Review on Seismic Response Analysis of Unsymmetrical Building using Viscous Dampers.

Swaraj Kondhare, M.Tech Student, MIT Art Design & Technology University Pune, swarajkondhare@gmail.com

Anandrao Jadhav, Assistant Professor, MIT Art Design & Technology University Pune, India, anandrao.jadhav@mituniversity.edu.in

Abstract— This paper presents Current advancements in the application of various energy-dissipative systems or devices, including dampers, are primarily responsible for reducing the seismic response of buildings. It is also utilized as a shock absorber in bridges and for the rehabilitation and retrofitting of damaged building structures. Different kinds of dampers are available on the market based on the preferences of researchers and designers; nonetheless, it was found that fluid viscous damper were most often chosen. Studies comparing FVD to other types of dampers are also in favor of FVD because of its encouraging and noteworthy performance in several researchers' investigations. It is also more advantageous to employ due to its flexibility, wide variety of applications, and decrease in damping force.

Keywords — Fluid Viscous Dampers; Seismic Response; Base Shear; Storey Displacement.

I. INTRODUCTION

Today's fast industrialization and population expansion restrict how much land, energy, and water can be used. This increases the need for high-rise buildings in urban areas due to a dearth of suitable land and the requirement that structures be built on land that is located in a higher seismic zone. Therefore, it is essential that we design our building structures to withstand seismic forces using appropriate methods, such as base isolations and energy dissipation systems. Despite its limitations, the base isolation technique is more difficult to employ than dampers. Since dampers come in a large variety and can be installed in a building system with flexibility, they can also be used for retrofitting. To meet its seismic demand, dampers in steel/concrete moment-resisting frames, structural walls, toggle brace systems, and pre-existing buildings have been the subject of numerous studies. In order to study the seismic response outcomes, different seismic analysis techniques are used. These techniques involve lab tests or the use of appropriate stimulation software tools. The results are then analyzed in terms of peak velocities, accelerations, displacement, drifts, and overturning moments. Given that dampers are more expensive for higher damping values, some research also concentrated on determining the best locations for dampers and how to lower the damping force in order to create cost-effective designs.

II. LITERATURE REVIEW

A. Xue-Wei Chen et al. [1]

investigated the seismic response of the four-story Wenchuan Hospital, a viscous damper facility in China. The design study's primary goal was to lessen the structure's reactivity. This was done at various seismic vibration levels, both with and without installed viscous dampers in the hospital building's concrete frame structure. Static pushover and nonlinear time history analysis were conducted using ETABS software and performed in 3D. Additional damping ratio was also computed in the ETABS software using a workable method. Viscose damping was added within the permitted ranges specified in the standards to control storey drift, *d*isplacement at the top, and plastic damage to the structure. The inclusion of K-braced dampening devices enhanced the internal force values and increased the structure's stiffness.

B. Munir et al. [2]

studied a 40-story residential high rise core wall construction as a case study for this purpose, comparing its mode with appropriate control measures.by constructing a linear elastic form model of the case study building and analyzing it using ETABS version 9.0. Following that, seven-time history recordings were applied to do a nonlinear time history analysis (NLTHA) for the largest earthquake that was taken into consideration. Using the PERFORM 3D program version 4, another model was made for NLTHA. Subsequently, nonlinear 24 FVD were positioned in the X direction as a control measure to lower the damping force and seismic demand. Applying FVDs resulted in a 27%, 12%, and 26% decrease in base shear and moment demand values at the foundation level and middle level of the building, respectively. This work provides a clear explanation of the typical inelastic behavior of high-rise buildings with shear walls.

 DOI : 10.35291/2454-9150.2024.0281

C. J. K. Whittle et al. [3]

examined several damper placement techniques, including the standard placement method (SPM), simple sequential search algorithm (SSSA), Lavan analysis, and Takewaki application, to enhance the building's seismic performance. For the above methodologies investigation, two steel frame models with regular and uneven profiles were taken. Building modeling was done with SAP 2000, and both models included 20 recordings of ground motion data. The study's findings indicate that regular and irregular frame models perform significantly better when different damper placement techniques are applied. The Lavan method, in particular, performs the best because it is simpler and takes less time.

D. Jinkoo Kim et al [4]

adopted a straightforward approach to designing viscous damping utilizing the capacity spectrum in order to avoid laborious iterative procedures for achieving performance-based earthquake design. The required viscous damping in this method is computed in a way that meets the needs of the plastically deforming structure. This technique was used on the SDOF system for many design-related parameters. Subsequently, the identical procedure was used to the steel frame models of 10 and 20 stories to confirm it. After comparing the outcomes of dynamic nonlinear time history analysis, this method was shown to be effective. It is also applicable to structure models that satisfy the constraints and assumptions of the capacity spectrum method.

E. Giuseppe et al, (2014) [5]

investigated the behavior of the viscous and hysteretic dampers in the moment-resisting steel frame to seismic forces. To choose the best dampers to shield the structure from seismic data, an iterative process was used. To assess dynamic analysis to enhance the performance of the structure, a comparative study was conducted between three different types of steel frames (3-story, 4-story, and 12-story) with two types of dampers (viscous and hysteretic) installed in the middle bay and subjected to seven-time history records. The findings indicate that the use of dampers, as opposed to bare frames, enhanced the medium- and high-rise building's collapse mechanism; however, this requirement was not met for the low-rise scenario.

F. Rakesh K. Goel (2005) [6]

examined, using 20 time histories, the seismic response of the one-story linear asymmetric and nonlinear systems as well as nonlinear FVD. This paper's primary goal was to determine how a nonlinear damper affected the asymmetry in the systems plan. To do that, a comparison of the systems with nonlinear dampers added to a linear and nonlinear asymmetrical design was done. An iterative procedure was used to try applying the damper's coefficient value in a specific direction based on the eccentricity of the design. In order to optimize the behavior against harmonic and seismic loading with linear and nonlinear FVD, SDOF systems have been researched. The paper's findings indicate a discernible decline in damping force for asymmetrical systems with higher period values, but an increase in the expense of a greater damper force for systems with shorter periods. For linear systems, a nonlinear damper lowers the torque at the base; for nonlinear systems, the contrary is true. However, the plan's flaw in its asymmetry can be eliminated by combining a nonlinear damper and nonlinear system.

G. Bahnasy et al. [7]

compared the design optimization of the linear and nonlinear FVD considering seismic behavior of building structures. Observations made in this paper are Damping forces and number of dampers required for structure increases as value of the alpha α decrease below 0.7. Drift values way to increase in many cases for decreasing values of α. For 3 storey building decreasing α value reduces column ductility, but for 9 storey building ductility demand increases below 0.7 values. Finally, study recommends that the value of α changes with respect to height of the building. For low rise (≤ three storey) α = 0.5, for medium and high rise (9-20 storey) α=0.85 will be more appropriate.

H. D. Lee et al. [8]

outlined the FVD technology's future potential as well as its installation and operation techniques. This study described several bracing techniques for putting dampers in buildings. Future research on dampers for the goal of reducing seismic response should also consider the dampers' lifespan, the effects of linear and nonlinear relationships, and modeling software such as SAP and ETABS.

I. Ras et al. [9]

used linear FVD to analyze the seismic response and energy dissipation of a 12-story steel frame model. The effective damping ratio for a linear damper was determined analytically using the Kelvin and Maxwell models. The damping coefficient was then computed and distributed to the structure based on this result. SAP 2000 was used for modeling, and NLTH analysis was performed to verify that the deformation did not exceed the structural limit. A total of twelve diagonal positions were used to determine the best placement for improved outcomes. The structure's period, maximum displacement, acceleration, moment, and drift values were all decreased once the dampers were applied.

J. Amy Hwang. [10]

discuss about a number of problems that arise when

 DOI : 10.35291/2454-9150.2024.0281

dampers are applied, particularly viscous dampers. The author compares the selection criteria for FVD with conventional design techniques and presents a comparative analysis of FVD in relation to ADAS, viscoelastic friction dampers, and hybrid solutions. Although the ideal damper placement and its expression were explained in this research, the conclusion still states that the best site must be determined iteratively. The use of dampers in new construction is costly, unless the buildings include hospitals, bridges, fire stations, etc. A variety of software programs, including SAP and ETABS, were utilized to conduct a comparative analysis on dampers.

K. Mohsen Kargahi et al. [11]

created a process to determine the dampers' expected performance against seismic stresses for a four-story concrete frame building with a waffle slab. This process lowers the overall cost of dampers without sacrificing the building's necessary level of dampening. This was accomplished by comparing the data from pushover analysis with time history analysis, and it was discovered that nonlinear time history produces more thorough results. In addition to the viscous dampers' ideal cost, a 50% displacement reduction was attained, and the employment of genetic algorithms was recommended for further research.

L. D. I. