iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: V Month of publication: May 2020

DOI: http://doi.org/10.22214/ijraset.2020.5230

Seismic Retrofitting of Structures using Passive Energy Dissipation Devices: A Review

S. Kawalkar[1], S. Sanghai[2]
[1, 2]Department of Civil Engineering, G. H. Raisoni College of Engineering, Nagpur.

Abstract: Past earthquake record depicts there is a significant increase in human loss, structural as well as economic losses. Advancement in the research field has revised many designing codes that demand more structural stability in the seismic prone zone. This aspect leads to seismic retrofitting of existing structures, many methodologies have been put forth by an ample amount of research work, and among that use of energy dissipating system gains the focus for retrofitting in recent years. This paper attempts the review of different aspects related to seismic retrofitting with the help of passive energy dissipation devices. Designing philosophy, optimal locations and case studies are discussed in this literature. Summarising, it gives the total idea of the different parameters to be considered and recent research works summary.

Keywords: **Seismic performance, Energy dissipation, Optimal location, Retrofitting, Non-linear analysis.**

I. INTRODUCTION

The world has gone through many devastating earthquakes over the last few decades such as the Nepal earthquake of 2015, the Imphal earthquake of January 2016, Latur earthquake of 1993 [1]. Mexico earthquake in 1985 reported 16000 people injured, 4500 people died, were affected and 1778 structures were severely damaged [22]. Structures affected by earthquake needs to use their generic facility as soon as possible, thus effective economic and seismic resistant retrofitting strategies are needed with future perspective keeping in mind.

The Improvement of seismic performance of existing structures is a challenging and difficult task for engineers. Such a situation also arises, when standard codes of design are revised and they demand higher spectral acceleration. The solution to this problem is through two strategies are given, first by strengthening, i.e. increasing the capacity of the structures and second by reducing seismic demand of structure i.e. introduction of seismic energy dissipation devices [23] this paper reviews the various studies in respect to the second approach of reducing seismic demand on a structure. Passive energy dissipation devices do not require external energy supply for their working and they are easy to install thus it is a better choice for seismic retrofitting.

According to the design philosophy of earthquake resistant design of the structure, it should be resisted minor and frequent earthquakes without damages, should be able to resist moderate earthquakes with some nonstructural damage and resist the major earthquake without collapse of structure [24].

Performance-based Retrofitting and design of the structures is the trending concept in the recent era. Various guidelines related to that are coded in the FEMA-356 and ACT40 codes. Determination of performance point based on structure capacity and earthquakes demand is carried out through non-linear static analysis i.e. pushover analysis. Based on this performance point different types of energy dissipating devices are design for the purpose of retrofitting of existing structures.

II. RETROFITTING OBJECTIVES

FEMA-356 described the rehabilitation objectives based on target performance levels for structure as a whole. Three types of objectives are defined as i) Basic safety objectives, ii) Enhanced objectives and iii) limited objectives. Under basic safety objectives, target performance levels are defined as follows

A. For BSE-1 structure should be under the Life Safety Performance level.
B. For BSE-2 structure should be under the Collapse Prevention Performance level.

BSE-1 is the earthquake that has a 10% probability of Exceedance in 50 years i.e. return period of 474 years. BSE-2 is the earthquake that has a 2% probability of Exceedance in 50 years i.e. return period of 2475 years. The retrofitted structure should have to obey the above target objectives as per the FEMA code.

III.PASSIVE ENERGY DISSIPATION DEVICES

A. Design Philosophy

1) Habibi et.al [10] proposed the energy-based design method for the seismic retrofitting of the structure by using passive energy dissipating devices. The design aspect uses modal pushover analysis. Pushover analysis by two higher participating modes carried out for determining yield force. Literature gave the detailed step by step procedure for dissipation device design,

a) *Step 1:* a) elastic modal analysis

To determine i) modal shape vector ii) participation factor

$$m_i = \phi_i^T M \phi_i = 1$$

$$\Gamma_i = \phi_i^T M 1 / m_i$$

b) Modal push over-analysis to find yield force and yield strength coefficient

$$f_{yi} = \frac{F_{yi}}{\Gamma_i} \qquad C_{yi} = \frac{f_{yi}}{\Gamma_i m_i g}$$

c) To assign damping `

b) *Step 2:* To determine the ductility factor for the assign damping ratio.

