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BASE ISOLATION SYSTEMS IN BUILDING STRUCTURES

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Abstract: *This paper shows review of base isolation techniques and other ones used around the world. The basic idea of base isolation is to decouple the building structure from damaging components of the harmful motion. This paper summarizes a review of articles on base isolation techniques in building structures. Rubber bearing, lead rubber bearing, friction pendulum and other types of isolators will be described.*

Keywords: Base isolation, Vibration control, Damping.

1. Introduction

Base isolation separates the structures from the harmful motion of the ground by providing flexibility and energy dissipation capability through the insertion of the devices, so called isolators, between the foundation and the building structure (Ismail et. al., 2010).

Various vibration control strategies are employed to reduce the effect of harmful vibrations. They can be divided into four categories: passive, semi-active, active and hybrid control (Fig. 1).

Passive vibration control devices have constant parameters (stiffness and damping), do not require an external source of energy for operation and are relatively cheap compared with active or semi-active control methods. These devices are comparatively simple to design, make and maintain.

Compared to passive control, active control of a structure is characterised by the two basic features: some amount of external energy is required, decision-making process is based on data measured actually in time. The active control system consists of four basic components: structure, sensors, control computer (controller) and actuators (actuating devices). Each of these elements works as a subsystem and all are integrated with each other so that the output from one component provides the input to the other, in a closed control loop. The system is composed of sensors located in special places within a structure, which measure dynamic external load and response of a structure equipment, which processes measured information and calculates required control forces as per a determined algorithm and devices which generate these forces. Active control equipment requires a substantial amount of external energy for performing servo - motor control (about several dozen kilowatts). A compromise between the passive and active control system is the semi-active control system. Semi-active control devices combine the advantages of passive and active equipment. In the semi-active control system, an external source of energy is required only for changing parameters of the device used (damping or/and stiffness). The characteristics of such device may be changed during its operation (Gołębiowska & Sakiewicz, 2013).
There are following systems of passive control: (1) base isolation (elastomeric rubber bearing, elastomeric lead rubber bearing, elastomeric high damping rubber bearing, friction pendulum, sliding with restoring force, sliding with yielding devices), (2) energy dissipation devices (viscous damper, viscoelastic damper, hysteretic damper, friction damper, electro-magnetic damper), (3) mass dampers (tuned mass dampers, tuned liquid dampers, impact damper).
Energy dissipation devices are generally installed as integral parts of building structures (Gołębiowska & Rojek, 2010).

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Tuned mass damper (TMD) consists of the mass, spring and damping element. The frequency of the TMD is generally tuned to the fundamental frequency of the primary structure. They are placed in buildings, chimneys, masts, towers and other tall structures (Gołębiowska & Sakiewicz, 2008).
In this paper, a brief description of the basic construction, mechanical behaviour of selected type base isolation is presented.

2. Base Isolation

A variety of base isolation bearings have been developed and implemented around the world for many years. In general, base isolation is classified into two categories: (1) bearing (elastomeric, sliding), (2) others systems (spring, rollers, sleeved piles, hybrid systems, etc.). The main concept of base isolation is explained in Fig. 2. The shift of the fundamental period of the structure out of the range of dominant excitation frequencies is the base of this concept. The local soil conditions have a great impact on the reliability of the base isolation (Symans, 2004).

Elastomeric bearing is composed of alternating layers of natural, or synthetic, rubber bonded to intermediate steel shim plates (Fig. 3). Elastomeric bearing can be classified into two categories: low-damping rubber and high-damping rubber.

