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PASSIVE VIBRATION ISOLATION OF STRUCTURES

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Abstract— **Sudden shaking of ground by the seismic waves is termed as Earthquake. Earthquake is the word with which we all are familiar for centuries. Countries like Japan have been dealing with earthquake and developed technologies in past that are still valid today. Today we have technologies recently developed successfully designed for the Earthquake resistant structures. Passive Vibration Isolation devices are one of the technologies used widely now a day. This paper focuses on the Passive vibration Isolation devices used as recent development in buildings.**
Passive Vibration Isolation refers to the isolation of the vibration by passive techniques. Common passive techniques include Pneumatic or air isolators, Mechanical springs and spring dampers, pads like made of rubber, Tuned mass dampers, Kinematic isolators and like many more. Many countries are widely and principally used this technology like Japan, China, U.S.A., New Zealand, Italy. Isolation have many advantages like reduces displacement of structure, Enhances the performance of structure during seismic load, safety of structure is improved and reduces the cost of the structures. However, the isolation is less efficient for high-rise buildings; it cannot do on every structure in case of soft soil.

Keywords— **Seismic, Isolation, Earthqauke, Seismic Retroffiting**

I. INTRODUCTION

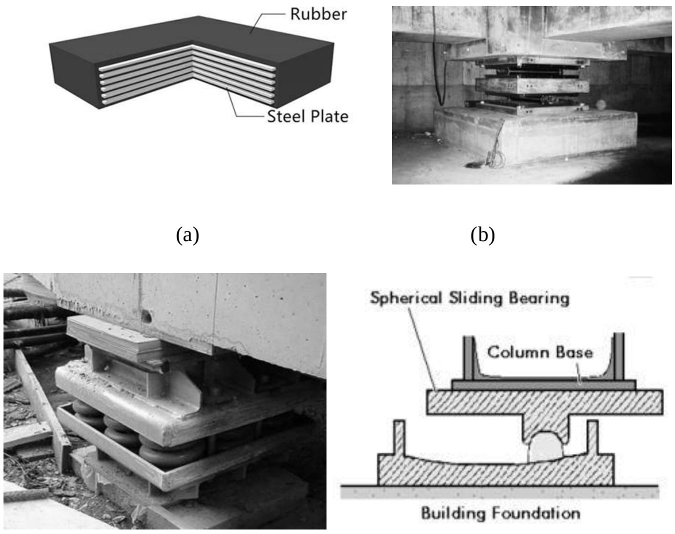
When we think about vibration the first word strikes in our minds is oscillation. In common, vibration is the oscillation occurs about an equilibrium point. Vibration is sometime becomes undesirable for example if we are sitting in our homes than we never want that our homes shake and collapse. Therefore, it becomes undesirable for our engineered structures. Mechanical waves cause this vibration and to absorb or damp these waves we use passive vibration isolation. Passive vibration isolation makes use of materials such as rubber pad or hydraulic dampers to isolate the engineered structure at some rate, which help to reduce the vibration, cause by the seismic waves. Here our focus will be the use of Isolation in our civil engineering structures from earthquake. There are following type of Passive Vibration Isolation used in different fields of engineering not in civil engineering alone -

- Air Isolator
- Springs or spring dampers
- Elastomer or cork pads
- Molded or bonded elastomer mounts
- Negative-stiffness isolators
- Wire rope isolators
- Bungee cord isolators
- Base isolators
- Tuned Mass Dampers

However, there are six major type of base isolation system used in the civil engineering structures –

- **Elastomeric Rubber Bearings -** Laminated elastomeric rubber bearings are multilayered with rubber (natural or synthetic) and reinforced with steel plates. This makes the bearing pad sufficient vertical rigidity, which can reliably transfer the concentrated down-loads and impact loads of the superstructure to both ends of the pier with small deformations. Steel plates help to prevent the bulging of rubber layers. It has fine elasticity, which can adapt the rotation of beam end but also has great shearing deformation capacity, which can satisfy the horizontal displacement of the superstructure.
- **Roller And Ball Bearing –** It intended for the protection of building and non-building structures from the impact of lateral strong earthquakes. The metallic bearing support consists of cylindrical rollers and balls. These are use with skyscrapers having soft ground.
- **Springs -** Steel springs are most likely used in mechanical applications as in roller bearings. It is not adopted in structural applications because it is flexible in both vertical and horizontal directions. This will increase service deflections.
- **Sliding Bearing –** Sliders used in such a way that it slides on the flat or spherical sliders. Based on the slider geometry, if flat sliders are provided it is named as flat sliding bearing and if the slider is spherical it is named as spherical sliding bearing. When the seismic vibration occurs, the material

moves on the sliders instead of being stiff, which can absorbs the energy and gives protection to the vibrations. Shaped or spherical sliders are often preferred over flat sliding systems because of their restoring effect. Flat sliders provide no restoring force and there are possibilities of displacement with aftershocks. To modify the effect of sliding bearings, it is also used with multilayer rubber bearings, which is called as Sliding support with rubber-pad (SSR).