c) *Step 3:* To determine the equivalent velocity of absorbed energy.

d) *Step 4:* a) to calculate absorbed energy and total absorbed energy.

$$E_{ai} = \frac{m_i (\Gamma_i V_{ai})^2}{2} \qquad E_{a_T} = \sum_{i=1}^{2} E_{ai}$$

b) To calculate elastic strain energy.

$$E_S = \frac{2\pi^2}{T_1^2} m_1 \left(\frac{\Gamma_1 D_{s1}}{\mu_1} \right)$$

e) *Step 5:* to find plastic strain energy need to dissipate.

$$E_D = E_{a_T} - E_S$$

If ED <1 no need of energy dissipators

Otherwise, damping demand is calculated by

$$\xi_D = \frac{E_D}{4\pi E_S}$$

f) *Step 6:* To compare dissipative plastic energy with elastic strain energy.

g) *Step 7:* Distribute EDi over the height of the structure according to the energy profile of the corresponding mode.

h) *Step 8:* Convert all the calculated entities to MDOF system and distribute over the height of the structure.

i) *Step 9:* To determine an energy dissipation device characteristic based on energy to be dissipated.

j) *Step 10:* Design the bracing member according to axial force.

The validation of the above design method was done by nonlinear time history analysis. Results showed that structure retrofitted with the above method remains in an elastic zone.

2) Madan et.al [2] Proposed performance energy-based performance design formulation of passive energy dissipation devices (PED). The following procedure was given,

a) *Step 1*- To calculate earthquake input energy for MDOF system (E)

b) *Step 2*- To estimate elastic energy of the equivalent SDOF system (Ee)

c) *Step 3*- Total energy need to be dissipated (Edissipate) by retrofitted structure equals to [E-Ee]

d) *Step 4*- To find energy dissipated in plastic hinges (Ep)

e) *Step 5*- To calculate energy to be dissipated by PED equals to [Edissipate -Ep]

f) *Step 6*- For friction dampers, to estimate frictional sleep load.

A formulation for various steps was given by the author in respective research work.

B. Location Estimation

Lin et.al [12] proposed the optimal location of linear viscous damper for two-way unsymmetrical building. This method did not depend on the earthquake excitation. The targeted response was observed on the basis of the rate of elastic strain energy dissipation rather than the response parameter. Numerical validation is given in the latter part and concluded that results obtained in permissible ranges. Qu et.al [7] uses the modified weight coefficient method for determination of optimum numbers of dampers and optimum location of dampers. Force analogy method was use to modify the weight coefficient method. Optimum location selected based on the performance index value. Bogdanovic et.al [8] gave the optimal placement of viscose dampers based on a fitness function. Fitness function depends on the inter storey drift, energy dissipation capacity of dampers and input energy. Results showed the elimination of the plastic elements. Plastic hinges reduced by 80% and acceleration reduced by 38%. Tolvar et.al [3] focused on the location and number of the dampers in structure. Two structures with less time periods and a large time period were selected. 1,3,5 dampers per storey modes were tested for two earthquake motion and observed the variation in storey drift. Large numbers of dampers were not always beneficial to reduce drift. The equal distribution of the dampers leads to good control in drift. First storey dampers were more effective than the top storey location. Yousefzadeh et.al [21] presented study on optimal location and characteristics of TADAS dampers in a steel frame structure. Optimum placement of damper was governed by the benefit to cost ratio, storey drift. The problem statement was defined in the set chromosomes Genetic algorithm for detailed study and concluded that performance of structure improved i.e. all hinges remains in the life safety zone. Singh et.al [16] they proposed optimal sizing and location of viscose and viscoelastic dampers by using a genetic algorithm. The genetic approach can be formulated for any required performance function such as base shear, overturning moment or floor acceleration. By genetic algorithm method author obtained a 66% reduction in RMS value of floor acceleration. Wu et.al [18] Presented the location of dissipation devices based on the inter storey drift caused by storey translation and torsional response, Concluded that the location of dampers are greatly affected by ground motion characteristics and suggested that the energy dissipation devices should be located very near to the geometric centre of the structure due to consideration of the torsional effect.Pérez et.al [14] present work for the study of the location of friction dampers in structures. With optimization technique of Firefly Algorithm linked with a computational routine. Study results that inter-storey drift and floor acceleration reduced by 50% for installation of only three dampers through the out structure. Shrikhande et.al [15] studied inter-storey drift and base shear parameter for optimal location of fluid viscose dampers in 10 storey building with consideration of soil-structure interaction. The effectiveness of damping devices decreases with the plan irregularity. The optimal location for regular buildings founds more promising at the lower stories and upper stories. The number of dampers beyond a certain number did not contribute towards seismic controlling of structure. Damper effectiveness increases as the stiffness of soil increases.

