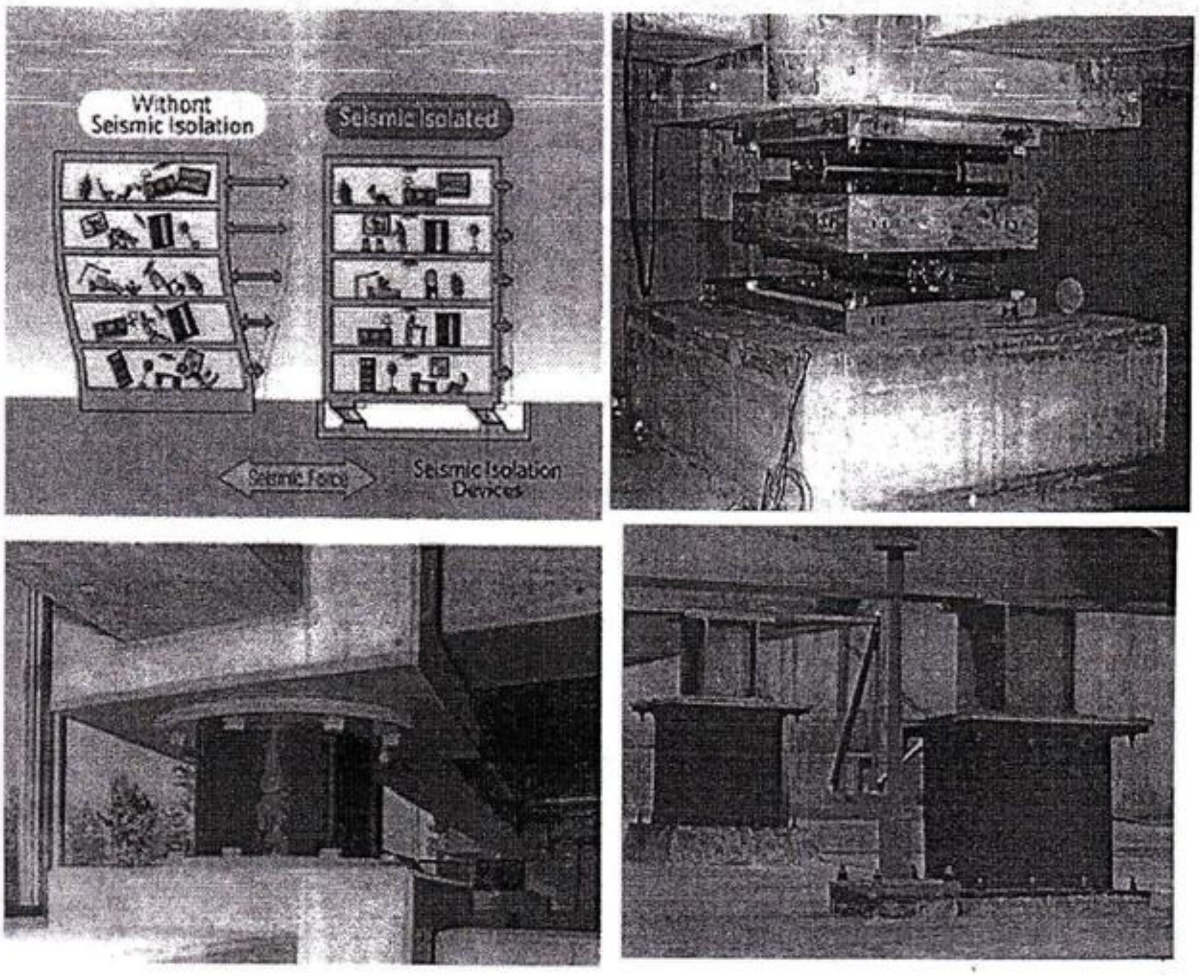


Fig (a) Isolator

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3. Explain the Types of Seismic Base Isolation System May | June 2009

- ✓ There are two basic types of isolation systems. The system that has been adopted most widely in recent years is typified by the use of elastomeric bearings, where the elastomer is made of either natural rubber or neoprene. In this approach, the building or structure is decoupled from the horizontal components of the earthquake ground motion by interposing a layer with low horizontal stiffness between the structure and the foundation.
- ✓ This layer gives the structure, a fundamental frequency that is much lower than its fixed-base frequency and also much lower than the predominant frequencies of the ground motion. The first dynamic mode of the isolated structure involves deformation only in the isolation system, the structure above being to all intents and purposes rigid.
- ✓ The higher modes that will produce deformation in the structure are orthogonal to the first mode and consequently also to the ground motion. These higher modes do not participate in the motion, so that if there is high energy in the ground motion at these higher frequencies, this energy cannot be transmitted into the structure.
- ✓ The Isolation system does not absorb the earthquake energy, but rather deflects it through the dynamics of the system. This type of isolation works when the system is linear and even when undamped; however, some damping is beneficial to suppress any possible resonance at the isolation frequency.
- ✓ The second basic type of isolation system is typified by the sliding system. This works by limiting the transfer of shear across the isolation interface. The sliding systems are simple in concept and have a theoretical appeal.
- ✓ A layer with a defined coefficient of friction will limit the accelerations to this value and the forces which can be transmitted will also be limited to the coefficient of friction times the weight. Sliding movement provides the flexibility and force---displacement trace provides a rectangular shape that is the optimum for equivalent viscous damping.

Response of Buildings

- ➢ As a result of an earthquake, ground beneath each building begins to move, say first to left, building responds with movement, which tends toward the right that is the building undergoes displacement towards right (Fig c).
- ➢ The building's displacement in the direction opposite to ground motion is actually due to inertia. The inertial forces acting on a building are the most important of all those generated during an earthquake. But when the ground shakes, isolated buildings do not move. No inertia force is transferred to the building due to shaking of ground. The inertia force acting on buildings have been reduced.

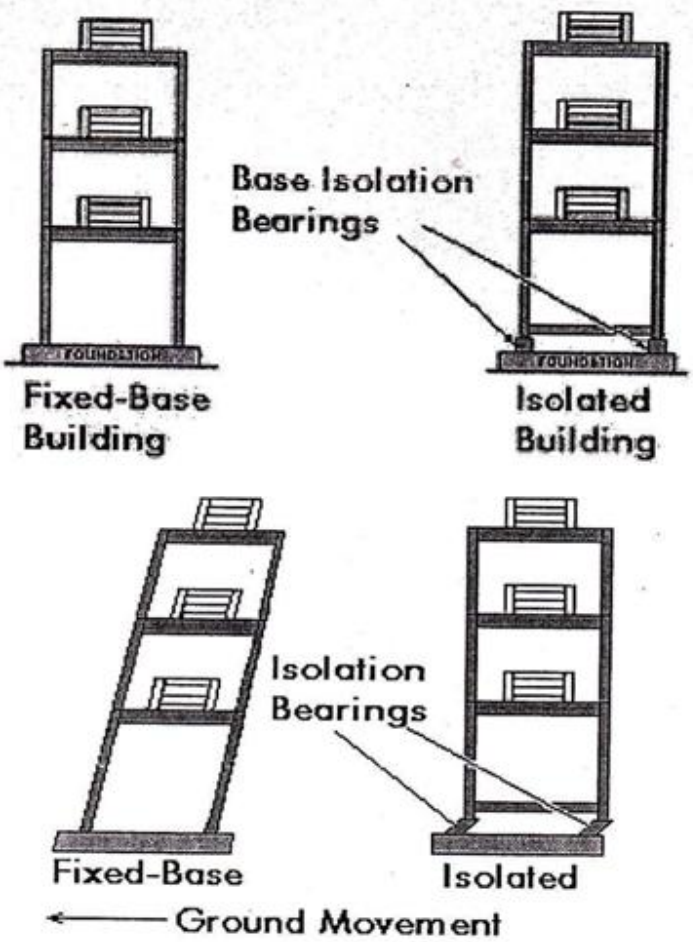


Fig (c)

- Acceleration is decreased because base isolation system lengthens a building's period of vibration. And in general, structures with longer periods of vibration tend to reduce acceleration, while those with shorter periods tend to increase or amplify acceleration. The inertial forces which the building undergoes are proportional to the building's acceleration during ground motion.

Criteria to be met by Building for Effective Base Isolation

The following are criteria for an effective base isolation system:

- ✓ Not founded on soft soil
- ✓ Buildings of low to medium height *(H/L < 1,f(O.I-O.3* Hz), and unusually heavy)
- ✓ Contents of building sensitive to high frequency vibration
- ✓ Lateral loading system making the building rigid
- ✓ Wind lateral load and other non-earthquake loads < 10% weight of structure.

4. Why is Base Isolation Effective?

- The base isolation systems reduce the base shear primarily because the natural vibration period of the isolation mode, providing most of the response, is much longer than the fundamental period of the fixed-base structure, leading to a much smaller spectral ordinate.
- The higher modes are essentially not excited by the ground motion, although their pseudo-accelerations are large because their modal static responses are very small.
- The primary reason for effectiveness of base isolation in reducing earthquake induced forces in a building is the lengthening of the first mode period. The damping in the isolation system and associated energy dissipation is only a secondary factor in reducing structural response.

5. Applications of Base Isolation May/June 2009

- Base isolation systems are found useful for short period structures, say less than 0.7 s including soil-structure interaction. Base isolation provides an alternative to the conventional, fixed-base design of structures and may be cost-effective for some new buildings in locations where very strong ground shaking is likely.
- It is an alternative for buildings that must remain functional after a major earthquake (e.g. hospital, emergency communications centres, computer processing centres, etc.). Several new buildings have been isolated using rubber or elastomeric bearings.
- Several commercial brands of base isolators are now available in the market especially in foreign countries. Care should be taken to identify the most suitable type of device for a particular building. These examples are described as follows.

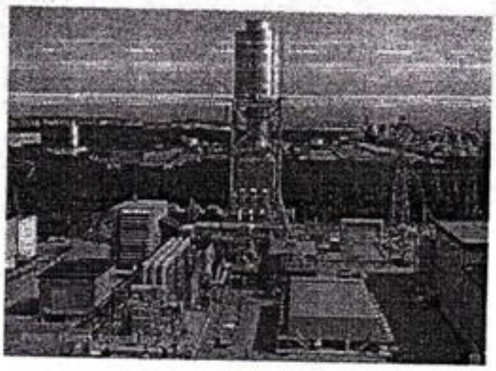
(i) U.S. Applications

The first base-isolated building in the United States is the Foothill Communities Law and Justice Center at Los Angeles (Fig d). Completed in 1985, the building is four stories high with a full basement and sub-basement for the isolation system, which consists of 98 isolators of multilayered natural rubber bearings reinforced with steel plates.

The University of Southern California Teaching Hospital in eastern Los Angeles is an eight- story concentrically braced steel frame supported on 68 lead rubber isolators and 81 elastomeric isolators, constructed in 1991 (Fig e).

(ii) Base Isolation in Japan

The system most commonly used in the past has been natural rubber bearings with mechanical dampers or lead-rubber bearings. Recently, however, there has been an increasing use of high-damping natural rubber isolators.



There are now several large buildings that use these high-damping bearings: an outstanding example is the computer center *for* the Tohoku Electric Power Company in Sendai, Miyako Province Fig (f).

(III) Base Isolation in India

The first base isolated structure is the new 30,000 m2 with 300 beds, Bhuj Hospital, Gujarat reconstructed after the devastating earthquake of 26 Jan 2001 (Figure 18.9). It is reputed to be able to stand a force of tremor on the Richter scale 10.

Figure 18.9 Bhuj hospital, Gujarat.

It is being founded on Robinson Seismic Lead Rubber Bearings which will give it the highest possible earthquake protection. This will protect the patients and ensure that the hospital will remain operational following future seismic attacks.

6. Write short notes on anyone type of dampers with neat sketch. May | June 2013

Damping refers to any process that causes an oscillation in a system to decay rapidly to zero amplitude. It is a very important phenomenon in vibration suppression or isolation. Damping causes the energy to be diverted from vibration to other energy sinks.

Dampers can be installed in the structural frame of a building to absorb some of the energy going into the building from the shaking ground during an earthquake. Thus the dampers reduce the energy available for shaking the building. This means that the building deforms less, so the chance of damage is reduced. Thus by equipping a building with additional devices which have high damping capacity, we can greatly decrease the seismic energy entering the building.

Types of Dampers

Commonly used types of seismic dampers include:

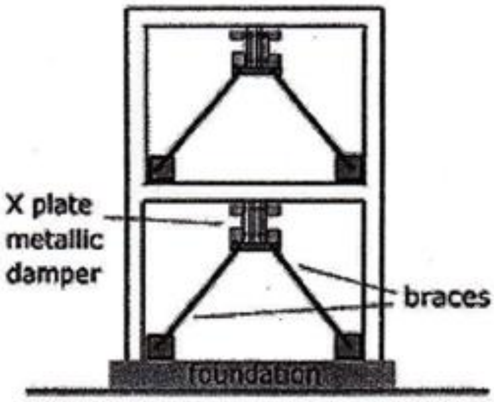
1.Metallic dampers or Yielding dampers

2.Friction dampers

3.Viscous dampers

1. **Metallic dampers or Yielding dampers**

Metallic dampers are made up of steel. In this type, the *energy* is absorbed by metallic components that yield. They are designed to deform so much when the building vibrates during
an earthquake, which they cannot return to their original shape.



2 storey steel frame with metallic dampers in position

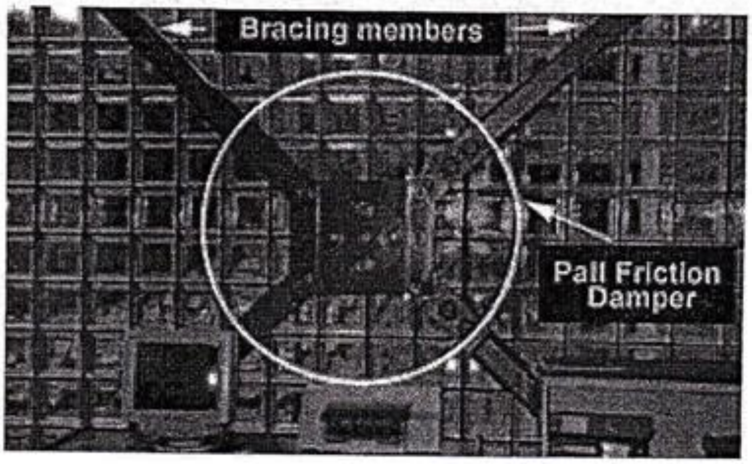
This permanent deformation is called inelastic deformation. It uses some of the earthquake energy, which goes into building. There are different types of metallic dampers. X shaped plate dampers are used where two braces meet (Fig). As the building vibrates, the braces stretch and compress, pulling and pushing the damper sideways and making it deform.

2. **Friction dampers**

Friction dampers are designed to have moving parts that will slide over each other during a strong earthquake. When the parts slide over each other, they create friction, which uses some of the energy from the earthquake that goes into the building.

The damper is made up from a set of steel plates, which have slotted holes in them, and they are bolted together. At high enough forces, the plates can slide over each other creating friction. The plates are specially treated to increase the friction between them. Fig.

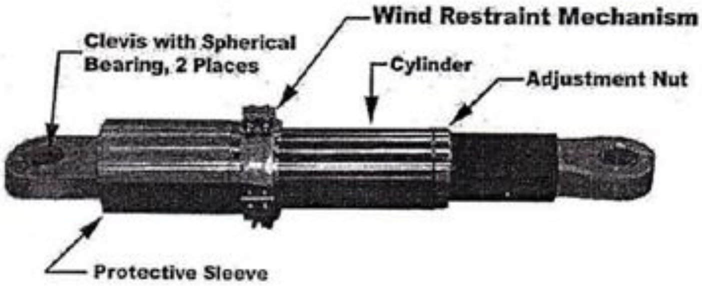
shows a typical friction damper.



3. Viscous dampers

Viscous fluid dampers are similar to shock absorbers in a car. They consist of a closed cylinder
containing a viscous fluid like oil. A piston rod is connected to a piston head with small holes
in it. The piston can move in and out of the cylinder. As it does this, the oil is forced to flow through holes in the piston head causing friction.

