Seismic Performances and Evaluation of Structures Equipped with Supplemental Brace Damper System

[1]Owais Rasool
Postgraduate in Civil Engineering
Department of Civil Engineering
National institute of Technology
Srinagar Kashmir

[2] Dr. Manzoor Ahmad Tantray
Professor in Civil Engineering
Department of Civil Engineering
National institute of Technology
Srinagar Kashmir

[3]Aijaz Masoodi
Associate professor
Department of Civil Engineering
National institute of Technology
Srinagar Kashmir

***Abstract*---- The usefulness of supplementary energy dissipation devices is now quite well-known in the earthquake structural engineering community for reducing the earthquake-induced response of structural systems. The main objective of this study is, therefore, to formulate a general framework of comparing passive energy dissipation systems for seismic structural applications. The following four types of passive energy dissipation systems have been examined in the study: (1) viscous fluid dampers, (2) viscoelastic dampers, (3) yielding metallic dampers and, (4) friction dampers. For each type of energy dissipation system, effectiveness of each damper is calculated in modifying response of a structure like acceleration, displacement and drift of a structure.**

Key Words: Magnitude, Visco elastic damper, friction damper, seismic

I. INTRODUCTION

Many methods have been proposed for achieving the optimum performance of structures subjected to earthquake excitation. The conventional approach requires that structures passively resist earthquakes through a combination of strength, deformability, and energy absorption. The level of damping in these structures is typically very low and therefore the amount of energy dissipated during elastic behavior is very low. During strong earthquakes, these structures deform well beyond the elastic limit and remain intact only due to their ability to deform inelastically. The inelastic deformation takes the form of localized plastic hinges which result in increased flexibility and energy dissipation. Therefore, much of the earthquake energy is absorbed by the structure through localized damage of the lateral force resisting system. This is somewhat of a paradox in that the effects of earthquakes (i.e. structural damage) are counteracted by allowing structural damage. An alternative approach to mitigating the hazardous effects of earthquakes begins with the consideration of the distribution of energy within a structure. During a seismic event, a finite 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 is always some level of inherent damping which withdraws energy from the system and therefore reduces the amplitude of vibration until the motion ceases. The structural performance can be improved if a portion of the input energy can be absorbed, not by the structure itself, but by some type of supplemental “device.” This is made clear by considering the conservation of energy relationship:

$$E = E_k + E_s + E_h + E_d$$

Where E is the absolute energy input from the earthquake motion, E_k is the absolute kinetic energy, E_s is the recoverable elastic strain energy, E_h is the irrecoverable energy dissipated by the structural system through inelastic or other forms of action, and E_d is the energy dissipated by supplemental damping devices. The absolute energy input, E, represents the work done by the total base shear force at the foundation on the ground (foundation) displacement. It, thus, contains the effect of the inertia forces of the structure. In the conventional design approach, acceptable structural performance is accomplished by the occurrence of inelastic deformations. This has the direct effect of increasing the energy E_h. It also has an indirect effect. The occurrence of inelastic deformations results in softening of the structural system which itself modifies the absolute input energy. In effect, the increased flexibility acts as a filter which reflects a portion of the earthquake energy. The recently applied technique of seismic isolation accomplishes the same task by the introduction, at the foundation of a structure, of a system which is characterized by flexibility and energy absorption capability. The flexibility alone, typically expressed by a period of the order of two seconds, is sufficient to reflect a major portion of the earthquake energy so that inelastic action does not occur. Energy dissipation in the isolation system is then useful in limiting the displacement response and in avoiding resonances. However, in earthquakes rich in long period components, it is not possible to provide sufficient flexibility for the reflection of the earthquake energy. In this case, energy absorption plays an important role. Modern seismic isolation systems incorporate energy dissipating mechanisms. Examples are high damping elastomeric bearings, lead plugs in elastomeric bearings, mild steel dampers, fluid viscous dampers, and friction in sliding bearings. Another approach to improved earthquake response performance and damage control is that of supplemental damping systems. In these systems, mechanical devices are incorporated in the frame of the structure and dissipate energy throughout the height of the structure. The means by which energy is dissipated is either: yielding of mild steel, sliding friction, motion of a piston within a viscous fluid, orificing of fluid, or viscoelastic action in rubber-like materials. There are no of supplemental damping devices which can absorb energy and add damping to the building, in order to reduce seismic response these devices can be combined with base isolation or placed elsewhere up the height of buildings often in diagonal braces .Supplemental damping devices are especially suitable for tall buildings which cannot be effectively base isolated being very flexible compared to low rise buildings their horizontal displacement needs to be controlled this can be achieved by using damping devices which can use part of energy in making the displacement tolerable. Retrofitting the existing buildings is often easier with dampers than with base isolators. There are many types of dampers which are used to mitigate seismic effects they are

1. FLUID DAMPERS
2. FRICTION DAMPERS
3. VISCOELATIC DAMPERS
4. HYSTERETIC DAMPERS

Viscous fluid dampers:

These devices,(see fig 1) originally used as shock and vibration isolations systems in the aerospace and automotive industries, operate on the principle of resistance of a viscous fluid to flow through a constrained opening. The input energy is dissipated by viscous heating due to the friction between fluid particles and device components Different viscous materials have been considered to enhance stiffness and damping properties of the main structure.

Solid Viscoelastic Devices:

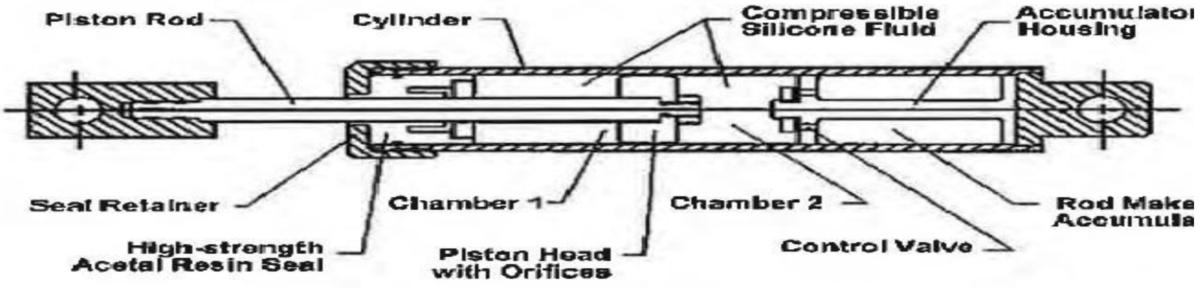
Typical viscoelastic dampers consist of polymeric material layers bonded between steel plates. These devices are designed to dissipate vibration energy in the form of heat when subjected to cyclic shear deformations. Viscoelastic dampers have been successfully employed to suppress wind-induced response in high-rise buildings.

Yielding metallic devices:

They consists of triangular plate elements that are made to deform as cantilever beams, . Because of their shapes, the metal plates in these devices experience uniform flexural strains along their length. Thus when the strain reaches the yield level, yielding occurs over their entire volume. During cyclic deformations, the metal plates are subjected to hysteretic mechanism and the plastification of these plates consumes a substantial portion of the structural vibration energy. Moreover, the additional stiffness introduced by the metallic elements increase the lateral strength of the building, with the consequent reduction in deformations and damage in the main structural members.

Friction devices:

They exhibit a hysteretic behavior similar to the one displayed by the metallic devices. These devices rely on the resistance developed between moving solid interfaces to dissipate a substantial amount of the input energy in the form of heat (fig 2). During severe seismic excitations, the friction device slips at a predetermined load, providing the desired energy dissipation by friction while at the same time shifting the structural fundamental mode away from the earthquake resonant frequencies.



(a) Schematic

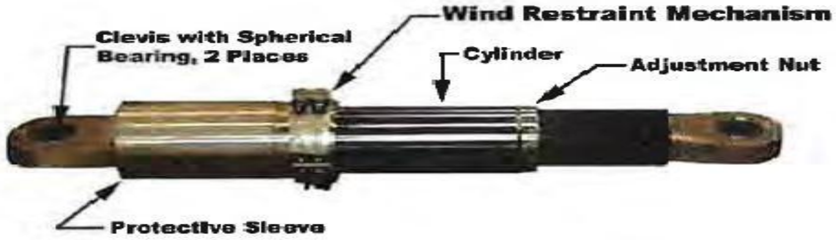


Fig 1: Fluid viscous damper

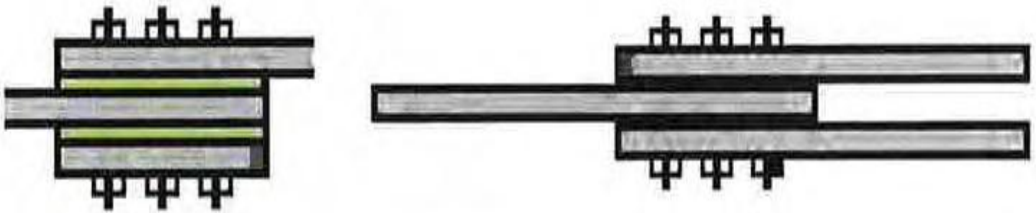


Fig 2: Friction damper device

OBJECTIVE OF STUDY UNDERTAKEN

Analytical methods are now available to analyze and evaluate structures installed with these supplemental damping devices. However we need to evaluate the seismic response of the buildings installed with these dampers during certain design intensity levels of earthquake motion. Obviously, there is a need to develop systematic and quantitative approaches to popularize the use of these very effective devices in the practice of earthquake structural engineering. With the currently available computing facilities and developments in the area of structural optimization, it now seems quite possible to design building structures installed with supplemental passive devices in an optimal manner. Following are broad line objectives:

1. Evaluating the seismic response of buildings during an earthquake.
2. Investigate the nonlinear behavior of buildings during an earth quake.
3. Evaluating the seismic response of building with supplemental damper-brace systems.
4. Evaluating the performance of different supplemental dampers during an earthquake.
5. To introduce a program for inelastic damage analysis of reinforced concrete structures (IDARC).

II. METHODS AND PROCEDURES

PROCEDURE

a. A frame was selected as case study frame.
b. Collected data was evaluated and was found sufficient enough to carry out seismic evaluation of the frame.
c. Elecentro wave 1940(NS components) was selected as an accelerogram (fig 6).
d. Frame was modeled using IDARC analysis software.
e. IDARC 2D building frame was analyzed with different brace-dampers .
f. Different responses like displacement drift acceleration were compared.

CASE STUDIES

There is one case study frame considered in this work. . This case study frame will be analyzed for four design earthquakes with magnitudes of 5,6,7,8 in the analysis to evaluate the performance of the case study frame. The frame is then provided with supplemental damper brace systems and response of the frame is evaluated and compared with original frame without brace dampers.(see Figs.(3a,3b.3c,3d).Details of dimensions and reinforcement is given in Table 1 and 2 and arrangement is given in Fig 4and 5.The program included following types of dampers

I. Viscoelastic(VE) dampers by 3M Company.
II. Fluid viscous dampers by Taylor devices.
III. Friction dampers by Sumitomo construction.
IV. Friction damper by Teken co.