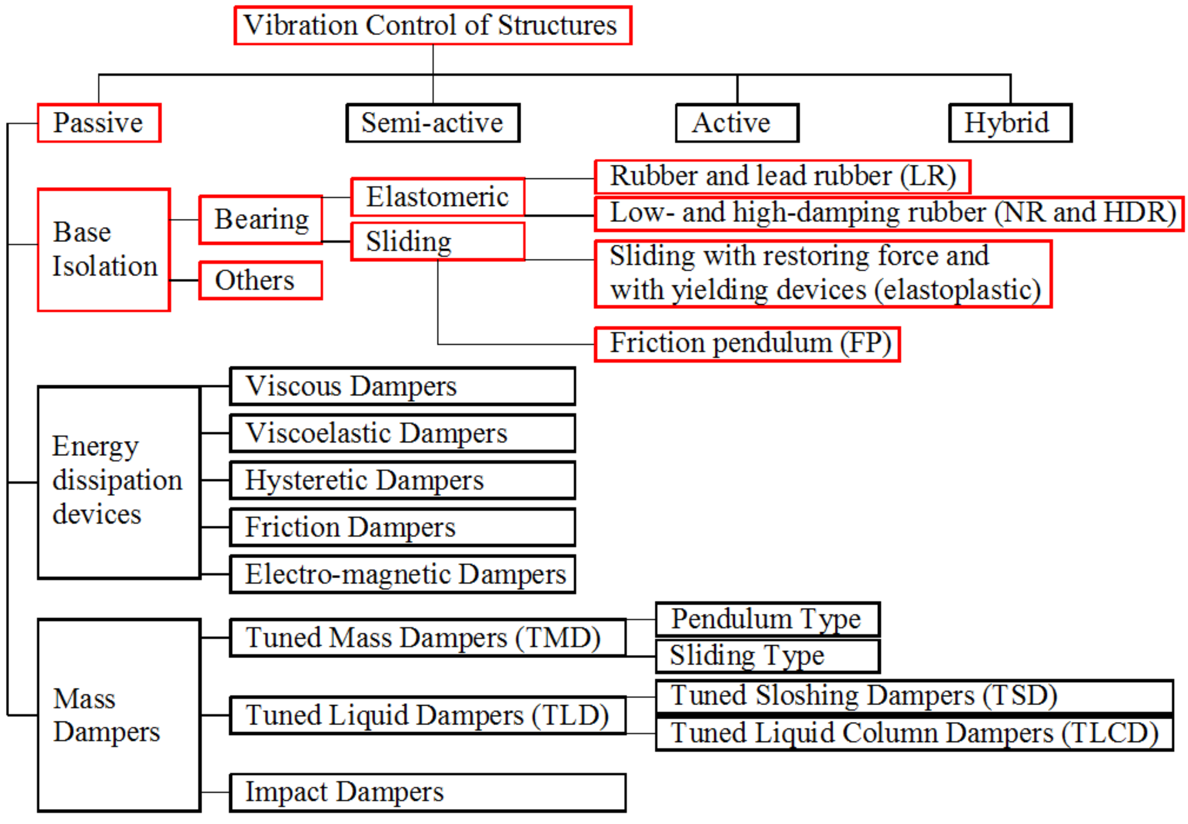

Fig. 1: Various types of vibration control.

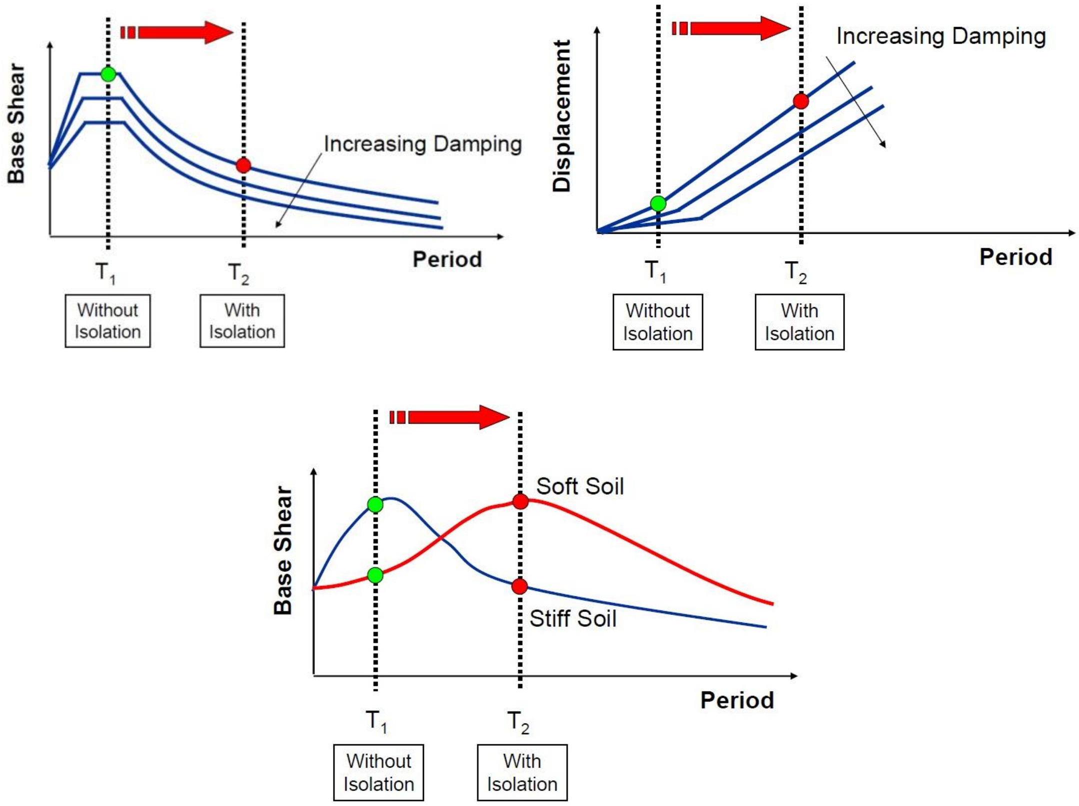

Fig. 2: Concept of base isolation (Symans, 2004).

Fig. 4 shows improved version of elastomeric rubber bearing where a centrally located lead core inside is introduced, which has energy dissipating capacity. Then, isolator essentially works as hysteretic damping device.

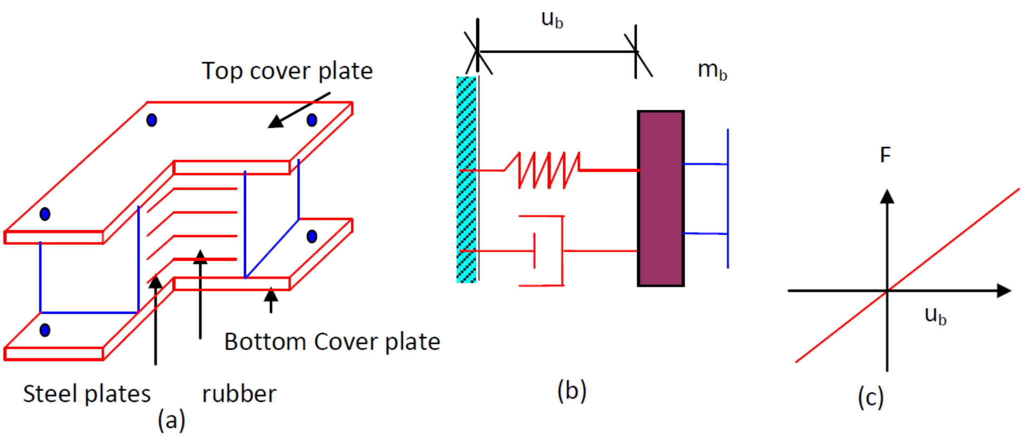

Fig. 3: Elastomeric rubber bearing (a) sectional details (b) schematic diagrams (c) force deformation behavior (Patil & Reddy, 2012).

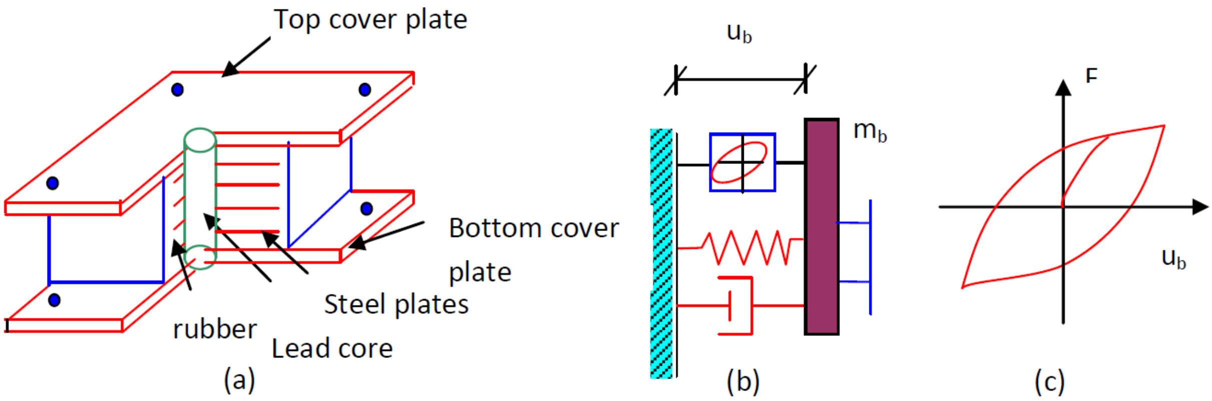

Fig. 4: Lead rubber bearing (a) sectional details (b) schematic diagrams (c) force deformation behavior (Patil & Reddy, 2012).