When the damper is installed in a building, the friction converts some of the earthquake energy going into the moving building into heat energy. The damper is usually installed as part of a building's bracing system using single diagonals. As the building sways to and fro, the piston is forced in and out of the cylinder. Fig. shows a viscous damper.



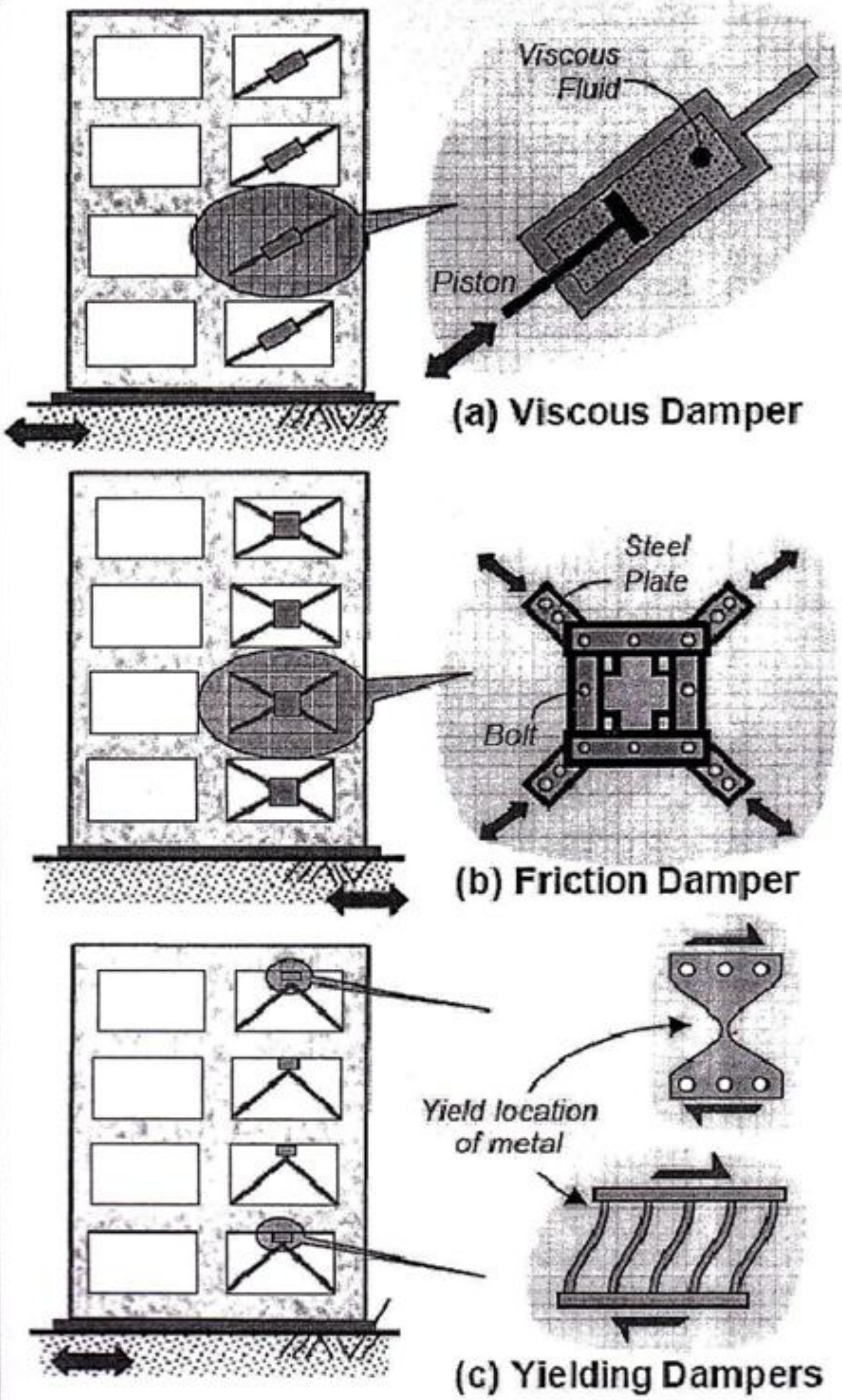


Figure 3: Seismic Energy Dissipation Devices –
each device is suitable for a certain building.

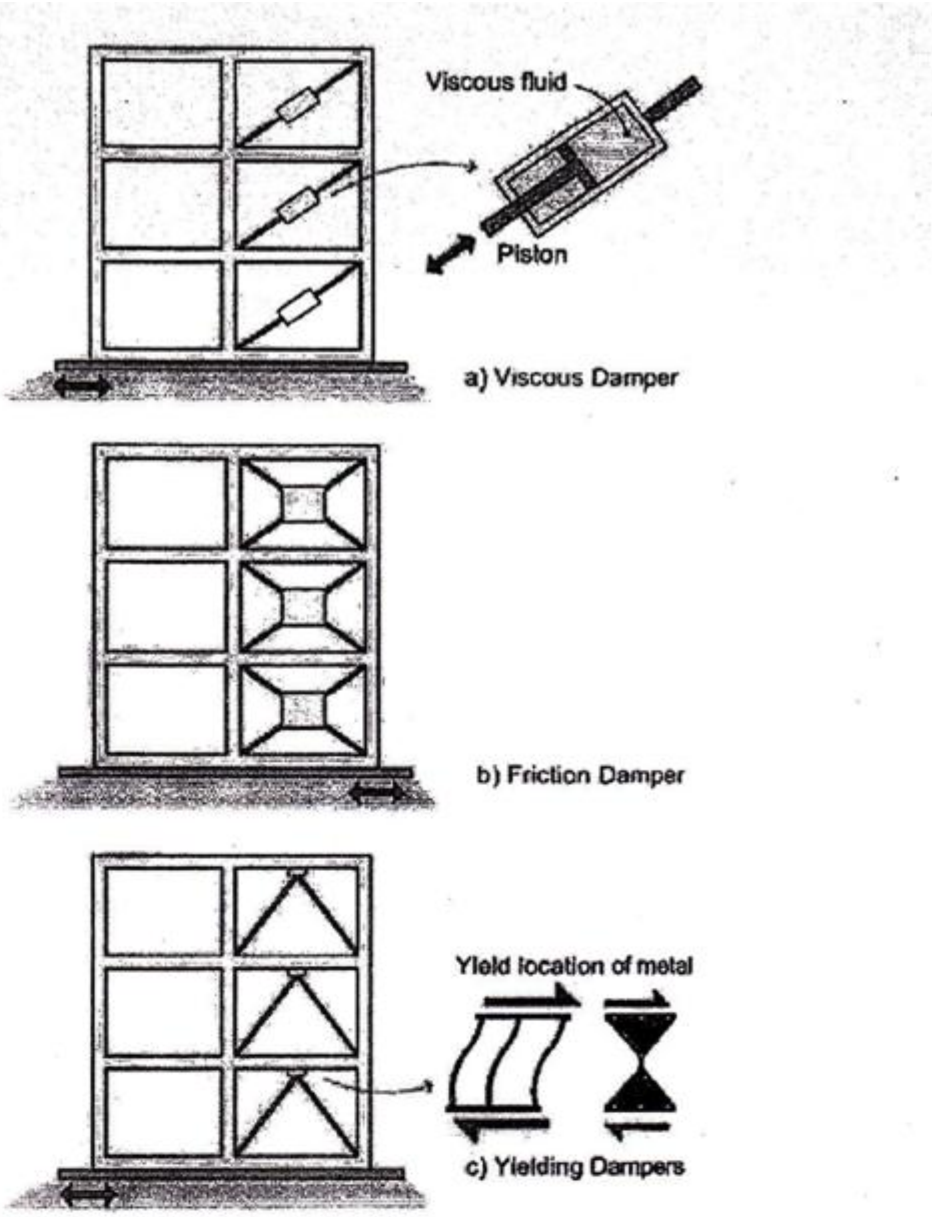


Figure 5.4. Dissipation devices.

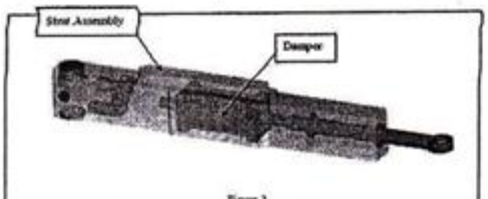


Figure 2.