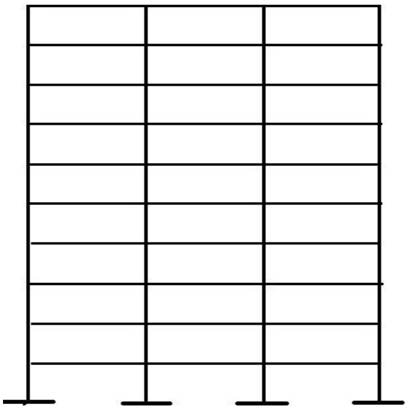


Fig 3a

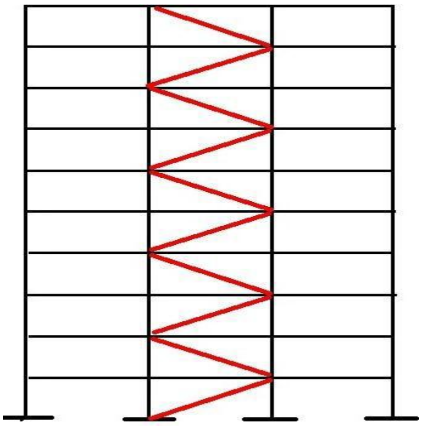


Fig 3b

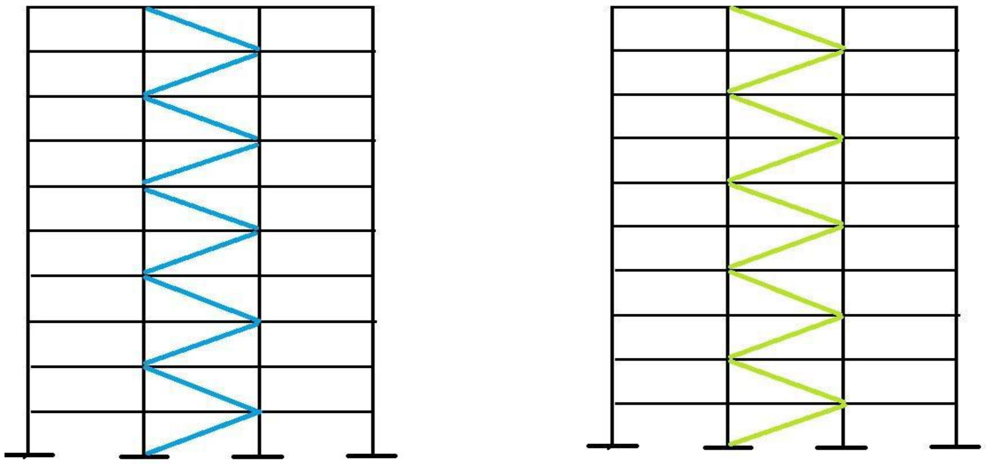


Fig 3a.Front elevation of frame without brace dampers .Fig3b.Front elevation of frame with friction damper braces.
Fig 3c.Front elevation of frame with hysteretic damper braces. Fig 3d.Front elevation of frame with VE damper braces

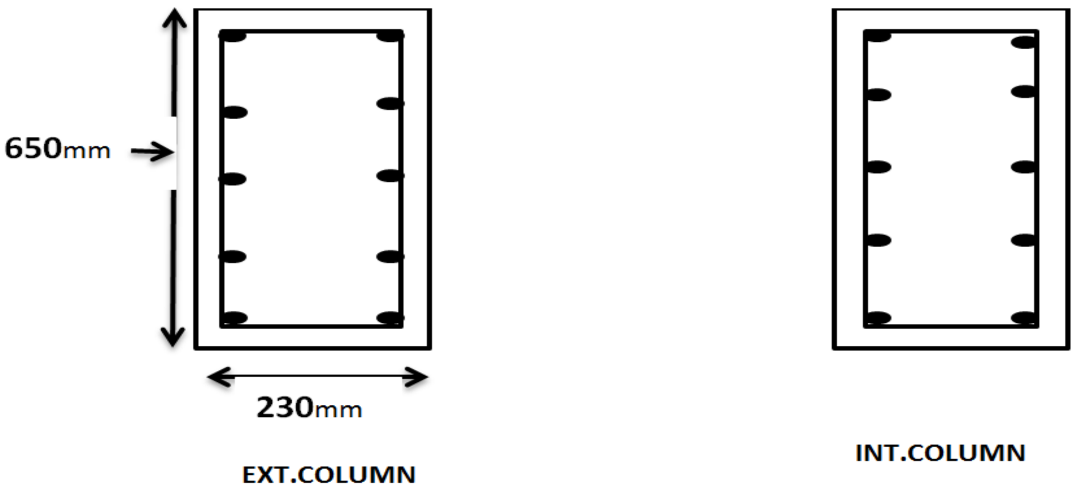


Fig.4 Arrangement of Reinforcement in Exterior and Interior Column

TABLE NO1.DETAILS OF REINFORCEMENT IN COLUMNS (MM)

STORY No.	LONG.REINFORCEMENT		TRANS. REINFORCEMENT	COVER
	ext	*Int*		
1&2	10#25φ	6#25Φ 4#20Φ	8Φ@100mm c/c	CLEAR COVER TO LONGITUDINAL REINFORCEMENT 40MM
3&4	6#25Φ 4#20Φ	10#20Φ		
5&6	10#20Φ	6#20Φ 4#16Φ		
7&8	6#20Φ 4#16Φ	10#16Φ		
9&10	10#16Φ	6#16Φ 4#16Φ		

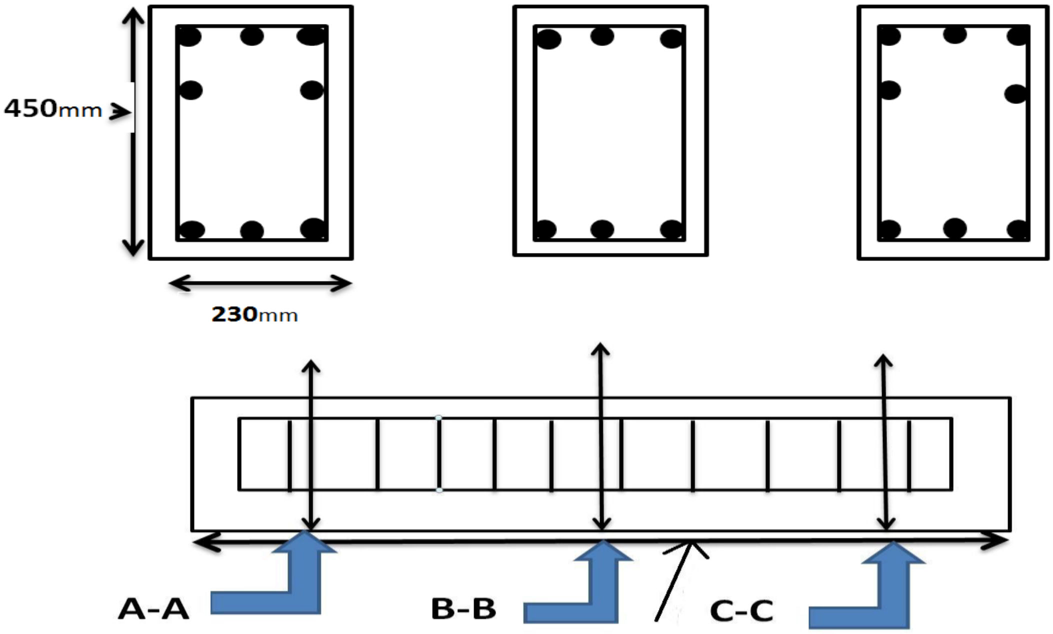


Fig.5 Arrangement of Reinforcement in beams

TABLE NO 2:.DETAILS OF REINFORCEMENT IN BEAMS (MM)

SECTION	LONG.REINFORCEMENT		TRANS.REINFORCEMENT	COVER
	top	*bottom*		
A-A	3#16Φ 2#12Φ	3#16Φ	8Φ@150mmc/c	CLEAR COVER TO LONGITUDINAL REINFORCEMENT 25MM
B-B	3#16Φ	3#16Φ		
C-C	3#16Φ 2#12Φ	3#16Φ		

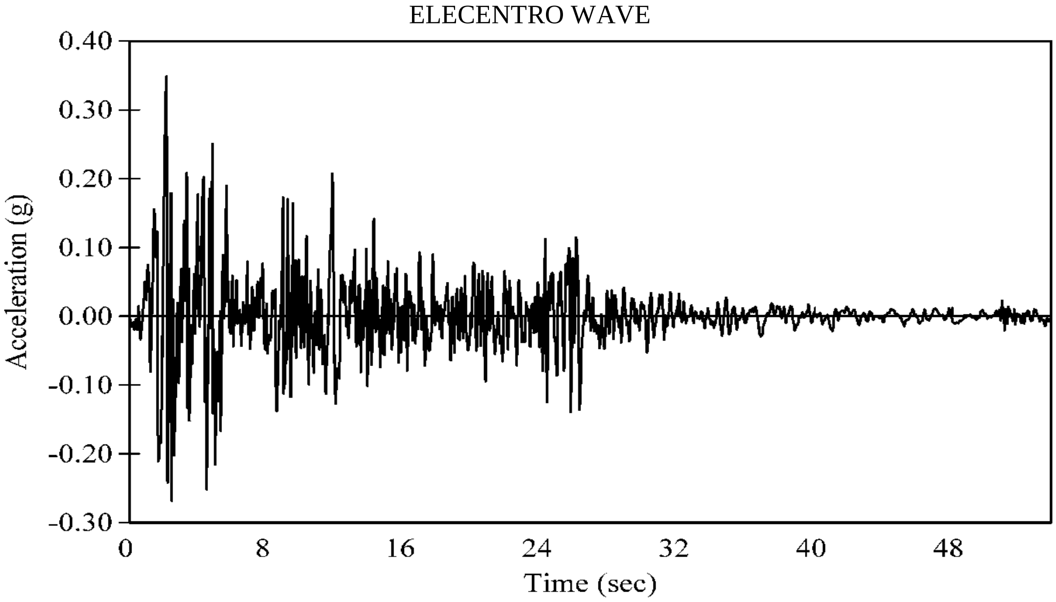


Fig 6: Elcentro Wave (Imperial Valley Earthquake)

IDARC SOFTWARE
(Inelastic Damage Analysis of Reinforced Concrete Building)

The computer program IDARC was introduced in 1987 as a two-dimensional analysis program to study the non-linear response of multistory reinforced concrete. The program was developed assuming that floor diaphragms behave as rigid horizontal links, therefore, only one horizontal degree of freedom is required per floor. This approach greatly reduces the total computational effort. Therefore, the building is modeled as a series of plane frames linked by a rigid horizontal diaphragm. Each frame is in the same vertical plane, and no torsional effects are considered. Since the floors are considered infinitely rigid, identical frames can be simply lumped together, and the stiffness contributions of each typical frame factored by the number of duplicate equal frames.