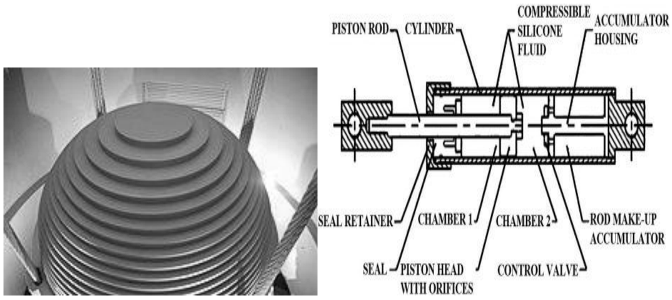


(a) (b)

(c) (d)

Fig. 1. (a) Laminated elastomeric bearing pad internal structure. (b) Housing complex mounted on roller bearings (c) Spring Isolators (d) Spherical Sliding Base Isolator

- **Tuned Mass Dampers –** Tuned Mass Dampers (TMD) are also known as harmonic absorbers or seismic dampers. It is a device used to reduce the amplitude of mechanical vibrations. We all are familiar with Taipei 101. It uses atop tuned mass damper. TMD consist of a damped mass-spring-system. The behaviour of the TMD mass in the six possible directions and rotations can be adjusted with springs and dampers. In doing so, the TMD can reduce vibrations in various directions and frequencies with just one mass. The springs of a TMD are adapted to the main system in such a way that the interaction of TMD and main system leads to an increased damping of the main system. In this way, the vibration of the main system is reduced.
- **Hydraulic Linear Dampers -** A force proportional with the displacement is developed in the hydraulic damper devices, which dissipate the energy through hysteretic cycles of loading-unloading. Unlike the other base isolation devices that absorbs energy hydraulic dampers converts the kinetic energy into the thermal energy. The force developed in a hydraulic damper is proportional with the deformation velocity. In a linear damper, the kinetic energy of the moving object is transferred through the steel rod to the valve in the damping cylinder. Hydraulic fluid is pushed through the valve and heat is generated. As the spring returns the valve to its original position, hydraulic fluid flows back into the damping chamber.



(a) (b)

Fig. 2. (a) Tuned Mass Damper (b) Hydraulic Linear Damper

II. SOME NOTABLE CIVIL ENGINEERING STRUCTURE USING PASSIVE VIBRATION ISOLATION

A. New Zealand Parliament House and Library -

With the aim of seismic retrofit of the very important historical, structure in Wellington a special engineered base isolation system was adopted to make sure both pair of buildings can withstand an earthquake of 7.5 on the Richter scale. A system of base isolation was devised to separate Parliament House and the Parliamentary Library from their original foundations and place them on lead-rubber bearings. Parliament house in 1912 and Parliament library built in two faces (1883 and 1899), are both constructed from unreinforced masonry, principally stone (granite) and brick. By the 1980s, the foundations of both buildings were showing signs of deterioration and with the Wellington Fault within 400m of the parliamentary site, there was concern as to the likely impact of an earthquake on these buildings. It was determined by, the Department of Scientific and Industrial Research that the risk of an earthquake up to 7.5 Richter Magnitude could occur every 500 to 600 years. A Geological Survey showed that the fault had not moved for 350 years and so the likelihood of it doing so on this scale in the 150-year design life of the buildings predicted at 10% to 50%. Taking all this predictions, around 412 base isolator bearings were installed (see Fig.10) within the existing foundations of the both buildings and the buildings above separated from their original foundations by a 20mm seismic gap. They are designed to take

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the weight of the building and let the foundations move sideways - up to 30cm each way - going with the earthquake. The use of a solid lead core is significant because lead is able to soften when under pressure thereby absorbing energy that would be transferred as movement. Reinforced concrete applied to the walls, which were joined to the floors with concrete and steel.

