DESIGN OF A NEW PASSIVE ENERGY DISSIPATION SYSTEM FOR EARTHQUAKE RESISTANT STRUCTURE

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Abstract - The basic principle of conventional earthquake-resistant design that has been applied for the last 75 years is intended to ensure an acceptable safety level while avoiding catastrophic failures and loss of life. Over the last half century, a large amount of research has been conducted into developing innovative earthquake-resistant systems in order to raise seismic performance levels while keeping construction costs reasonable. Those structural control systems are broadly classified into three categories as Passive and, Active control, and Seismic isolation system. Passive control systems have been considered as an effective and inexpensive way to mitigate earthquake risks to the structures. Among different passive energy dissipation systems available metallic dampers are popular (and inexpensive) choice for an energy dissipation device because of its relatively high elastic stiffness, good ductility and its high potential for dissipating energy in the post yielding region. One of the metallic dampers namely Added Damping and Stiffness (ADAS) is the most commonly used metallic dampers in seismic design. Usually, X-plates are chosen for mounted on a Chevron type bracing are usually chosen for ADAS. In principle, these devices dissipate energy through flexural yielding along the out-of-plane direction of the device, with an assumption of nearly rigid supporting Chevron bracing system along its in-plane direction. Clearly, these devices will be effective in resisting seismic excitation along one of the horizontal directions (in plane direction of the bracing). Passive energy dissipation systems represent an alternate to seismal isolation as a way of protective building structures against the consequences of damaging earthquakes. the fundamental operate of passive energy dissipation devices in an exceedingly building is to soak up or consume some of the earthquake input energy, thereby reducing energy dissipation demand on primary structural members and minimizing structural harm. The means that by that the energy is dissipated is either through the yielding of steel, slippery friction, motion of a piston or a plate inside a viscous fluid, motion of Associate in Nursing orifice viscous fluid device, or elastic action of compound materials.

***Key Words*: Passive Energy Dissipation, ADAS (Added Damping and Stiffness), X-Plates chevron type bracing, Elastomeric Bearings, Mild steel Dampers, Fluid viscous dampers, and Friction in sliding bearings.**

1. INTRODUCTION

Historically, aseismic design has been primarily based upon a mix of strength and ductility. For small, frequent seismic disturbances, the structure is predicted to stay within the elastic vary, with all stresses well below yield levels however, it's not affordable to expect that a conventional structure can respond elastically one subjected to a serious earthquake. Instead, the civil engineer depends upon the inherent ductility of buildings to catastrophic failure, whereas accepted an exact level of structural and nonfunctional injury. This philosophy has led to the event of aseismic design code that includes lateral force ways and, a lot of recently, inelastic design response spectra. Ultimately, with these approaches, the structure is intended to resist a similar static load. Results have been reasonably successful. In recent years, serious efforts are undertaken to develop the idea of energy dissipation or supplemental damping into a possible technology, and variety of those devices are put in structure. This treatise introduces the fundamental concepts of passive energy dissipation, and discusses current analysis, development, design and code-related activities during this exciting and quick expanding field. At a same time, it ought to be stressed that entire technology continues to be evolving. Vital enhancement in each hardware and deign procedures will definitely continue for variety of years to return.

1.1 SEISMIC DESIGN

In conventional seismic design acceptable performance of a structure during earthquake shaking is based on the lateral force resisting system being able to absorb and dissipate energy in stable manner for a large number of cycles. Energy dissipation happens in specially elaborate ductile plastic hinge regions of beams and columns bases, that additionally kind a part of the gravity load carrying system. Plastic hinges area unit regions of targeted harm to the gravity frame, which often is irreparable.

Situations exist in which the conventional design approach is not applicable when a structure must remain functional after an earthquake, as is the case of important structures (Hospitals, multi – story etc.), the conventional design approach is inappropriate for such cases, the structure may be designed with sufficient strength so that inelastic action is either prevented or is minimal.