III. RESULTS

IDARC ANALYSIS FOR EARTHQUAKE OF MAGNITUDE 5

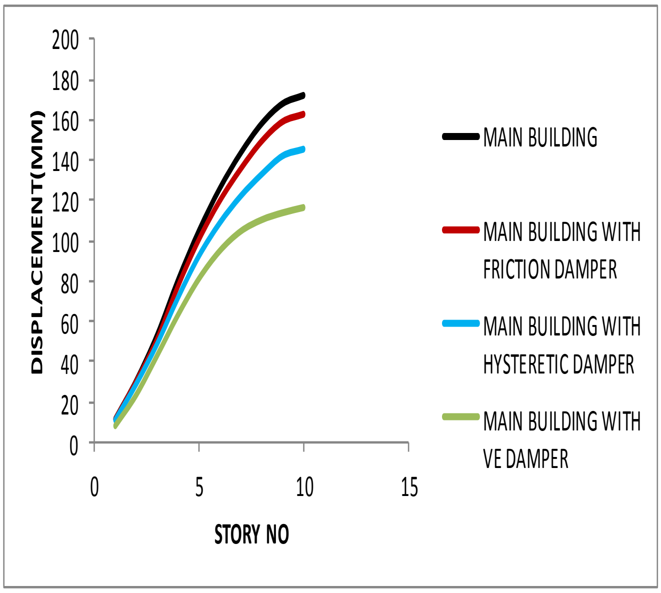


Fig 7: Displacement Comparison

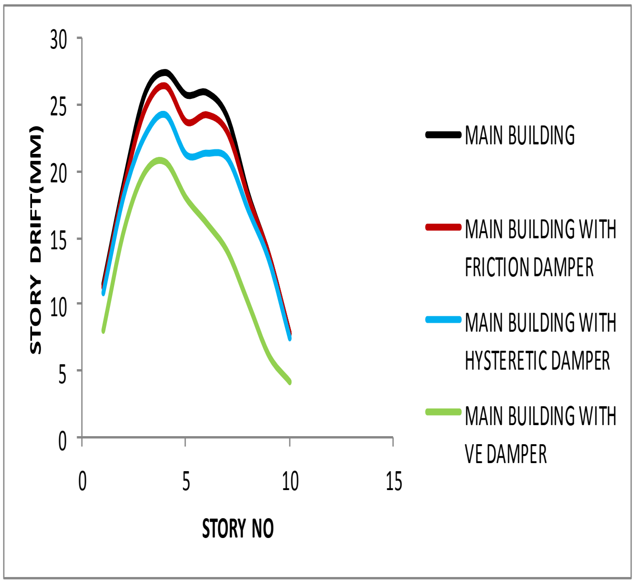


Fig 8: Drift Comparison

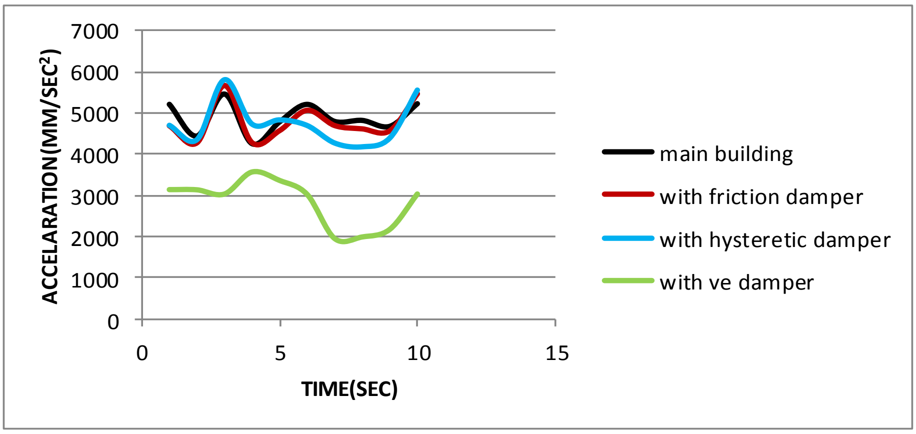


Fig 9: Accelaration Comparison

IDARC ANALYSIS FOR EARTHQUAKE OF MAGNITUDE 6

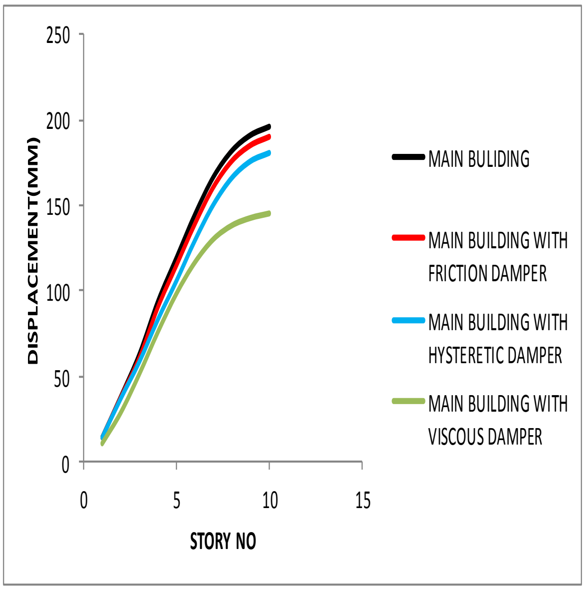


Fig 10: Displacement Comparison

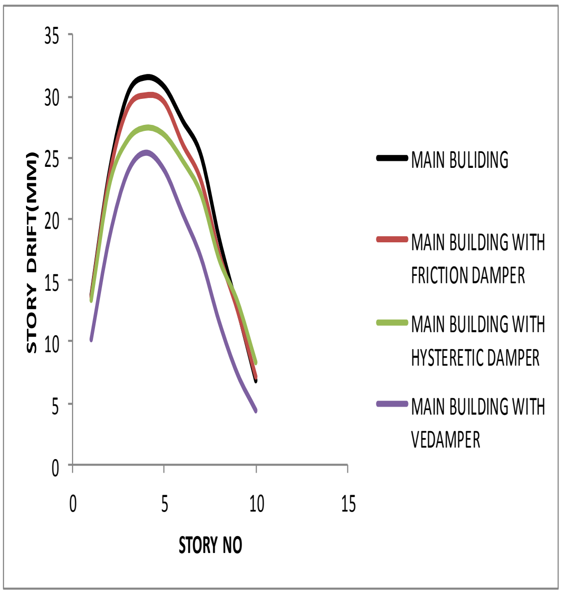


Fig 11: Drift Comparison

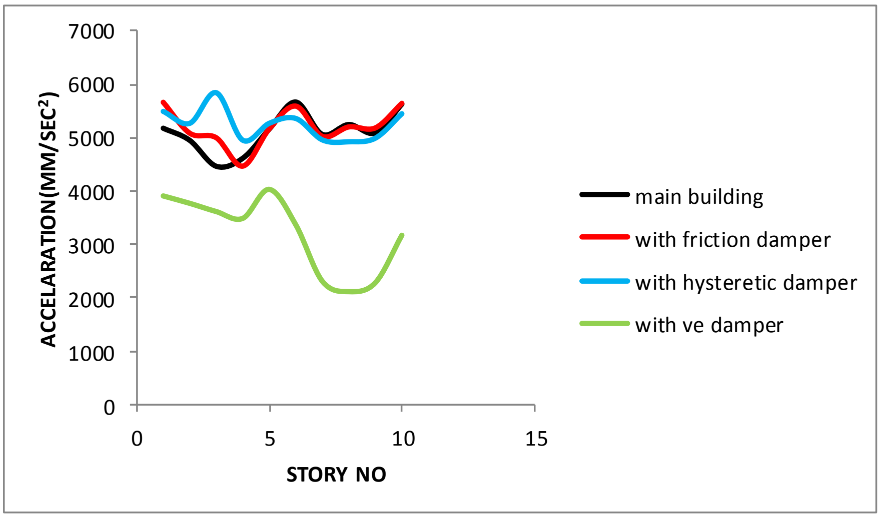
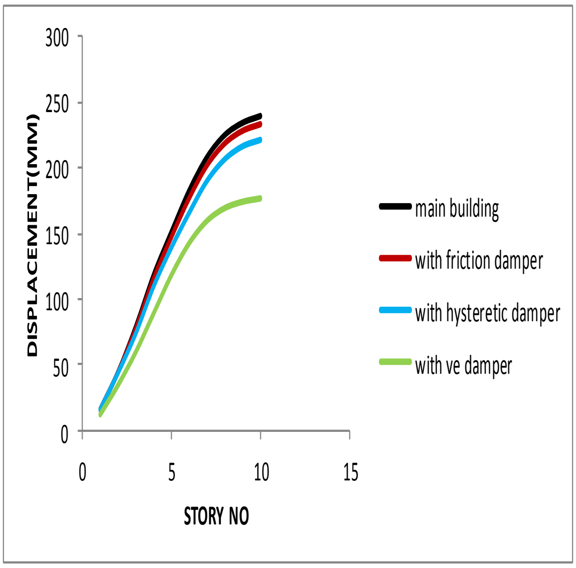


Fig 12: Accelaration Comparison

IDARC ANALYSIS FOR EARTHQUAKE OF MAGNITUDE 7



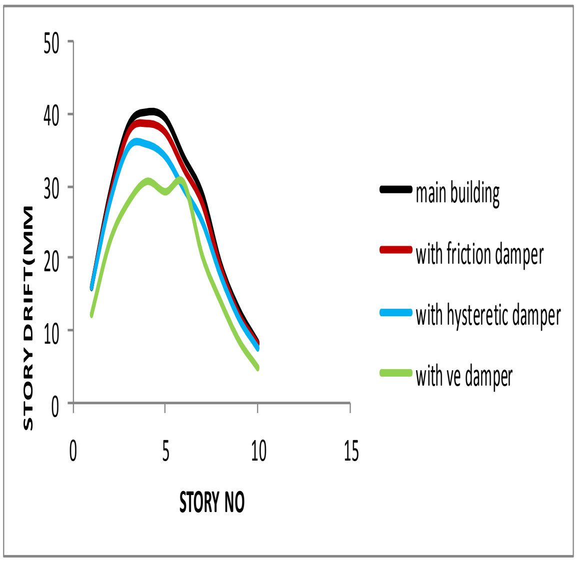


Fig 13: Displacement Comparison

Fig 14: Drift Comparison

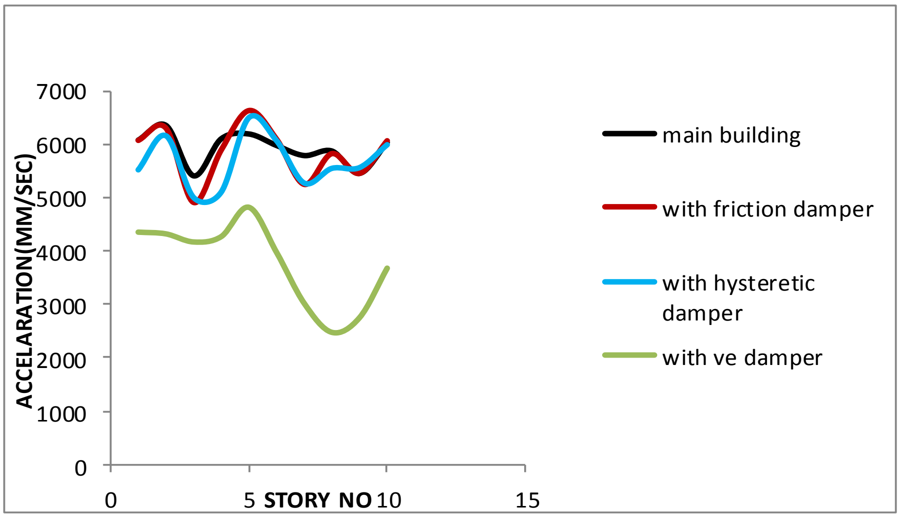
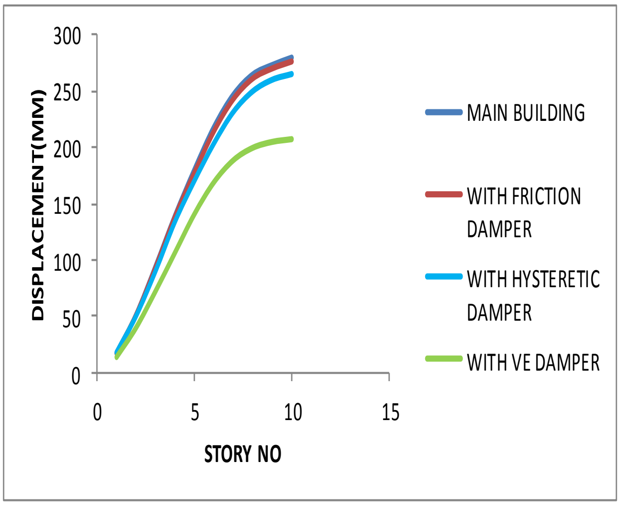


Fig 15: Accelaration Comparison

IDARC ANALYSIS FOR EARTHQUAKE OF MAGNITUDE 8



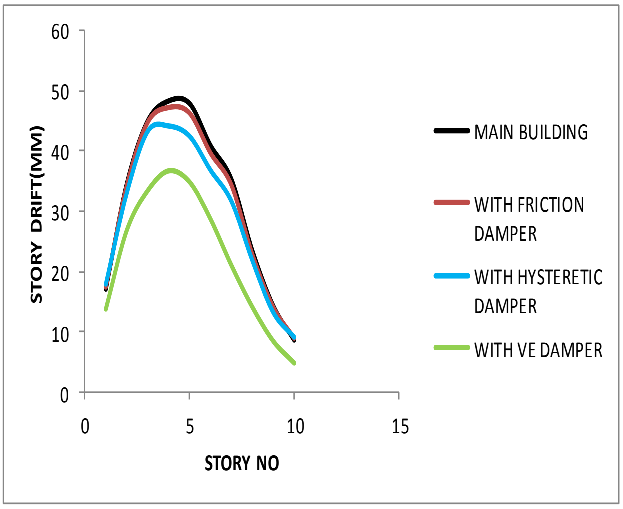


Fig 16: Displacement Comparison

Fig 17: Drift Comparison

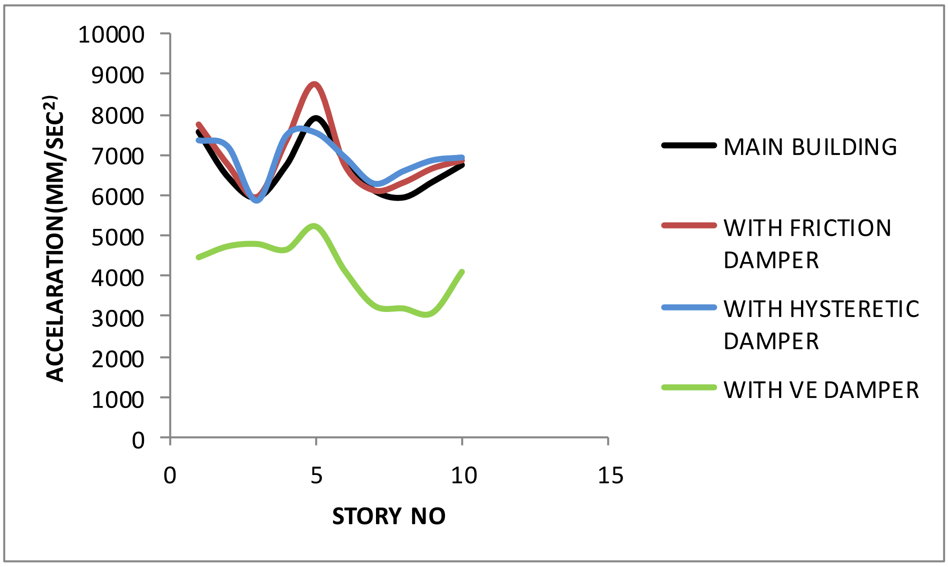


Fig 18: Acceleration Comparison

IV.DISCUSSION

- Significant reduction in response can be achieved using supplemental damping devices; however the strengthened or stiffened structure may produce undesired increases of accelerations while damping additions may lead to reduction in acceleration response.
- Passive dampers significantly enhance energy dissipation in structures. The dampers increase the collapse time of a structure and delays damage. Passive dampers reduce seismic response and thus reduce damage to the structure
- Although the installation of these devices invariably incurs additional cost, their strategic use is cost-effective as the extra expense is often offset by the need to increase the lateral stiffness and strength of the structure in conventional approaches and the need to enhance the ductility capacity of the structure when adapted to seismic environment
- The deformations are successively reduced for all dampers. Story shear has somewhat increased, however in certain cases base shears have also reduced thus implying that
  the proper addition of dampers increases overall stiffness of structure
- From above results visco-elastic damper braces produces largest reduction in deformation
- About 10-30% response reduction was achieved by supplemental damper brace system

V. CONCLUSION

It has been viewed out from the discussion of analysis results that the displacement and damage parameters are substantially reduced for buildings with dampers in comparison with those without dampers. Optimum number and type of dampers should be installed throughout the buildings to achieve required result.

