ISSN: 2320 - 8791
www.ijreat.org

Recent Trends And Advancements In Aseismic Design Of Structures

N. SOUNDARYA[1]

[1]ASSISTANT PROFESSOR, DEPARTMENT OF CIVIL ENGINEERING, VEL TECH [R.S.TRUST], CHENNAI. TAMIL NADU, INDIA

ABSTRACT

A structure is basically classified into three types; wind exited structure – Ex Tacoma Narrows Bridge, Tacoma, Washington, Human exited structures- Ex Millennium Foot Bridge, London, England and Seismically exited structure. In earthquake engineering, One of the constant challenges is to find new and better ways of designing new stuctures or strengthening existing ones so that they can be protected effectively from the damaging effects of the seismic loads. . More than a century ago, the control of structures to improve their performance during earthquakes was first proposed, but only in the last 25 years structures have been successfully designed and built using earthquake protective systems. The design strategies used in seismic resistant design are: (i) Ductility / Strength based methods and (ii) Response control based methods. This paper focuses on the Response control based methods. As the structures built so far couldn't adapt to the environment and used their stiffness (columns) to resist loads and when there was no control they had to have bigger, heavier and more expensive structural members to resist loads.

1. Keywords: Passive, active, semi-active controls, seismic forces.

1. INTRODUCTION

It is a challenging task to the civil engineers to control the seismically exited structures. The seismic hazard mitigation was traditionally done by designing structures with a good strength capacity and were designed to deform in a ductile manner. Newer concepts of structural control includes passive control, active control, semi active control and hybrid control methods.

Semi-active control systems maintain the reliability of passive control systems and takes advantage of the adjustable parameter characteristics of an active control system.

1.1 PASSIVE CONTROL SYSTEMS

This systems consists of Sensors, Controller(Computer controlled), and Control Actuators. This type of systems does not require an external power source. The response forces are the forces developed in response to the motion of the structure. The energy in the passively controlled system, including the passive devices, cannot be increased.

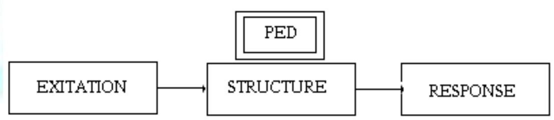


Fig. 1 PED: PASSIVE ENERGY DISSIPATOR

Such systems are used to increase the energy dissipation capacity of the structure through localized and separate energy dissipation devices located either within the isolation system or at the top of the structure. These systems are also known as supplemental energy dissipation systems. Such systems will absorb a considerable quantity of the input seismic energy and hence, the transfer of seismic energy directly to the structure is greatly reduced.

These systems may also increase the strength and stiffness of the structure and does not require an external source of power, and hence it is reliable. Because even if power fails during an earthquake the building will be safe as they do not require external power to safeguard the structure. They simply use the motion of the structure to produce relative motion inside the passive control devices and the passive control devices dissipate energy.

DISSIPATION MECHANISMS USED:

- **Transferring of energy among vibrating modes**
  - Supplemental oscillators, which act as dynamic vibration absorbers.

- **Conversion of kinetic energy to heat**
  - Frictional sliding
  - Yielding of metals
  - Phase transformation in metals
  - Deformation of visco-elastic solids or fluids
  - Fluid orificing

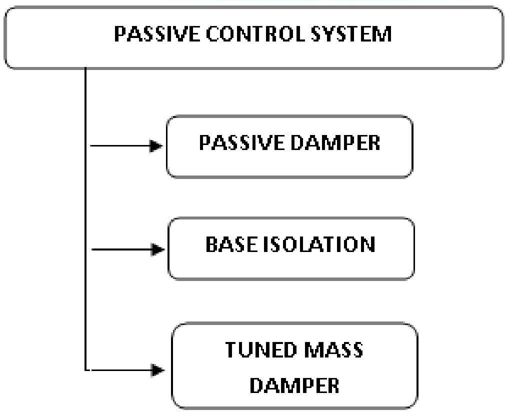


Fig.2

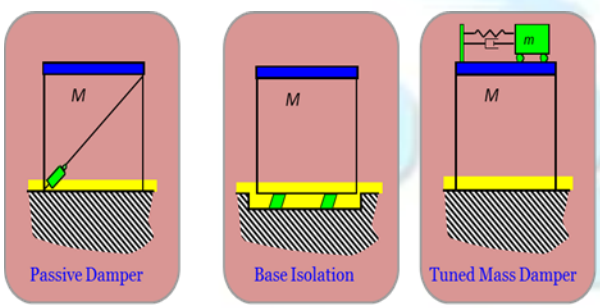


Fig.3: Types of Passve control systems used

A. PASSIVE DAMPER CONTROL:

It reduces the effect of seismic excitation to which a structure is subjected to and transfers the vibration of energy of a structure to a control-actuator. It gives additional damping effect of a structure and prevents the structure from exhibiting resonance vibration.

Different dampers used are:

- riction Dampers
- etallic Dampers
- isco-elastic Dampers
- luid dampers

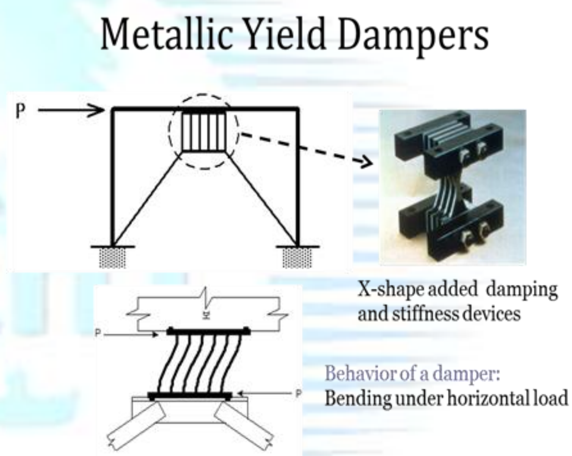


Fig.4: Metallic Yield Dampers

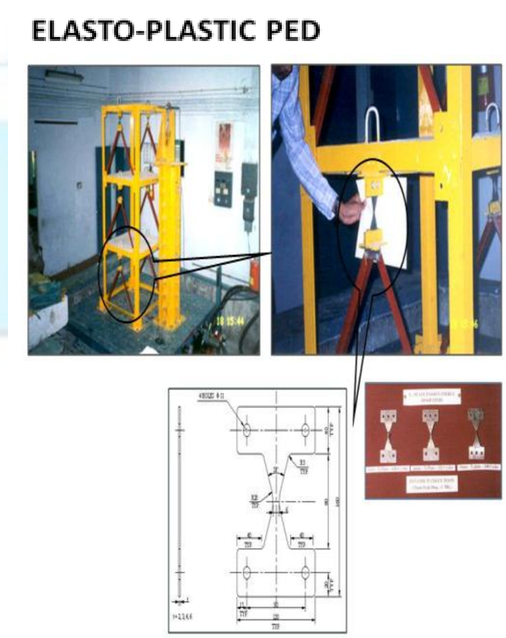
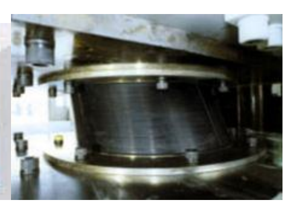


Fig.5: Elasto Plastic PED

B. BASE ISOLATION

This technique uncouples the structure from the ground and protects it from earthquake ground motions. For this the stiffness of the structural system is reduced, by introducing ISOLATORS which are flexible elements. Such Isolators are placed near the base of the structure and hence its name. It may also be placed on the pier cap if it is a bridge. Sometimes additional damping may be provided to limit the isolator displacements. In February 1870, Jules Touaillon of San Francisco, Has filed a patent for 'Earthquake proof Building' which consists of steel balls which rolls over shallow dishes. This was not very famous as it was impractical in those days. In the mid 1970's in New- Zealand, In a rail bridge across the South Rangitikei River, in the central region of North Island, structural separation of columns from pile caps were done, and a stepping motion was enabled. At the pile cap, displacement control is done by steel torsion bars which act as energy dissipator. In 1982, lead filled elastomeric bearings were used as isolators in Clayton building in Wellington. After 25 years almost 400 buildings and bridges in Italy, Japan, New Zealand and the United States were constructed as seismically isolated structures.
Common isolation systems include elastomeric and sliding bearings with or without dampers or damping mechanisms. For instance, Elastomeric bearings can be fabricated from a high damping rubber compound or can contain a lead core. Sliding bearings dissipate energy by friction and it uses a separate mechanism to provide a self-centering capability or employs a curved sliding surface that may be conical, spherical, or of any curvature. Combinations of elastomeric and sliding bearings are also used together with roller-based systems in some places. The rollers may be cylinders or sometimes balls sandwiched between flat or curved plates. Variations to this arrangement involves added damping mechanisms such as metallic and Hydraulic dampers.



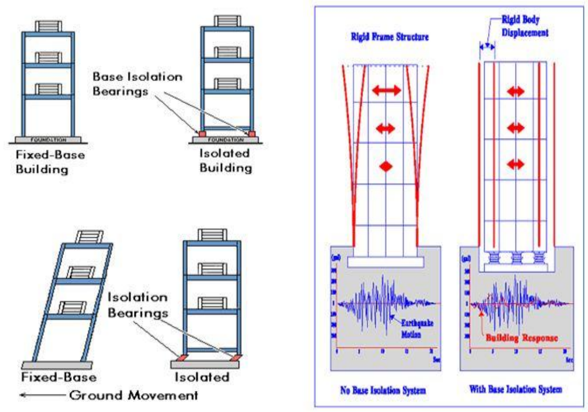


Fig.6 : Base Isolator working

Fig.7: Hospital at bhuj, India retrofitted with Base Isolators.

ADVANTAGES

- High energy dissipation
- No external power
- Good for using in large structures
- Compact
- Have both lateral stiffness and Vertical support

DISADVANTAGES

- Difficult to install to existing structures

1.2 ACTIVE CONTROL SYSTEMS

It consists of a structure whore responses are controlled, Sensors, Controller (Computer Controlled), Control Actuators.

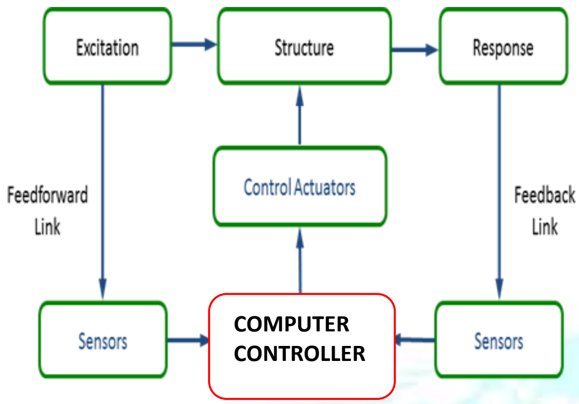


Fig.8: Flow chart of Active Control System

When the structure is excited due to seismic loads or wind loads, the excitation is recorded by the sensor in the forward link and sent to the computer, at the same time when it hits the structure. The structure sends response to sensors in the Feedback Link which is forwarded to the computer controller. Based on a predetermined Control Algorithm, the appropriate control signals are determined and sent to the Control Actuator. The control forces or the opposing force to make the structure stand stable is generated in the actuators.

This force generation requires a lot of power; it might be as high as tens of kilo watts for small structures to several megawatts for large structures.

There are three types of control configuration:
(i) Closed-Loop control
(ii) Open-Loop Control
(iii) Open- Closed Loop Control

(i) Closed Loop Control: If the structural response variables are measured and continually monitored and that information is used to make continual corrections to the forces applied then it is called a closed- loop system.
(ii) **Open-Loop Control: If the control forces are regulated only by measured excitations of earthquake inputs, this can be achieved by measuring acceleration at the structural base.**
(iii) Open- Closed Loop Control: If information on both response quantities and excitation are used for the control it is called Open- Closed Loop Control.

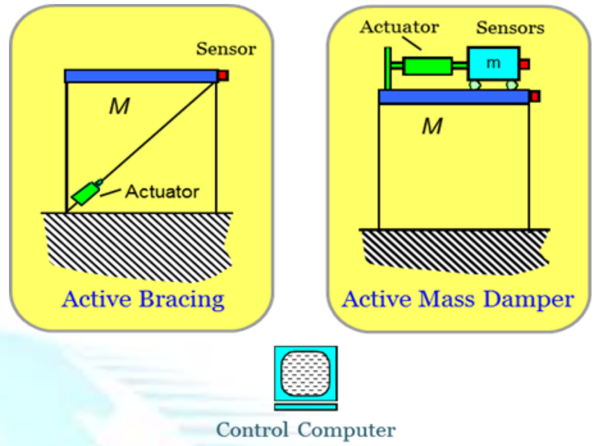


Fig.9: Types of Active control systems used.

A. ACTIVE BRACING SYSTEM

In this prestressed tendons or braces are connected to a structure and its tensions are controlled by electro-hydraulic servo mechanisms. This method is largely acceptable as tendons or braces are generally a part of almost many structure. Separate installation of such tendons and braces is not essential, hence it is easy to install and no big additions o0r modifications to existing structures is required. Hence, it is used in retrofitting and structural strengthening of existing structures.

In the year 1980, Active tendon control was first studied on small – scale structural models at Roorda, Studies were carried out on simple cantilever beams, a free standing column and a king post truss and control devices tested on them were, tendon control using manual operations and tendon control using servo-valve controlled actuators.

In the year 1988, experimental studies were carried out in three stages, At stage 1 & 2 a three storey steel frame model was used. At stage 1, the top two floors were rigidly braced and a single degree of freedom system was simulated. It was then mounted on a shaking table which would supply external load similar to that of seismic loads. The opposing or the control forces were transmitted to the structure through the diagonal pre-stressed tendons as shown in the fig.

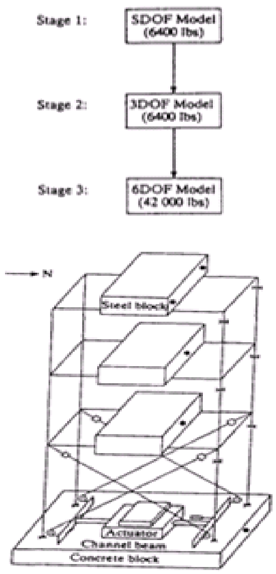


Fig.10 Lab Test of model structures at stages 1&2 Active Bracing System

This model was made dynamically similar to a real structure and were designed such that realistic structural control situations could be evaluated, the models were carefully calibrated models, realistic base excitation was used.

Moreover, these experiments permitted a comparison between the experimental and analytical results and hence, it was possible to extrapolate the results to real structural behaviour. And adding to that, time delay, robustness of control algorithms, model errors and also structure-control interactions were directly assessed.

In an SDOF system, a reduction of about 50% of relative displacement in the first floor was achieved. This was because, the control system has induced a damping of 1.24% in the uncontrolled to about 34% in the controlled case.

Then stage 3 experiment was to study a larger and heavier six-storey building model, It was a welded frame too using artificial mass simulation. It weighed about 42,000lbs and its height was 18 feet. A single actuator is placed at the base with diagonal tendons connected to a single floor.

In this case, multiple connections were made, as this type of connections are used in our day to day building constructions. The arrangements made were:

(i) Single actuator at the base which was in turn connected to a single floor using diagonal tendons.
(ii) Single actuator at the base, and the tendons connected applied proportional loads as they were simultaneously connected to two floors.
(iii) Two actuators, at two levels, and two pairs of independent tendons acting independently.
(iv) Active mass damper was used as 'SECOND CONTROL SYSTEM'.
Results obtained were,

When El-Centro acceleration was given as input scaling to 25% from the natural, reduction of maximum relative displacements at the top-floor was 25% of the actual intensity. When extrapolated to full scale, Control force and power were also within the practical limits.

B. AC TIVE MASS DAMPER

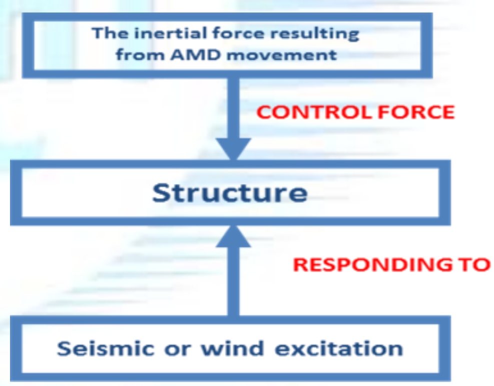


Fig.11 Working

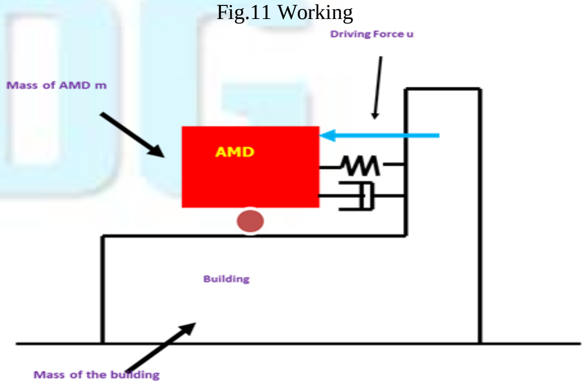


Fig.12 Active Mass Damper

It is a mass of weight installed into the top floor or near the top floor, which counteracts to the seismic forces and is controlled by a computer.

The design process involves,

(i) Developing of mathematical model of the structure and choosing of the actuators and sensors.
(ii) Adopting a mathematical model for the disturbances or the seismic or wind load.
(iii) Deciding the specifications: Peak load, acceleration, time to settle down after disturbance is applied.
(iv) Choosing the control algorithm. To obtain the 'proportionality constant', actuation voltages, forces from sensor voltages.
(v) To design the controller so that performance specs are met. Examples of control algorithm are, proportional, integral, derivative, robust control etc.

1.3 SEMI-ACTIVE CONTROL SYSTEMS

It takes advantage of both the systems as explained below:

PASSIVE CONTROL SYSTEM – RELIABILITY – It protects the structure using control forces developed as a result of the motion of the structure.

ACTIVE CONTROL SYSTEM – ADAPTABILITY- It monitors the feedback and generates appropriate command signal.

SEMI-ACTIVE SYSTEM- RELIABILITY OF PASSIVE + ADAPTABILITY OF ACTIVE

ADVANTAGES

- Don't require large power sources
- Can operate on battery power, which is critical during seismic events when the main power source to structure may fail
- Performance is better than passive devices and have potential to achieve similar performance with fully active devices

Typical semi-active control devices work by changing or controlling a part of characteristics of CONTROL ACTUATOR 'only' at appropriate time instants. It is called the adaptive nature of the SA control. Such dampers are called controllable dampers.

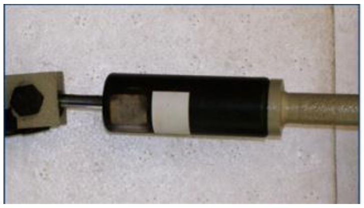


Fig. 13 MR- Damper

WORKING:

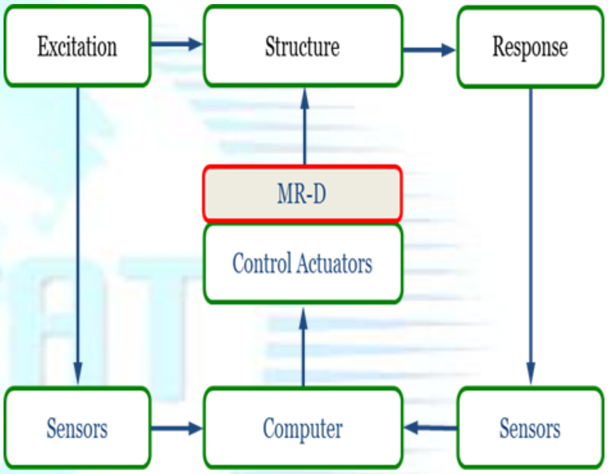


Fig.14 Working

A. MAGNETORHEOLOGICAL DAMPER OR MR DAMPER:

Such a damper is controlled by algorithms. This algorithm controls the fluid's viscosity with electromagnetic fields. When the fluid is brought near an electromagnetic field, the particles inside the fluid align itself as shown in the figure according to its field line. When this alignment takes place the properties also gets changed, which helps the damper to start its work of shock absorption. Thus here we can clearly see that, it does not consume any high power to get actuated. And also it is highly reliable just like the passive devices.

The measured responses during a test of input 120% El Centro Earthquake was for a 3 storey building model, MR used was Rheonetic SD-1000, height 158cm & mass 304kg:

- 75% reduction in peak displacements.

- 50% reduction in peak acceleration &
- 30% better response reduction than when the device is operated in passive capacity.

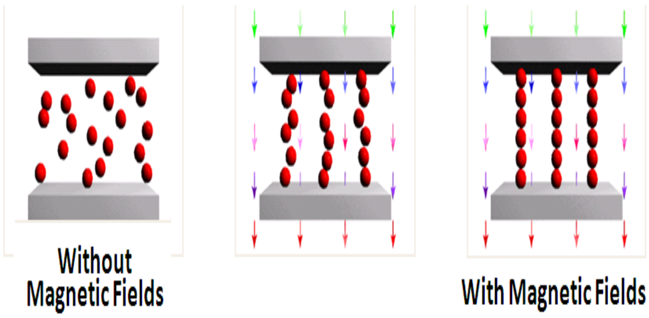


Fig.15 Changes in property when an electro-magnetic field is used

2. CONCLUSION AND FUTURE DIRECTION OF SEISMIC STUDIES

- Functionally upgraded Passive device or to find out SMART PASSIVE DEVICES
- SMART PASSIVE DEVICES must do the function of Semi- Active Devices.

[4] T.T. Soong and G.F. Dargush, "*Passive Energy Dissipation Systems in Structural Engineering"*, John Wiley & Sons, 1997.

- And most important is to find a device which uses wireless sensor network.
- Its control must be decentralized and it should be capable of harvesting the energy given out by the Earthquake.

3. ACKNOWLEDGEMENT

I take immense pleasure in thanking our college Chairman, Vice- Chairman, Director, Trustee, Principal and Vice- Principal, **Vel Tech Group of Institutions, Chennai,** for their constant support in encouraging me and for their financial support also.

4. REFERENCES

[1] Spencer, B.F., Jr., "*Current Practice and Future Trends in Structural Control*," Lotte Symposium, 2008.

[2] Housner, et al., "*Structural Control: Past, Present, and Future*," Journal of Engineering Mechanics, ASCE, 123(9), 1997.

[3] T.T. Soong, "*Active Structural Control: Theory and Practice"*, John Wiley & Sons,1990.

[5]A. Nishitani and Y. Inoue (2001). "*Overview of the application of active/semiactive control in Japan*," Earthquake Engineering & Structural Dynamics, Vol. 30(11), pp.1565-1574.