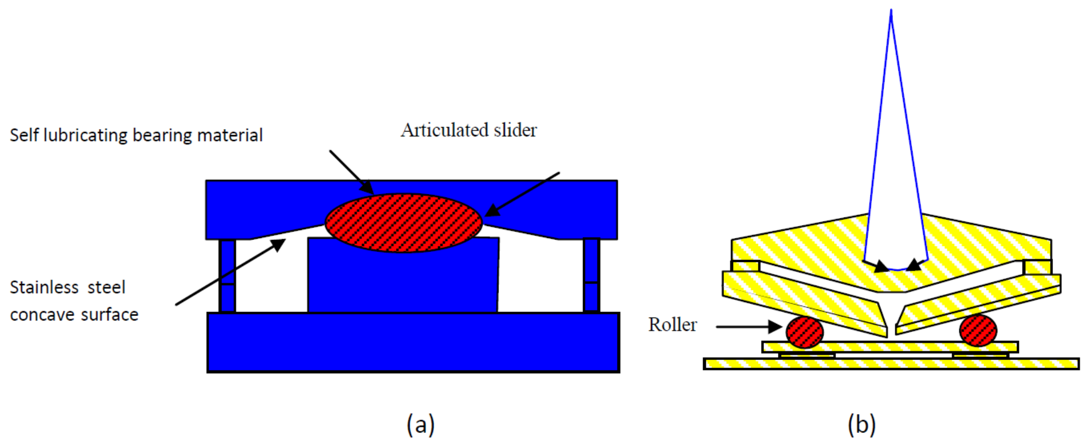

Fig. 5: Friction pendulum base isolator (a) friction pendulum system (b) roller pendulum system (Patil & Reddy, 2012).

Sliding bearing support the weight of structure on a bearing, that rest on a sliding interface. Most sliding bearings use polytetrafluorethylene type material and stainless steel for bearing material at the sliding interface. The single friction pendulum bearing (FP) consists of a base plate, an articulated slider and a spherical concave dish (Fig. 5). Sliding bearing dissipates energy by friction, and may use a separate mechanism to provide a self-centering capability or employ a curved sliding surface that may be spherical, conical or of varying curvatures. Recently, multi-spherical types of the FP bearing have been developed. The triple pendulum bearing consists four spherical sliding surfaces and three independent pendulum mechanisms and offers the most adaptable behavior of the multi-spherical sliding bearings (Fenz & Constantinou, 2008).

There are some other types of isolators: springs, rollers and sleeved piles. Spring isolators and rollers are used for machinery isolation. The disadvantage of springs is little damping. Rollers are more resistant to service load as springs. Sleeved piles provide flexibility but no damping.

Nowadays hybrid isolation systems are often used, because they are high performance in reducing vibration, possess the ability to adapt to different loading conditions and are able to control multiple vibration modes.

3. Conclusion

Common vibration control systems in use today include elastomeric and sliding bearings with and without energy dissipation devices and/or mass dampers. The benefit of base isolation is that the damping capacity can be obtained in one device. However, because the nonlinear vibration characteristics of base isolation devices, the vibration reduction is not optimal for a wide range of input ground motion intensities. For wide range of excitation the hybrid control strategies can be effective, consisting of a base isolation combined with passive energy dissipation devices and mass dampers.

References

Fenz, D.M. & Constantinou, M.C. (2008) Spherical sliding isolation bearings with adaptive behavior: Theory. Earthquake Engineering and Structural Dynamics, 37, pp.163-183.

Gołębiowska, I. & Rojek, J. (2010) Urządzenia pasywnej kontroli drgań w obiektach budowlanych. Ekologia i Technika, Vol. XVIII, nr 5, pp. 290-298.

Gołębiowska, I. & Sakiewicz, W. (2013) Passive control of structural vibrations. Lightweight Structures in Civil Engineering. Contemporary problems. Scientific Conference of IASS Polish Chapters XIX LSCE 2013, Olsztyn, 6 December, pp.38-41.

Gołębiowska, I. & Sakiewicz, W. (2008) Control systems for vibrating structures. Lightweight Structures in Civil Engineering, Local Seminar of IASS Polish Chapter XIV LSCE, Warsaw, 5 December, pp. 40-43.

Ismail, M., Rodellar, J. & Ikhouane, F. (2010) An innovative isolation device for aseismic design. Engineering Structures 32, pp.1168-1183.

Patil, S.J. & Reddy, G.R. (2012) State of art review – base isolation systems for structures. International Journal of Emerging Technology and Advanced Engineering, Vol. 2, Issue 7, pp. 438-453.

Symans, M.D. (2004) Seismic Protective Systems. Seismic Isolation. Instructional Material Complementing FEMA 451, Design Examples.