IV. SEISMIC RETROFITTING

Wang et.al [5] proposed seismic performance up-gradation of 35 storey steel moment-resisting frame with the help of three types of energy dissipation devices. Global response controlled best achieved by fluid viscous dampers but none of three energy dissipaters were effective in seismic control of the building. Olariu et.al [6] discussed the effectiveness of base isolation for seismic retrofitting of existing historic structures. Formulation of Pendulum Rubber Bearing and conclusion put forth showed that this concept of retrofitting is effective in controlling both floor acceleration and inter-storey drift also structure gave uniform behavior for an earthquake in any direction and any time period. Gandelli et.al [9] put forth a case study on seismic retrofitting of publically important buildings such as hospital by means of hysteretic braces. The hysteretic brace displacement-based Design method was discussed. Drift and acceleration sensitive parameter were observed for seismic performance evaluation of the hospital. The conclusion showed that the retrofitting system was effective in drift reduction (approximately 80% reduction) but less effective in acceleration control behavior of the building. Malfunctioning of elevators, false ceiling, and furniture was reported for a post-earthquake emergency. Xiqing et.al [11] developed a program on Matlab for evaluation of a system for seismic retrofitting based on different parameters. Mahrenholtz et.al [13] The application of buckling restrained braces for seismic retrofitting was discussed in this literature. The objective was to increase the energy dissipation capacity of a structure by cyclic bucking capacity of braces. The performance was observed on the basis of storey drift. Wada et.al [17] performed a case study on seismic retrofitting of existing 11-story RCC building using post-tension rocking wall and shear steel dampers. The objective of retrofitting was to eliminate weak storey effect and reduce frame damage. Rocking wall imparts continuous stiffness to structure. Shear steel dampers' location was between the rocking wall and the existing building column. C/s of rocking wall was approximately 50% of storey column c/s. time history analysis was done and concluded that the rocking wall had minimal effect on the fundamental time period, the local concentration of deformation eliminated. Thus retrofitted structure met objectives. Yildirim et.al [19] a case study on seismic retrofitting of single-storey industrial building at the Turkey with a retrofitting objective of immediate occupancy for design basis earthquake and collapse prevention for maximum considered earthquake. Rotational frictional dampers were used for retrofitting. In short direction dampers were placed at beam-column joint and for long direction dampers placed in brace type. Linear and non-linear iterative procedure adopted for calculation of effective damping ratio and concluded that linear analysis was 45% to 50% more conservative.