VI. REFERENCES

[1] Pall, A.S. and Marsh, C. “Response of friction damped braced frames,” J. Struct. Engrg., ASCE, 108(6), (1982) : 1313-1323.
[2] A.S. Pall, V. Verganelakis and C. Marsh, “Friction Dampers for Seismic Control of Concordia University Library Building,” Proc. 5th Canadian Conference on Earthquake Engineering, Ottawa, Canada, pp. 191-200, 1987.
[3] A. Filiatrault and S. Cherry, “Performance Evaluation of Friction Damped Braced Steel Frames under Simulated Earthquake Loads,” Report of Earthquake Engineering Research Laboratory, University of British Columbia, Vancouver, Canada, 1985.
[4] I.D. Aiken and J.M. Kelly, “Experimental Study of Friction Damping for Steel Frame Structures,” Proc. PVP Conference, ASME, Pittsburgh, Pennsylvania, Vol. 133, pp. 9-100, 1988.
[5] M.C. Constantinou, A.M. Reinhorn, A. Mokha and R. Watson, “Displacement Control Device for Base-isolated Bridges,” Earthquake Spectra, 7 (2), 179-200 (1991).
[6] British Standards Institution (BSI), “Commentary on Corrosion at Bimetallic Contacts and its Alleviation,” Standard PD 6484: 1979, London, U.K., 1979.
[7] I.D. Aiken and J.M. Kelly, “Earthquake Simulator Testing and Analytical Studies of Two Energy Absorbing Systems for Multistory Structures,” Report No. UCB/EERC-90/03, University of California, Berkeley, 1990.
[8] Valles,R.E,Reinhorn A.M,Kunath,S.K.,Li,C and Madan,A(1996)IDARC 2D Version 4 ;A computer program for inelastic damage analysis of buildings NCEER-96-0010
[9] R C. Lin, Z. Liang, T.T. Soong and R.H. Zhang, “An experimental Study of Seismic Structural Response with Added Viscoelastic Dampers,” Report No. NCEER-88-0018,National Center for Earthquake Engineering Research, Buffalo, New York, 1988
[10] K.C. Chang, T.T. Soong, S.T. Oh and M.L. Lai, “Seismic Response of a 2/5 Scale Steel Structure with Added Viscoelastic Dampers,” Report No. NCEER-91-0012, NationalCenter for Earthquake Engineering Research, Buffalo, New York, 1991.

[11] S.Y. Hsu and A. Fafitis, “Seismic Analysis Design of Frames with Viscoelastic Connections,” J. Struct. Engrg., ASCE, 118(9), 2459-2474 (1992)

[12] T. Fujita (Ed.), “Seismic Isolation and Response Control for Nuclear and Non-nuclear Structures,” Special Issue for the Exhibition of the 11th International Conference onStructural Mechanics in Reactor Technology (SMiRT 11), Tokyo, Japan, 1991.

[13] R.G. Tyler, “Tapered Steel Energy Dissipators for Earthquake Resistant Structures,”Bulletin of the New Zealand National Society for Earthquake Engineering, 11 (4), 282-294 (1978).

[14] 86 14. .R.I. Skinner, R.G. Tyler, A.J. Heine and W.H. Robinson, “Hysteretic Dampers for the Protection of Structures from Earthquakes,” Bulletin of the New Zealand National Society for Earthquake Engineering, 13 (1), 22-36 (1980).

[15] J.M. Kelly, M.S. Skinner and K.E. Beucke, “'Experimental Testing of an Energyabsorbing Base Isolation System,” Report No. UCB/EERC-80/35, University of California, Berkeley, 1980.

[16] J.M. Kelly, “Base Isolation in Japan, 1988,” Report No. UCB/EERC-88/20, University of California, Berkeley, 1988.

[17] R.G. Tyler, “Further Notes on a Steel Energy-absorbing Element for Braced

[18] Frameworks,” Bulletin of the New Zealand National Society for Earthquake Engineering,18 (3), 270-279 (1985).

[19] A.S. Whittaker, V.V. Bertero, J.L. Alonso and C.L. Thompson, “Earthquake Simulator Testing of Steel Plate Added Damping and Stiffness Elements,” Report No. UCB/EERC- 89/02, University of California, Berkeley, 1989.

[20] T. Fujita (Ed.), “Seismic Isolation and Response Control for Nuclear and Non-nuclear Structures,” Special Issue for the Exhibition of the 11th International Conference on Structural Mechanics in Reactor Technology (SMiRT 11), Tokyo, Japan, 1991.

[21] U.S. Geological Survey Earthquake Hazards Program. Retrieved July 30, 2010.

[22] a b Hough, S.E. (2004). Finding fault in California: an earthquake tourist's guide. Mountain Press Publishing. p. 185. ISBN 978-0-87842-495-5. Retrieved January 19, 2012.

[23] Trifunac & Brune 1970, p. 138

[24] "Imperial Valley Earthquake". Southern California Earthquake Data Center. Retrieved July 30, 2010.

[25] Gunn, A.M. (2007). "Imperial Valley, California. earthquake". *Encyclopedia of Disasters: Environmental Catastrophes and Human Tragedies, Volume 1*. Greenwood Publishing Group. pp. 364–365. ISBN 978-0-313-34002-4. Retrieved January 20, 2012.