Alternate design procedures are developed that incorpor ate earthquake protecting systems within the structure. These systems could take the shape of seismic isolation systems or supplemental energy dissipation devices. The behavior and effects of those systems could begin with the thought of the distribution of energy at intervals a structure. when earthquake happens, a definite quantity of energy is input into a structure. This input energy is transformed into both kinetic and potential (strain) energy which must be either absorbed or dissipated through heat. If there were no damping, vibrations would exist for all time. However, there's continuously some level of inherent damping that withdraws energy from the system and thus reduces the amplitude of vibration till the motion ceases. The structural performance may be improved if some of the input energy may be absorbed, not by the structure itself, however by some sort of supplemental device.

According to conversation of energy.

$$E = E_{K.E} + E_S + E_h + E_d$$

Where 'E' is the absolute energy input from earthquake motion.

$E_{k.E}$ = Absolute kinetic energy
E_S = Recoverable elastic strain energy.
E_h = Irrecoverable energy dissipation by the structural system through inelastic or other forms of action.
E_d = Energy dissipation by supplemental damping devices.
The absolute input energy E represents the work done by the total base shear force at the foundation on the ground (foundation) displacement.

In the conventional design approach, acceptable structural performance is accomplished by the occurrence of inelastic deformation. This has the direct impact of accelerating energy E_h. The incidence of inflexible deformation ends up in softening of the structural system that itself modifies the absolutely the input energy.

Modern seismic isolation systems incorporate energy dissipating mechanisms. Examples are high damping elastomeric bearings, Lead plugs in elastomeric bearings, mild steel dampers, viscous fluid dampers, and sliding friction bearings.

1.2 Motion Control System

Seismic isolation and energy dissipation system are classified as earthquake protection systems since their function is to mitigate earthquake hazard. Mitigation is defined as the action taken to reduce the consequences of earthquake, such as a seismic strengthening or upgrading, installation of a seismic isolation or energy dissipation system etc. however energy dissipation systems are also useful in reducing dynamic response under wind and other types of service loads. Thus in general, seismic isolation and energy dissipation systems may be termed motion control systems.

The term control systems denote what was previously termed energy dissipation systems, whereas the term passive and semi – active denote, respectively systems that requires no externally supplied power and systems that require minimal externally supplied power to operate.

Dynamic vibration absorbers have been used for the reduction of response of structures subjected to wind excitation, occupant activity and machine vibration. Many of the application are tall modern buildings with very small inherent damping. In these cases, dynamic vibrations absorbers can enhance damping by a small amount typically less than 5% of critical, which is sufficient to suppress wind induced motion for the comfort of occupants. The effectiveness of dynamic vibration absorbers structural system undergoes inelastic action. The reasons for this reduction ineffectiveness are (a) De-tuning of the absorbers when inelastic action occurs, and (b) The enhancement of damping is insignificant in comparison to that generated by inelastic action.

The distinction between passive and active control systems is shown in figure 1 and figure 2, which depict the elements of these system. A passive control system, whether an energy dissipation system or a dynamic vibration absorber (or even a seismic isolation system), develops motion control forces at the points of attachment of the system. The power needed to generate these forces is provided by the motion of the points of attachment during dynamic excitation. The relative motion of those points of attachment verify the amplitude and direction of the control forces.

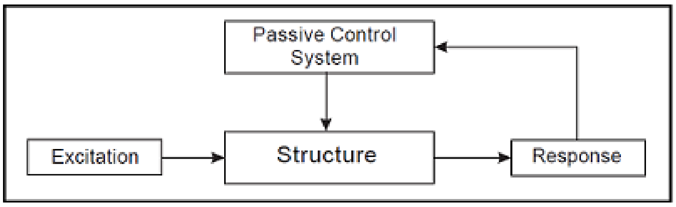

Figure -1: Elements of a Passive Control System

Active Control System

An active control system also develops motion control force as shown in figure 2. However, the magnitude and direction of these forces are determined by a controller based on information from sensors and a control strategy (algorithm), and supplied by the active control system. Semi

–active control systems generally originate from passive control systems which have been modified to allow for adjustment of their mechanical properties specifically, energy dissipation devices which operate through shearing of viscous fluid, orificing of fluid or sliding friction have been modified to behave in a semi – active manner.

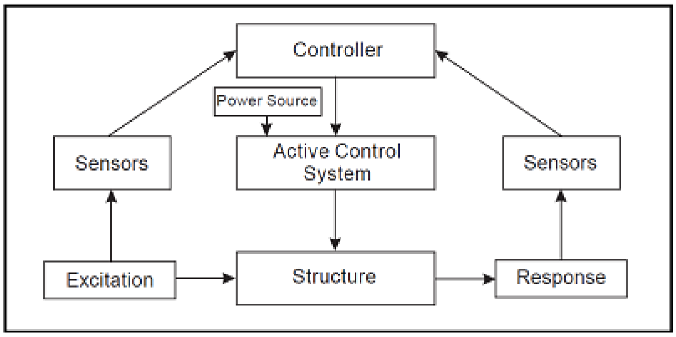

Figure -2: Elements of an Active Control System

Passive energy dissipation systems utilize a wide range of materials and technologies as a means to enhance the damping, stiffness and strength characteristics of structure. The behavior of individual passive devices and system is provided, with emphasis on the development of appropriate mathematical models. This information is needed to better understand the principal assumptions employed in the simplified design procedure and to better appreciate the capabilities and limitations of the viscous devices. Broadly speaking, dissipation may be achieved either by the conversion of kinetic energy to heat or by the transferring of energy among vibrating models. The first mechanism incorporates both hysteretic devices that dissipate energy with no significant rate dependence and viscoelastic devices that exhibit considerable rate (or frequency) dependence. Include in the former group are devices that operate on principles such as yielding of metals and frictional sliding's, while the latter group consists of devices involving deformation of viscoelastic solids or fluids and these employing fluid orificing. A third classification consists of re-centering devices that utilize either a preload generated by fluids pressurization or internal springs, or a phase transformation to produce a modified force – displacement response that includes a natural re-centering component.

2. Hysteretic System

Hysteretic systems, that, dissipate energy through a mechanism that is independent of the rate of load application. Included in this group are metallic dampers that utilize the yielding of metals as the dissipative mechanism and friction dampers that generate heat through dry sliding friction. Typical force-displacement responses for these devices obtained under constant amplitude, displacement – controlled cyclic conditions are displayed in figure 3. The quantities F and X represents the overall device force and displacement, respectively. The cyclic loading at displacement amplitude x_0 and circular frequency w, this displacement at time t can be written.

$$x(t) = x_0 \sin w t$$

In figure 3, that for both metallic and friction devices, the response remains essentially unchanged at various excitation frequencies, thus demonstrating rate independence. However, the devices are inherently nonlinear. The force output clearly does not scale with the displacement and significant path dependence is apparent. This nonlinearity of hysteretic devices must be considered in both structural analysis and design. It should also be noted that in all cases, energy dissipation occurs only after a certain threshold force is exceeded.

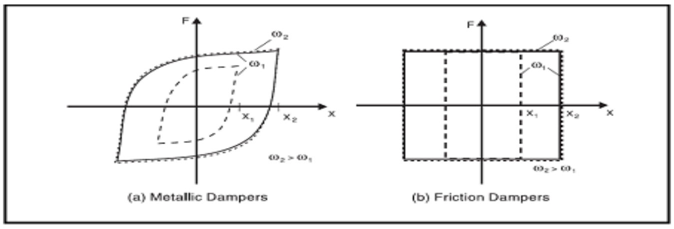

Figure -3: Force-displacement Response of Hysteretic Devices

2.1 Metallic Dampers

The most effective mechanism for the dissipation of energy, input to a structure at the time of an earthquake, is through the inelastic deformation of metallic substances. In traditional steel structures, aseismic design relies upon the post-yield ductility of structural members to provide the required dissipation. However, the idea of utilizing supplemental metallic hysteretic dampers within the superstructure to absorb a large portion of the seismic energy began with the conceptual and experimental work.

Examples of metallic dampers that have received significant attention in recent years include the X-shaped and triangular plate dampers illustrated in Figure 4. These parallel plate devices are typically installed within a frame bay between a chevron brace and the overlying beam. As a result, the dampers primarily resist the horizontal forces associated with inter-story drift via flexural deformation of the individual plates. Beyond a certain level of force, the plates yield and thus provide a supplemental amount of energy dissipation. The tapered shape of the plates promotes nearly uniform yielding throughout their length.

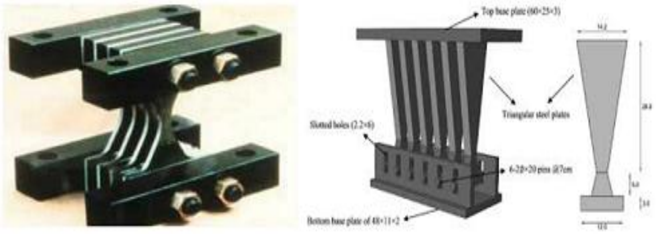

Figure-4: Metallic Damper Geometries

2.2 Friction Dampers

The process involved in energy dissipation in metallic dampers can be classified as one form of internal friction. On the other hand, attention will now shift to dampers that utilize the mechanism of friction between two solid bodies sliding relative to one another to provide the desired energy dissipation. An examination of the effects of frictional damping on the response of building structures was conducted by Mayes and Mowbray (1975), however it appears that Keightley (1977) was the first to consider frictional devices for building applications.

There has been considerable progress during the intervening years, and a number of devices have been developed. Two representative types of friction dampers are illustrated in Figure5. In this Figure 5a shows a design proposed by Pall and Marsh (1982) for application in conjunction with cross-bracing in framed structures. Brake lining pads are utilized for the sliding surfaces. Another friction device, based upon an industrial damper, is shown in Figure 5b. In this uniaxial device, which was recently tested by Aiken and Kelly (1990), copper alloy friction pads slide along the inner surface of the cylindrical steel casing. The required normal force is provided through the action of the spring against the inner and outer wedges.

While there are numerous forms of friction that can be effectively used to mitigate damage to structures during environmental disturbances, solid sliding friction as their basic dissipative mechanism. Thus, in friction dampers, irrecoverable work is done by the tangential force required to slide one solid body across the surface of another. It is naturally of paramount importance that a consistent, predictable frictional response be maintained throughout the life of the damper. However, this response depends to a considerable extent on surface conditions, which may in turn be affected by environmental factors.

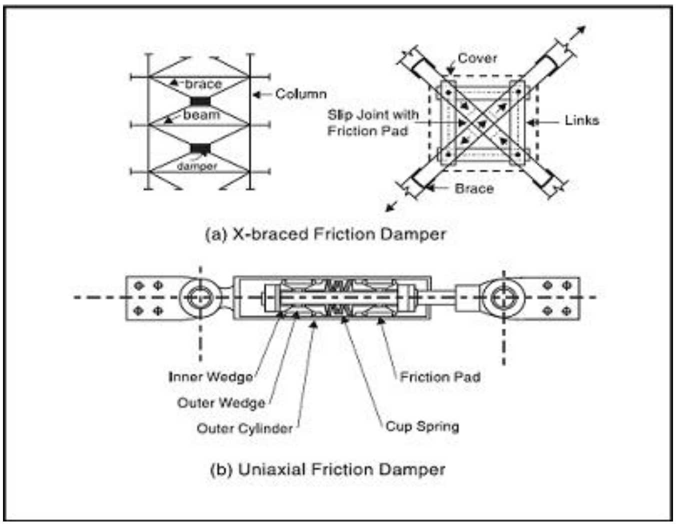

Figure -5: Representative Friction Dampers

3. Viscoelastic System

A range of passive systems that dissipate energy in a rate dependent manner, includes viscoelastic solid dampers and viscoelastic fluid dampers, with the latter expanded to incorporate devices based upon both fluid deformation and orificing. The force-displacement responses obtained for these devices under constant amplitude, displacement-controlled cyclic conditions are provided in Figure 6a. In general, these devices exhibit both damping and stiffness, although the important case of a purely viscous damper in which force and displacement are 90° out-of phase is illustrated in Figure 6b. Notice that for viscoelastic devices, the response is dependent upon frequency. However, in Figure 6 and in many applications, the behavior is confined to the linear range.

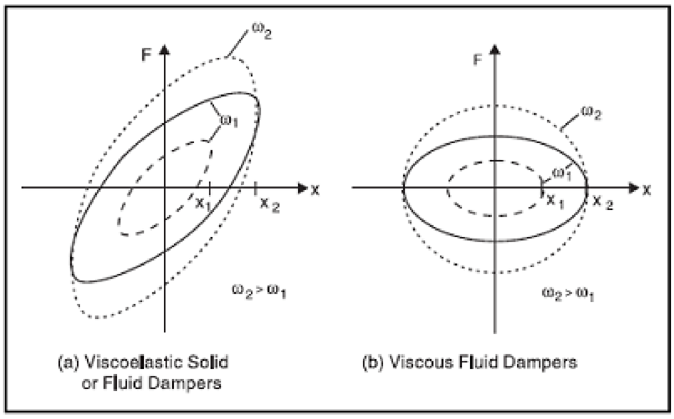

Figure -6: Force-displacement Response of Viscoelastic Devices

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3.1 Viscoelastic Solid Dampers

Viscoelastic solid materials widely used civil engineering structural applications. These are usually copolymers or glassy substances that dissipate energy when subjected to shear deformation. A typical viscoelastic (VE) damper, which consists of viscoelastic layers bonded with steel plates, is shown in Figure 7. When these are fitted in a structure, shear deformation and output energy dissipation takes place when the structural vibration induces relative motion between the outer steel flanges and the center plate.

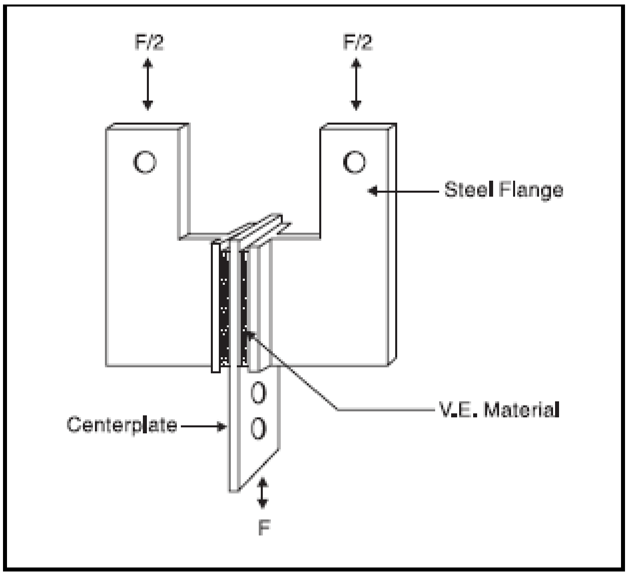

Figure-7: Viscoelastic Solid Damper Configuration

3.2 Viscoelastic Fluid Dampers

The action of solids to enhance the performance of structures subjected to transient environmental disturbances. However, fluids can also be used in order to achieve the desired level of passive control. In that case, dissipation occurs through conversion of mechanical energy to heat as a piston deforms a thick, highly viscous substance, such as a silicone gel. Figure 8a depicts one such damper, which has found application as a component in seismic base isolation systems. While these devices could also be deployed within the superstructure, an alternative, and perhaps more effective, design concept involves the development of the viscous damping wall (VDW) illustrated in Figure 8b. In this design, the piston is simply a steel plate constrained to move in its plane within a narrow rectangular steel container filled with a viscous fluid. For typical installation in a frame bay, the piston is attached to the upper floor, while the container is fixed to the lower floor.

3. CONCLUSIONS

This paper has provided a discussion on the key features of the most commonly utilized passive energy dissipation devices and design of structures incorporating such devices. The interest within the structural engineering community in implementing these devices in retrofit and new building applications is evidenced by the relatively rapid growth in applications since the mid-1990s. This move toward increasing numbers of implementations has coincided with the development of guidelines for the analysis and design of structures incorporating the devices.

Although each type of passive energy dissipation device acts primarily to dissipate energy, its mechanism for doing so leads to distinctly different hysteretic behavior, and thus performance of the structure to which it is attached. The basic characteristics of the device in terms of its displacement and/or velocity dependence must be considered in the analysis and design process. The Provisions permit linear static and dynamic analysis

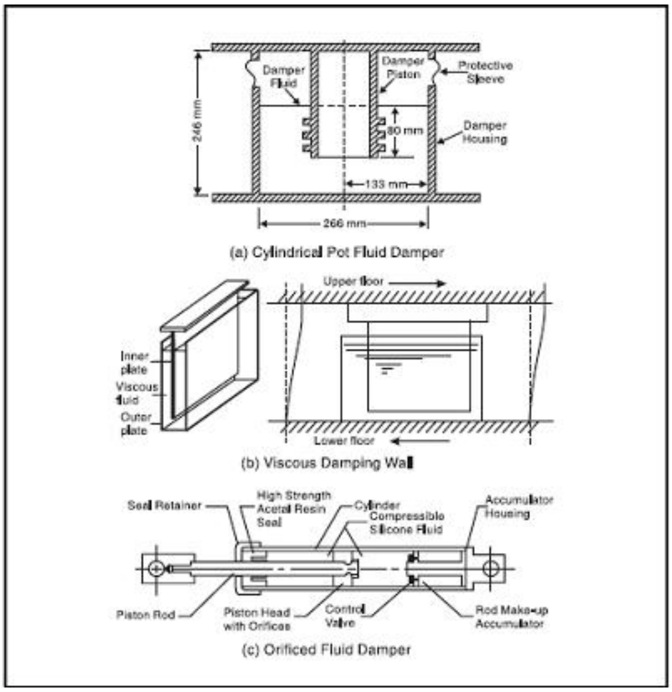

Figure-8: Viscoelastic Fluid Dampers

under certain conditions. Finally, the introduction of energy dissipation devices within the structural framing of a building introduces a number of analysis and design issues that must be considered by the structural engineer but which are not directly addressed in code-based documents.

REFERENCES

[1] Clough R.W and Penzien J., *Dynamics of structure*, 2nd ed., McGraw- Hill, New York, 1993.

[2] EERI, "*Bhuj, India Earthquake of January 26, 2001: Reconnaissance Report*", Earthquake Spectra, Supplement to Vol. 18, July 2002.

[3] SP: 6-1 (1964), ISI *Handbook for structural Engineers-Part – 1 – Structural Steel Sections*, Bureau of Indian Standards, New Delhi.

[4] Be, K. "Tsunami and Mechanism of Great Earthquake", *Physics of the Earth Planet Interior*, 7: 143-153, 1973.

[5] IS 1893, *Indian Standard Criteria for Earthquake Resistance of Structure* (fourth revision), Indian Standard Institute, New Delhi, 1984.

[6] G.S. Balakrishna, Jini Jacob, *Seismic analysis of building using two types of passive energy dissipation devices*, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).

[7] Lin, W.-H., and Chopra, A. K. _2003_. "*Earthquake response of elastic single-degree-of-freedom systems with nonlinear viscoelastic dampers*." *J. Eng. Mech.*, 129_6_, 597-606.

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