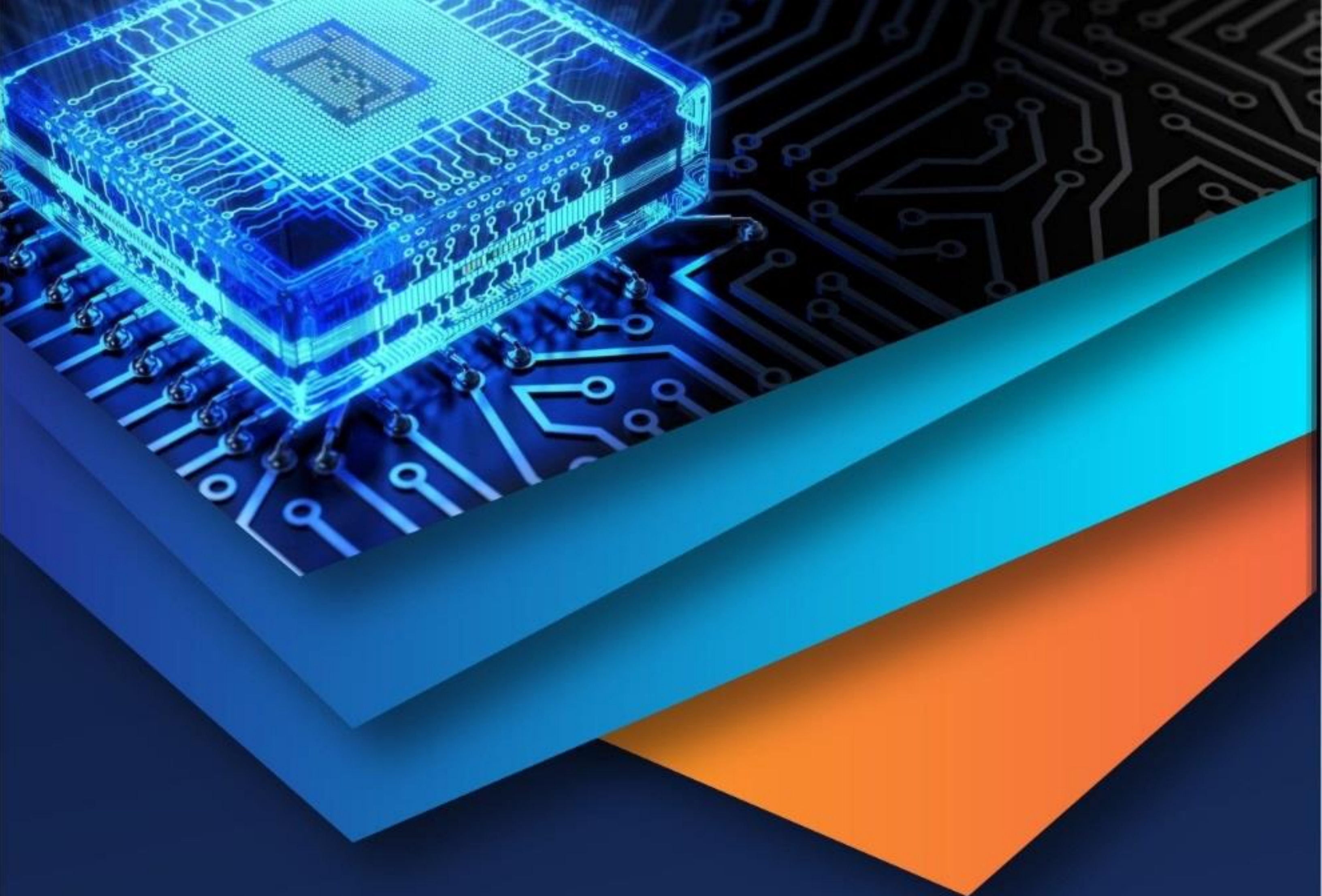
V. CLOSER STATEMENT

Various literatures available and studies put forth the following remarks,

1) Retrofitting by Passive Energy Dissipaters is an effective and promising strategy of seismic up-gradation of existing structures.
2) FEMA 356 and ACT 40 provide guidelines for performance-based seismic retrofitting of structures.
3) The retrofitting objective shall be decided according to location, importance and intended use of structure.
4) Location and number of energy dissipating devices are the governing factors for the seismic response control scheme

REFERENCES

[1] Pramodini naik, Satish Annigeri, "Performance evaluation of 9 storey RC located in north goa", 11th International Symposium on Plasticity And Impact Mechanics, Implast 2016.
[2] Alok Madan, Arshad Hashmi, "Performance Based Seismic Retrofit of Masonry Infilled Reinforced Concrete Frames Using Passive Energy Dissipation Devices", World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering, Vol:8, No:12, 2014.
[3] Carolina Tovar, Oscar López , "Effect Of The Position And Number Of Dampers On The Seismic Response Of Frame Structures", 13th World Conference on Earthquake Engineering, August 1-6, 2004.
[4] M.C. Constantinou, T.T. Soong, G.F. Durgush, "Passive Energy Dissipation Systems For Structural Design And Retrofit", multidisciplinary center for earthquake engineering research.
[5] Shanshan Wang, Stephen Mahin, "Seismic Upgrade of an Existing Tall Building by Different Energy Dissipation Devices", University of California, Berkeley, 2016
[6] Ioan OLARIU, Felicia OLARIU And Dragos SARBU, "Base Isolation Versus Energy Dissipation For Seismic Retrofitting Of Existing Structures", 12WCEE, 2000.
[7] Ji-ting Qu and Hong-nan Li, "Study on Optimal Placement and Reasonable Number of Viscoelastic Dampers by Improved Weight Coefficient Method", Mathematical Problems in Engineering Volume 2013.
[8] Aleksandra Bogdanovic and Zoran Rakicevic, "Optimal Damper Placement Using Combined Fitness Function", Frontiers in Built Environment, Article 4, Volume 5, January 2019.
[9] Emanuele Gandelli , Andreas Taras , Johann Distl and Virginio Quaglini, "Seismic Retrofit Of Hospitals By Means Of Hysteretic Braces: Influence On Acceleration-Sensitive Non-Structural Components", Frontiers in Built Environment, Article 100, Volume 5, January 2019.
[10] Ali Habibi, Ricky W.K. Chan, Faris Albermani, "Energy-Based Design Method For Seismic Retrofitting With Passive Energy Dissipation Systems", Engineering Structures 46, 2013.
[11] Xiqing Li and Lin Liu, "An Evaluation System For Seismic Retrofitting Schemes Of An Existing Building Using Energy Dissipation Device", Applied Mechanics and Materials Vol 724, 2015.
[12] Jui-Liang Lin,Manh-Tien Bui, and Keh-Chyuan Tsaib, "An Energy-Based Approach To The Generalized Optimal Locations Of Viscous Dampers In Two-Way Asymmetrical Buildings", Earthquake Spectra, Volume 30, No. 2, May 2014.
[13] Christoph Mahrenholtz, Pao-Chun Lin, An-Chien Wu, Keh-Chyuan Tsai,Shyh-Jiann Hwang1, Ruei-Yan Lin and Muhammad Y. Bhayusukma, "Retrofit Of Reinforced Concrete Frames With Buckling-Restrained Braces", Earthquake Engineering & Structural Dynamics, DOI: 10.1002/eqe, 2014.
[14] Sergio Pastor Ontiveros-Pérez, Letícia Fleck Fadel Miguel, Leandro Fleck Fadel Miguel, "Optimal Location Of Optimized Friction Dampers In Civil Structures For The Seismic Passive Control", Proceedings of the XXXVII Iberian Latin-American Congress on Computational Methods in Engineering Suzana Moreira Ávila (Editor), ABMEC, Brasília, DF, Brazil, November 6-9, 2016.
[15] Ajeet S. Kokil and Manish Shrikhande, "Optimal Placement of Supplemental Dampers in Seismic Design of Structures", JSEE, Vol. 9, No. 3, Fall 2007.
[16] Mahendra P. Singh and Luis M. Moreschi, "Optimal Placement Of Dampers For Passive Response Control", Earthquake Engineering And Structural Dynamics, DOI: 10.1002/eqe.132, 2002
[17] Akira Wada, Zhe Qu, Shojiro Motoyui, Hiroyasu Sakata, "Seismic retrofit of existing SRC frames using rocking walls and steel dampers", Front. Archit. Civ. Eng., DOI 10.1007/s11709-011-0114-x, China 2011.
[18] Bo Wu and Jin-Ping Ou, "Optimal Placement Of Energy Dissipation Devices For Three Dimensional Structures", Engineering Structures, Vol. 19, No. 2, pp. 113-125, 1997.
[19] S. Yildirim, A. Kalyoncuoglu, B. Erkus, and Y. Tonguc, "Seismic Retrofit Of Industrial Precast Concrete Structures Using Friction Dampers: Case Study From Turkey", ASCE and ATC 2015.
[20] FEMA-356, "Prestandard And Commentary For Seismic Rehabilitation Of Building", Federal Emergency Management Agency, Washington,DC
[21] A.Yousefzadeh, M.H. Sebt, M.Tehranizadeh, "The optimal TADAS damper placement in moment resisting steel structures based on a cost-benefit analysis", International Journal of Civil Engineering, Vol. 9, No. 1, March 2011.
[22] Arturo Tena-Colunga, Alejandro Vergara, "Comparative Study On The Seismic Retrofit Of A Mid-Rise Steel Building: Steel Bracing VS Energy Dissipation", earthquake engineering and structural dynamics, vol. 26, 637ð655 (1997)
[23] Nicola Impollonia, Alessandro Palmeri," Seismic performance of buildings retrofitted with nonlinear viscous dampers and adjacent reaction towers", Earthquake Engng Struct Dyn. 2018;1–23.
[24] A. A. Sophocleous, "Seismic Control of Regular and Irregular Buildings Using Viscoelastic Passive Dampers", journal of structural control vlo .8, n.2, decembe2001.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY