IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 1, January 2020, ||Series -II|| PP 74-81

State of Art on Earthquake Resistant Design of Structure using New Age Instrument VFD and MRD

A. P. Chaudhari, N. P. Kataria
M.E Scholar, Department of Civil Engineering, Prof. Ram Meghe Institute of Technology and Research Amravati, Maharashtra, India
Associate Professor, Department of Civil Engineering Prof. Ram Meghe Institute of Technology and Research Amravati, Maharashtra, India
Received 31 December 2019; Accepted 15 January 2020

Abstract: Due to an earthquake life, financial, mental losses and other bad effect are growing. In some condition there is increase in losses due to absence or improper severability of lifeline structure after disaster. So serviceability of lifeline structure (mostly hospital and bridges) after earthquake is more important in earthquake prone zone. Conventional earthquake resistant design will increase strength and ductility but structure will not be serviceable after major earthquake. So, there is a need to find additional way to protect lifeline structure. In this state of art, vibration control of a structure with help of varies new age dampers are discussed. This paper provides classification of control system, basic principle, construction, working, application and placing of Viscous fluid (VFD) and Magneto-rheological dampers (MR).
Keywords: *Earthquake, vibration control, Seismic control systems, viscous fluid dampers, MR damper.*

I. INTRODUCTION

From past few decades, the world has experienced number of destroying earthquakes. During earthquake, number of people losses their life, house and financial sources due to collapse and severe losses in structure. But some people save their life due to the situation but they suffering from highly serious injuries, mental attack, respiratory problem and inflectional diseases and need immediate primary medical treatment. So, serviceability of lifeline structure is important at that time. As per conventional method of designing, under minor but frequent shaking, the main members of the buildings that carry vertical and horizontal forces should not be damaged; however buildings parts that do not carry load may sustain repairable damage. Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts that do not carry load may sustain repairable damage. Under strong but rare shaking, the main members may sustain severe damage, but the building should not collapse (IS 1893:2016). Hence, as per above philosophy, after major earthquake, building does not serve the purpose. This aftermath damages in Health facilities lead to increase in dead/ injured ratio as shown in Table no.1

TABLE 1 COMPARATIVE DATA RELEVANT TO MAJOR EARTHQUAKES OF THE PAST DECADE (Motamedi et. al., 2002).

Place	Date	Local magnitude (Richters)	Ratio of casualties: dead/ injured (%)	City Damage, %	Health facilities damage, %
Iran (Bam)	2003 Dec	6.6	26,271/51,500: (51)	85	90
Haiti (Portau-Prince)	2010 Jan	7.2	212,000/512,000: (42)	90	22
Peru (Ica)	2007 Aug	7.9	514/1,604: (32)	Most of the city	60
China (Sichuan)	2008 May	8.0	69,170/443,329: (15)	80	N/A
Pakistan (Kashmir)	2005 Oct	7.6	73,276/ 153,276:(47)	60	90

So serviceability of lifeline structures is most important in earthquake affected area. Safety and serviceability improved by reducing vibration levels of structures due to unexpected lateral seismic loads. For that, providing new concepts of design of structures against seismic loading is necessary. So that, now a day's various types of vibration control systems are used in the structure which broadly divided in to active, passive, hybrid and semi active vibration control devises. In this state of art, vibration control of a structure with help of varies new age dampers are discussed. This paper provides classification of control system, basic principle, construction, working, application and placing of viscous and magneto-rheological dampers.

II. CLASSIFICATION OF CONTROL SYSTEM

As per earthquake resistance design philosophy, after major earthquake building can not be serve its purpose properly. but after major earthquake, there will be more neeed of health facilities and other lifeline structure (IS1893:2016). so additional external devices are come in to role which helps in reduce seismic vibrations. Large variation in characteristic of ground motion and building structure, various types of vibration control systems are used which broadly divided in to active, passive, hybrid and semi active vibration control devises.

A. Passive Control Systems

Passive control systems alleviate energy dissipation demand on the primary structure by reflecting or absorbing part of the input energy, thereby reducing possible structural damage. However, passive control systems are limited in that they cannot deal with the change of either external loading conditions or usage patterns. One type of passive control systems is seismic isolation (often referred as base isolation).The isolation system introduces flexibility and energy absorption capabilities, thereby reducing the level of energy which can be transmitted to the structure. The most important requirements for an isolation system are its flexibility to lengthen the natural period and produce an isolation effect, its sufficient rigidity under service loads

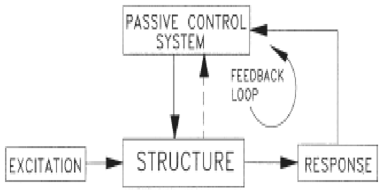

fig.1 Passive Control Systems(Michael,1999)

Energy dissipation of passive vibration control system is given by

E = Ek + Es + Eh + Ed

E = total input energy from environmental forces;

Ek = absolute kinetic energy;

Es = recoverable elastic strain energy;

Eh = irrecoverable energy dissipated by the structural system through inelastic or other inherent forms of damping; and

Ed = energy dissipated by structural protective systems.

There are so many structures in which passive vibration control system are used in past 30 years. metallic yield dampers were used to retrofit a two-story concrete building in San Francisco, and three reinforced concrete buildings in Mexico City ; Pall friction dampers have been installed in thirteen buildings in Canada including six retrofits and seven new facilities; visco elastic dampers were installed in the former World Trade Center in New York City to reduce wind-induced vibrations ; Taylor viscous fluid dampers were installed in the newly-constructed San Bernardino County Medical Center in California as components in the rubber bearing seismic isolation system; TMDs were installed in the Citicorp Center in New York City, the John Hancock Tower in Boston, the main towers of the Akashi-Kaikyo Bridge in Japan, and the Sydney Tower in Australia tuned liquid dampers were installed in the Nagasaki Airport Tower, the Yokohama Marine Tower, and the Shin-Yokohama Prince Hotel.

B. Active control system

The control systems which are behaved according to the measured response of the structure and for vibration control for generated by electro hydraulic or electromechanical actuators. The recorded measurements from the response and/or excitation are monitored by a controller which, based on a pre-determined control algorithm, determines the appropriate control signal for operation of the actuators. The generation of control forces by electro hydraulic actuators requires large power sources, which are on the order of tens of kilowatts for small structures and may reach several megawatts for large structures and it is very difficult in that situation for connection (Michael, 1999).

Based on the control strategy, active control can be classified as: open loop control system (when the left side loop of Figure is operative); close loop control (when the right side loop of Figure is operative); and open–close loop control (when the both loops of Figure are operative). An adaptive control system is a variation of open-close loop control with a controller which can adjust parameters of the system (Symans, 1999). The adaptive systems are generally used to control structures whose parameters are unknown and are based on tracking error between the measured response and the observed response.

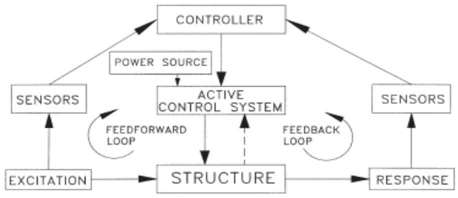

fig.2 ***Active control system (Symans,1999)***

AMD on Kyobashi Seiwa Building is the world's first AMD installed on a building which is located at Chuo-Ku, Tokyo. Duox on ANDO Nighikicho is located in Chiyoda–Ku, Tokyo. Trigon on Shinjuku Tower is located in Shinjuku–Ku, Tokyo are some world famous examples of active control system. Fig._ shows used mechanism in it.(Datta 2003)

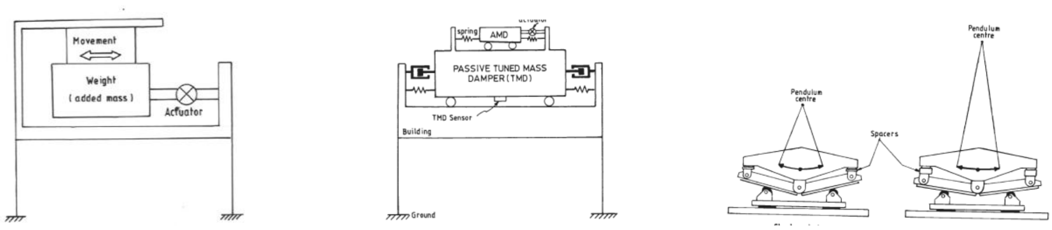

fig.3 ***Active control system (a) AMD on Kyobashi Seiwa Building (b) Duox on ANDO Nighikicho (c) Trigon on Shinjuku Tower (datta, 2003)***

C. Semi-active control systems

A semi-active control system may be defined as a system which requires a small external power source for operation (e.g. a battery) and utilizes the motion of the structure to develop the control forces, the magnitude of which can be adjusted by the external power source. Control forces are developed based on feedback from sensors that measure the excitation and the response of the structure. The feedback from the structural response may be measured at locations remote from the location of the semi active control system .

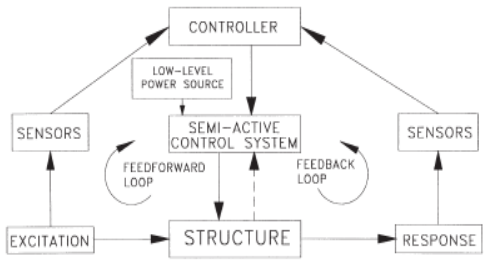

fig.4 ***Semi-active control systems(Symans, 1999)***

Different types of semi-active control devices include:
(i) Stiffness control devices - These devices are utilized to modify the stiffness. This establishes a new resonant condition during earthquakes. The devices used are stiffness bracings, which are engaged or released so as to include or not to include the additional stiffness in the system and operate generally through fluid control within tubes by valves (Symans, 1999).
(ii) Electro-rheological dampers/magneto-rheological dampers - They consist of a hydraulic cylinder containing micron-size dielectric particles suspended within a fluid. In the presence of current, particles polarize and offer an increased resistance to flow (a change from viscous fluid to yielding solid within milli-seconds). The magneto-rheological dampers are magnetic analogues of electro-rheological dampers and have electro-magnets located within the piston head which generate the magnetic field (Symans, 1999).
(iii) Friction control devices - They are energy dissipaters within the lateral bracing of a structure or are as components within the sliding isolation system. The coefficient of friction of sliding is controlled by the modulation of fluid pressure in a pneumatic pressure (Symans, 1999).

(iv) Fluid viscous devices - They consist of a hydraulic cylinder, with a piston dividing it into two sides. The cycling piston forces oil through an orifice, creating the output force. The output force is modulated by an external control valve which connects two sides of the cylinder (Symans, 1999).

D. Hybrid control systems

The three major classes of control systems described above are sometimes combined to form so called hybrid control systems. Hybrid control systems consisting of combined passive and active devices or combined passive and semi-active devices. Base isolation and actuators, ATMD, visco-elastic dampers and actuators, etc are done for special result. It is governed by a control algorithm in which the dynamic characteristics of structural system include those of passive control devices.

Tanida et al. (1991) developed an arch-shaped HMD that has been employed in a variety of applications, including bridge tower construction, building response reduction, and ship roll stabilization (Soong, 2000).

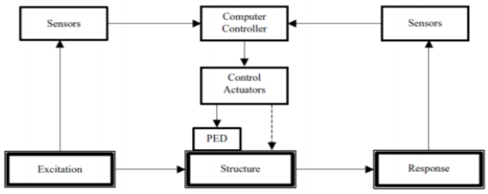

fig.5 Hybrid control system (Soong, 2000)

III. DAMPERS

Dampers are the devices which are used to absorb or dissipate the vibration caused by the earthquake to the structure and to increase the damping and stiffness of the structure. According to the phenomenon of energy decapitation there two type of dampers one viscous damping and Hysteretic damping. Viscous damping depends on frequency and Hysteretic damping assumes non-linear relations between stresses - deformations. Some materials, such as structural steel, are almost ideally elastic up to the elasticity limit. With these materials, that type of dissipation can occur during stress much lower than the stress at the elasticity limit. It can be explained by concentration of stress and residual stresses. Tuned mass damper (TMDs), Tuned liquid mass damper (TLDs), Friction damper, Metallic damper, viscous damper, Elasto- plastic damper are the some common damper which used in the practice (Housner et. al., 1997).

A. Viscous Damper

Viscous dampers are early invented for army and military application. But as need for vibration control due to wind excitation, blast and earthquakes, we are adopted in the structure since 1993. All static Force developed by viscous damper is always resists structure motion and it proportional to the relative velocity between the ends of the damper. The damping law is as follows (Lee et. al, 2001):

$$F = cv^{N} \qquad \text{……….} (1)$$

Where
F is the damper force,
C is an arbitrary constant (C remains constant over the full range of velocities),
V is velocity,
N is an exponent that can range from 0.3 to 1.95 (N remains constant over the full range of velocities)

As we see that there is no spring force in eq. 1 so all damping force is only depend upon relative velocity. viscous damper is made up of different part as shown in fig. no.6

1 Piston rod –it is nothing but rod which is made by highly alloy stainless steel which is suitable for resist compression buckling and must not flexure under load. For more durability of seal it must be proper finish (Lee et. al, 2001).

2 Cylinder-it is made of seamless steel (does not have any welding seam) and contain working fluid which comes in the operation when seismic activity occurred. Designing pressure is taken 1.5 of expected pressure for controlling of maximum seismic activity (Lee et. al, 2001).

3 Fluid- must be fire-resistant, non- toxic, thermally stable, cosmetically inert .it must be fulfill the guideline of OSHA (Occupational Safety & Health administration) (Lee et. al, 2001).

4 Seal- the seal must not allow fluid seepage .as dampers are come in used in higher time interval so that seal must have a property which does not exhibit long-term sticking. Seal is generally made up of polymers (Lee et. al, 2001).

5. Piston head -The piston head attaches to the piston rod and effectively divides the cylinder into two separate pressure chambers. This space between the outside diameter of the piston and in the inside diameter of the cylinder forms the orifice. Very often the piston head is made from a different material than the cylinder to provide thermal compensation. As the temperature rises the annulus between the piston head and the cylinder shrinks to compensate for thinning of the fluid (Lee et. al, 2001).
6. Accumulator -The damper uses an internal accumulator to make up for the change in volume as the rod strokes. This accumulator is either a block of closed-cell plastic foam or a movable pressurized piston, or a rubber bladder. The accumulator also accommodates thermal expansion of the silicone fluid (Lee et. al, 2001).

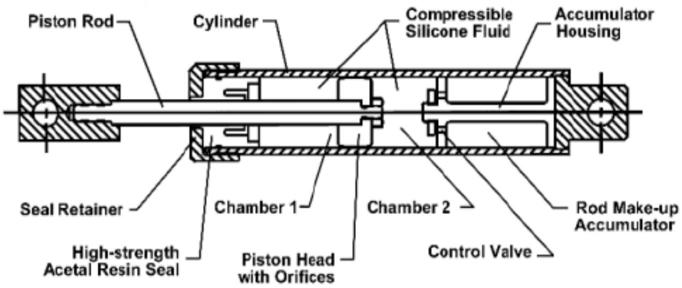

fig.6 Elements of viscous damper (Housner et. al, 1997)

According to the placing of dampers, the efficiency of damper are varies. Placing of damper are decided according to the mass and stiffness distribution of the building. The lateral forces in direction of X and Y are both considered during deciding placing (Lee et. al, 2001).
a) In Parallel with Base Isolators-This type of arrangement is offered if there is more at space is limited or where the base isolators would have to be extremely large. In Parallel with Base Isolators can cut predicted motion in half. These types of arrangement also effective reducing inter storey drift and shear.
b) Diagonal Members-In this pattern we placed damper like a conventional brace with the help of tubular extender but does not change in period of the building .it is generally used in refurbishments.
C) Chevron Brace-dampers installed in both legs of a chevron brace. The effect is similar to dampers is diagonal members.
d) Horizontally at the Top of a Chevron Brace - It is advance technique over chevron brace .apex of main damper is attached to two sub horizontal dampers.
e) Horizontally between adjacent structures -This type arrangement is generally adopted for avoiding pounding .in addition to that it also earthquake-induced motion
f) Toggle Brace -It is difficult to provide conventional damping when structural deformation is very small, such as less. Dampers installed horizontally between adjacent structures Than 1/8 Inch. In this case a toggle linkage such as amplify the damper Motion effectively.

B. Magneto-Rheological (MR) damper
Actually Magneto Rheological damper is related to rheology science in which flow and deformation of the materials under an applied magnetic field. Magneto-rheological fluid dampers provide in many places as semi active control devises, because of their simplicity, low input power requirement which is very important, scalability and inherent robustness as compare to other damper devices, such MR fluid dampers is very much effective in civil engineering applications. Magneto rheological fluids belong to the class of controllable fluids. The essential characteristic of MR fluids is their ability to reversibly change from free-flowing, linear viscous liquids to semi-solids having controllable yield strength in milliseconds when exposed to a magnetic field (Yang et. al, 2002).

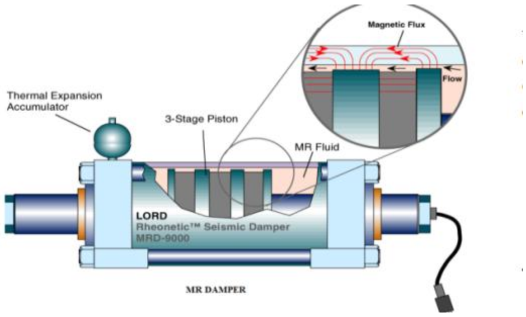

fig.7 MR damper (Yang et. al., 2002)

The initial discovery and development of MR fluids can be credited to Jacob Rabinow. These fluids are suspensions of micron-sized, magnetizable particles in an appropriate carrier liquid. Normally, MR fluids are free flowing liquids having a consistency similar to that of motor oil. However, in the presence of an applied magnetic field, the iron particles acquire a dipole moment aligned with the external field which causes particles to form linear chains parallel to the field, as shown in Fig. . This phenomenon can solidify the suspended iron particles and restrict the fluid movement. Consequently, yield strength is developed within the fluid. The degree of change is related to the magnitude of the applied magnetic field, and can occur only in a few milliseconds. A typical MR fluid contains 20–40% by volume of relatively pure, soft iron particles, e.g., carbonyl iron; these particles are suspended in mineral oil, synthetic oil, water or glycol. A variety of proprietary additives similar to those found in commercial lubricants are commonly added to discourage gravitational settling and promote particle suspension, enhance lubricity, modify viscosity, and inhibit wear. The ultimate strength of an MR fluid depends on the square of the saturation magnetization of the suspended particles. The key to a strong MR fluid is to choose a particle with a large saturation magnetization (Zalake et. al., 2008).

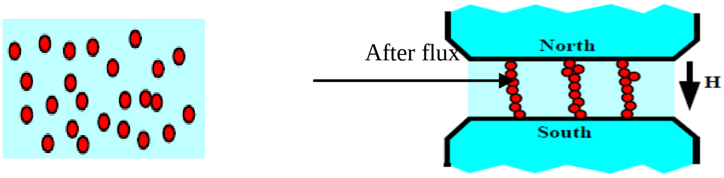

fig.8 MR fluids.

In all fluid based dampers, passive viscous damper and semi active MR damper was used, studied by huge number of researcher in the past. The benefit, application, use of different control low, to various structure studied by researcher which helps in future planning and application. The literature reviews of some researcher are as follow

Kataria and Jangid (2014) studied on optimum semi-active hybrid system for seismic control of the horizontally curved bridge with Magneto-rheological damper. They discussed the application of Magneto-rheological damper for a seismic control of the horizontally curved bridge isolated with different passive devices. The work include to find the effectiveness of hybrid system i.e. MR+ERB, MR+LRB and MR+FPS for seismic response control of the curved concrete box girder bridge problem, influence of variation in important parameters of the MR damper on the response of the bridge, to find optimum semi-active hybrid system for seismic control of the horizontally curved bridge. They find semi-active hybrid control system consisting of MR+LRB(Lead rubber bearing) is more effective than the other system(MR+ERB and MR+FPS).

Dyke and Spencer Jr. (1996) presented a number of recently proposed semi active control algorithms are evaluated which used in analysis of magneto-rheological damper. In this study, control of vibrations of a three-story structure using an mr damper is evaluated. This paper included control based on Lyapunov stability theory and decentralized bang-bang control. The results demonstrated that the performance of the resulting controlled system and the requirements of the control device are highly dependent on the control algorithm employed. Each semi-active controller performed noticeably better than the passive controllers.

Yang and et. al. (2002) gives studied on the essential features and advantages of MR materials and devices. They also work the derivation of a quasi-static axi symmetric model of MR dampers, which compared with both a simple parallel-plate model and experimental results. It is found that these models are not sufficient to describe the dynamic behavior of MR dampers. So conclusion of this paper is Dynamic response time is an important characteristic for determining the performance of MR dampers in practical civil engineering applications.

Puneeth Sajjan and Praveen Biradar(2016) was modelled and analyzed 8-story structure with and without viscous damper which is symmetrical in plan with the help of ETABs 2015 software. In this study earthquake loading define as per IS1893-2002 (Part 1) and analyzed in statically and dynamically by response spectrum for zone 2 and medium soil. They used viscous damper for control the seismic response with increasing the stiffness. They find that introducing viscous damper are resulting in decrease of building displacement (reduced about 60% to 85%) and building drift (reduced by 70% for mid story and about 60% to 80% for top story) but the difference in shear value is less because of the weight of the damper provided to the structure.

P.A.Vikhe And U.R.Kawade (*2016*) studied on seismic response control of high rise building by using Viscous Damper. They took 3 bays 14 storied frame structures and compare the result of building fixed base and using viscous damper. In this study Time period, storey drift and storey displacement evaluated and compared between two cases. They found lateral point displacement of fixed base building are more as compared to damper building in both x and Y Directions. They compare their result of storey drift with the minimum requirement of storey drift as per IS 1893:2000.

Miyamoto and et. al. (2004) were designed New steel buildings using performance based engineering and provisions of ASCE 7. They made analytical model of steel buildings with viscous dampers, integrating with damper limit states, were prepared and analyzed to determine their collapse performance. They concluded that, excellent performance and revealed that, the use of factors of safety to delay the onset of reaching limit states was beneficial.

Bhaskararao and Jangid (2007) studied on Optimum viscous damper for connecting adjust SDOF structures for harmonic and stationary white-noise random excitations. The governing equations of motion of the connected system are derived and solved for relative displacement and absolute acceleration responses of connected structures. They conclude that the damping in connected adjacent structures does not have noticeable effect on the optimum damper damping.

D. Lee And D. P. Taylor (2001) Studied On Viscous Damper. This paper describes all basic idea about the viscous damper. It illustrated the construction, detailed, future scope about the viscous dampers.

Infanti and et. al. (2004) visualized the seismic protection system to protect several bridges in Korea like the Seo-Hae Grand Bridge Approaches, Ok-Yeo Bridge, Chun-Su Bridge, E-Po Bridge, Kang-Dong and several others. In this study, use of viscous dampers was preferred to moderated seismic effect on structures which proven very helpful, particularly in retrofit applications where it is difficult to change service load static configurations and when there is requirement for additional damping.

Zizouni and et. al(2017) presented semi active control for MR damper is proposed for controlling the vibrations due to earthquake. They took three story structure with MR damper installed in the first floor. In this study, LQR strategy coupled with the clipping control to command the voltage of MR damper and in result, good performances and can significantly reduce the vibration.

Das and et al. (2008) gives control algorithm for feedback of three storey model building frame and is implemented by using the Fuzzy Logic and Simulink toolboxes of MATLAB. Clipped optimal control and bang-bang control are used for testing of control algorithms which is widely used. In order to find effective result study have five different capacities of the damper are used to control the response, namely (1) 450 N; (2) 1500 N; (3) 2250 N;(4) 3000 N; and (5) 4800 N. but it was seen that beyond a certain capacity of the damper (500 N), there is no significant effect was seen.

IV. CONCLUSION

An earthquake leads losses of their life, house and financial sources due to collapse and severe losses in structure. Damages in health facilities lead to increase in dead/ injured ratio. Serviceability of hospital and bridge is most important after earthquake which can be done by vibration control. From literature review, it can be concluded that;

- Structural control technology is very much important for earthquake resistant design structure.
- Effectiveness of vibration control system is depend upon selection of control system and devices type of sensors used, nature of the instrumentation network, level of available knowledge of previous earthquake, configuration and topology of site, variety of materials used in construction, the level of damage and deterioration in building before installation of system (if it use for retrofitting), complexity of analyzing , degree of information about the structural details of a structure, the depth of knowledge concerning the failure modes of the structure.
- Comparison of passive, active and semi-active structural control systems conclude that semi-active control systems provide more effective to seismic protection without the limitations of passive and active systems.
- Behaviour and nature of semi active devises are very complicated to find but it very much effective for performance enhancement versus construction costs and long-term effects of earthquake.
- Due to non-linear nature and uniqueness in each and every case, analyses for performance are important in every structure.
- Analysis and design of these complex systems is very challenging and interesting task.

ACKNOWLEDGEMENT

The author would like to thanks **Prof. N. P. Kataria** for his support and valuable suggestion.

REFERENCES

[1]. Ambraseys N. N. E1 Asnam (Algeria) “earthquake of 10 October 1980; conclusions drawn from a field study”. Quarterly Journal of Engineering Geology and Hydrogeology, 14, 1981, pp. 143-148.

[2]. Tanida, K., Koike, Y., Mutaguchi, K., and Uno, "Development of hybrid active-passive damper." Active and Passive Damping, 2 PVP-Vol. 211, 21-26(1991)

[3]. B .E Spencer, Jr and a S.J. Dyke " MR dampers -New approach for Protection of Structures" Conference on Decision and Control Kobe, Japan December 1996
[4]. S.J. Dyke, B.F. Spencer Jr., M.K. Sain and J.D. Carlson "Modeling and Control of Magnetorheological Dampers for Seismic Response Reduction"1996
[5]. Symans, M.D and Constantinou, M.C. "Seismic Testing of a Building Structure with a Semi-Active Fluid Damper Control System", Earthquake Engineering and Structural Dynamics, Vol. 26, No. 7, pp. 59-77. (1997).
[6]. G. W. Housner, A. G. Chassiakos, R. E. Skelton, B. F. Spencer "structural control: past, present, and future" J. Eng. Mech. 1997.123:897-971.
[7]. Michael D. Symans , Michael C. Constantinou, "Semi-active control systems for seismic protection of structures: a state-of-the-art review" Engineering Structures 21 (1999) 469–487.
[8]. D. LEE1 AND D. P. TAYLOR "Viscous Damper Development And Future Trends the Structural Design Of Tall Buildings" Struct. Design Tall Build. 10, 311320 (2001)
[9]. Yang a, B.F. Spencer Jr., J.D. Carlson, M.K. Sain "Large-scale MR fluid dampers: modeling and dynamic performance considerations" Engineering Structures 24 (2002) 309–323
[10]. Ni, Y.Q., Chen, Y., Ko, J.M. and Cao "Neuro Control of Cable Vibration Using Semiactive Magneto-rheological Dampers", Engineering Structures, Vol. 24, pp. 295-307. (2002)
[11]. T.K. Datta,"A State-Of-The-Art Review On Active Control Of Structures" ISET Journal Earthquake Technology, Paper No. 430, Vol. 40, No. 1, March 2003, pp. 1-17
[12]. Jann N. Yang, Anil K. Agrawal "Semi-active hybrid control systems for nonlinear buildings against near-field earthquakes" Engineering Structures 24 (2002) 271–280
[13]. Shih-Po Chang1, Nicos Makris, Andrew S. Whittaker and Andrew C. T. Thompson, Arup "Experimental and analytical studies on the performance of hybrid isolation systems" Earthquake Engng Struct. Dyn. (2002); 31:421–443
[14]. T T Soong And B F Spencer, Jr, "Active, Semi-Active And Hybrid Control Of Structures" 12wcee 2000
[15]. Samuele INFANTI, H.T. KANG, M.G. CASTELLAN "retrofit of bridges in korea using viscous damper technology" 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 221
[16]. A. V. Bhaskararao and R. S. Jangid, "Optimum viscous damper for connecting adjacent SDOF structures for harmonic and stationary white-noise random excitations " Earthquake Engng Struct. Dyn. 2007; 36:563
[17]. Diptesh Das1, T. K. Datta2 and Alok Madan, "Seismic Control Of Building Frames Using Mr Damper" World Conference On Earthquake Engineering , October 12-17, 2008, Beijing, China
[18]. Ms.A.A.Zalake, Mr.M.V.Kharade, Mr.A.A.Patil "An Overview Of Optimization Of Settling Time Of Mr Damper With Selected Mr Fluid Particle" International Journal Of Engineering Sciences & Research Technology, 2008
[19]. Nitin P. Kataria and R.S. Jangid "Optimum semi-active hybrid system for seismic control of the horizontally curved bridge with Magneto-rheological damper" Bridge Structures 10 (2014) 145–160
[20]. AlirezaHeysami "Types of Dampers and their Seismic Performance During an Earthquake" Current World Environment Vol. 10(Special Issue 1), 1002-1015 (2015)
[21]. Dharmesh Chandnani, Riddhi Joshi, Kumarpal Trivedi "Behavior Characteristics & Applications of Different Types of Dampers as Seismic Energy Dissipater" Journal of Computer Science and Network, Volume 5, Issue 2, April 2016
[22]. P.A.Vikhe, U.R.Kawade , "Seismic Response Control of High Rise Building by using Viscous Damper" IJARIIE-ISSN(O)-2395-4396(*2016*)
[23]. Puneeth Sajjan , Praveen Biradar, "Study On The Effect Of Viscous Damper For Rcc Frame Structure " International Journal of Research in Engineering and Technology eISSN: 2319-1163 (Sep-2016)
[24]. IS 1893-1 (2016): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings
[25]. K. Zizouni, I. K. Bousserhane , A. Hamouine, L. Fali "Mr Damper-Lqr Control for Earthquake Vibration Mitigation" International Journal of Civil Engineering and Technology (IJCIET) 2017
[26]. G. Sailaja N. Seetharamaiah and Maganti Janardhana., "Dynamic Behavior of a Structure using MR Fluid Damper" Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 8, Number 1 (2018)

A. P. Chaudhari. "State of Art on Earthquake Resistant Design of Structure using New Age Instrument VFD and MRD." *IOSR Journal of Engineering (IOSRJEN),* 10(1), 2020, pp. 74-81.