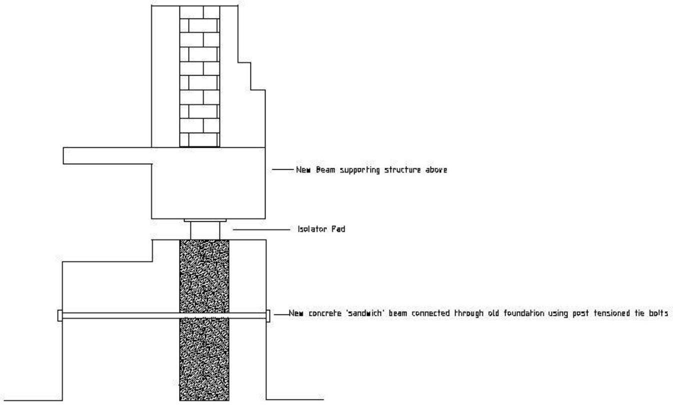
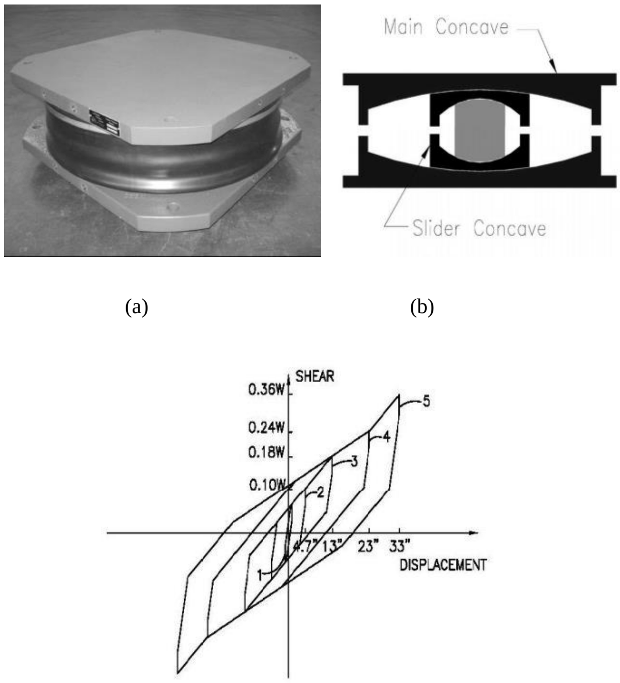


Fig. 3. Strengthening of Foundations below NZ Parliament House and location of isolators

B. Apple Park, Cupertino California -

With 700 steel base isolators, Apple Park is one of the Largest Base Isolated Buildings in the world uses technology that can reduce earthquake effects up to 80%. The configuration of the building includes an outside radius of 761 feet and a ring width of approximately 180 feet across. This ring is divided into 104 radial sectors with interior angle of about 3.46 degrees each. These radial sectors were grouped together in 9 radial wings of the building separated by 7 entrances and the cafeteria/restaurant wing itself. With column and wall lines placed on the radial grid lines. The building consists of 2 subterranean levels of parking and 4 floors of office space above grade.

When the ground shakes, the building can shift as much as four feet in any direction on the isolators. The building is designed to a performance level of minimal damage in a 2,500-year return period event. This led to vertical accelerations of 1.2 g's on the floor slabs – and the design requirement that they remain elastic and produce an insignificant amount of non-structural damage. The isolators used in the apple park are Triple Friction Pendulum. The triple Friction Pendulum with the articulated slider assembly in between of the two main concave sliding surfaces has become famous because it generates displacement amplitude dependent stiffness and friction behaviors. The Triple Friction Pendulum is intended to produce low friction and high stiffness at small bearing motion amplitudes and peak ground accelerations respectively to exert increasing friction at significantly reduced stiffness at medium bearing displacement amplitudes and peak ground accelerations respectively. Due to the design basis earthquake to generate further increasing friction at further lowered stiffness at large bearing displacement amplitudes and peak ground accelerations respectively due to earthquakes between design basis earthquake and the maximum credible earthquake and to exhibit stiffening behavior for earthquakes beyond of maximum credible earthquake to limit the required maximum displacement capacity.



(a) (b)

(c)

Fig. 4. (a) Triple Friction Pendulum Isolator (b) Schematic of Triple Friction Pendulum (c) Shear Vs Displacement of Triple Friction Pendulum

C. **BUILDING 116, NAVAL SUPPLY FACILITY, SAN DIEGO-**

The first application of the viscoelastic damper technology used in the San Diego located Building 116, Naval Supply facility for the purpose of seismic upgrade to reinforced concrete structure. Lateral load resisting system with 8-inch reinforced concrete perimeter walls. The 4-inch separation joint provided at the center of the building, in the north-south direction. The third and second floor systems are 10-1/4 and 9-inch flat slabs, respectively both with column capitals. The foundation consists of reinforced concrete wall footings at the exterior long wall with all columns resting on the 6-inch slab. Based on the nonlinear dynamic analysis, 64 dampers used to meet the seismic demand of structural elements of building.

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Each system consists of four damper units in a K-Brace configuration.

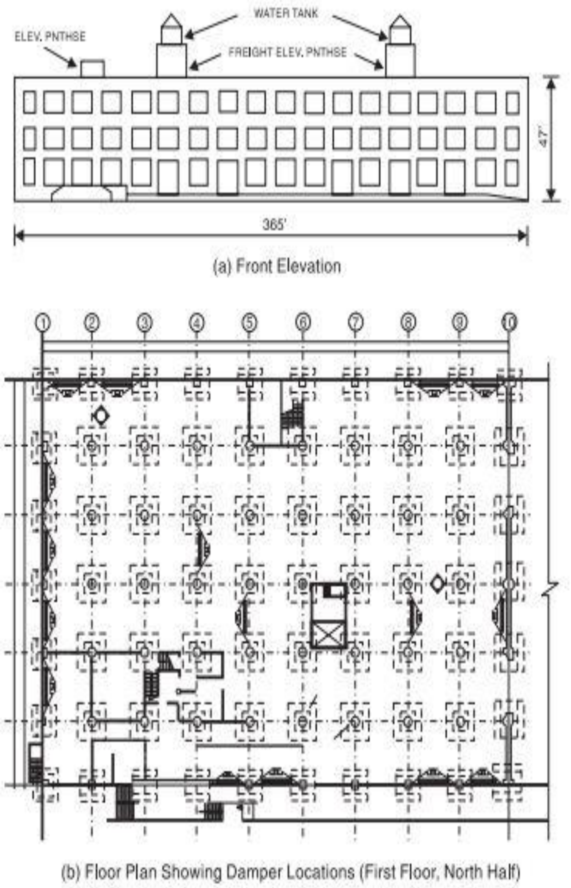

Fig. 5. Elevation and Plan of Building 116

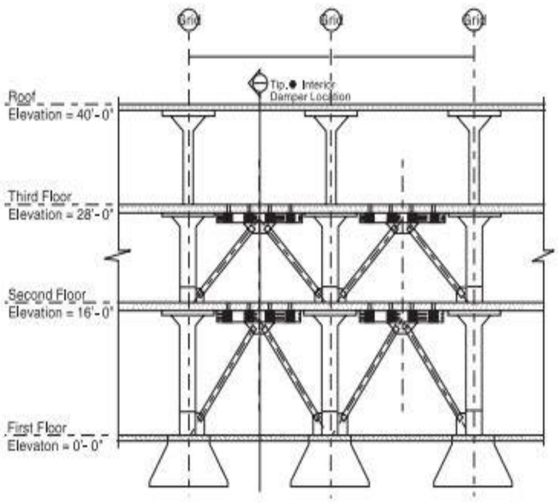

Fig. 6. Damper Configuration in Building 116

***D.* Centerpoint Tower Sydney, Australia** –

Construction of Sydney Tower Centrepoint shopping centre began in the late 1970's with the first 52 shops opening in 1972. The office component was completed in 1974 and the final stage of the complex, the Sydney Tower, was opened to the public in August 1981. The Tower is capable of withstanding earthquakes and with the early applications of Tuned Mass Damper (TMDs) can mitigate extreme wind conditions. The structure consists of a 45.72m office building topped with a 213.36m tower. The water tank of 2.13 m deep and wide with a capacity of 35,000 gal hanging from top serving as water and fire protection supply in conjunction with hydraulic shock absorber is incorporated with design of Tuned Mass Dampers (TMDs) to reduce wind induced motions. A 40-ton secondary mass was later installed on the intermediate anchorage ring to further increase damping which resulted in increase of damping in second mode with the level from 1.0% to 1.2% and from 0.4% to 1.5% in the first and second mode respectively. Results of Acceleration measurement showed that wind induced acceleration reduced by 40% to 50%.

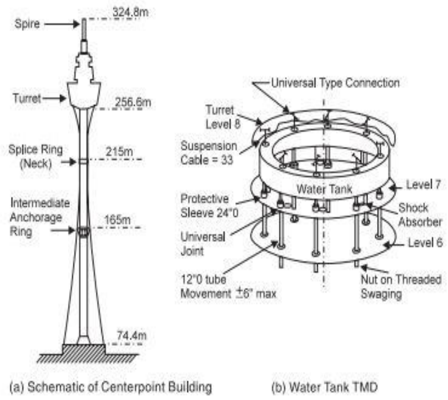

Fig. 7. Water Tank TMD at Centerpoint Tower Sydney Australia

III. CONCLUSION

The important historical structures that required to be preserve demands seismic retrofitting. Nowadays with the help of damping and isolation devices this can be achieved. Different types of devices such as Tuned Mass Dampers, Base isolators, Linear dampers are used according to the structural demand. Earthquake codes from different countries suggest there criteria for the earthquake resistant design these codes must be followed and practiced in the construction practices to mitigate the earthquake hazards.

Small house construction can also design with the base isolation technique. Modern developments are driving this method reliable in use. Different buildings and skyscrapers around the globe are engineered with this technology.

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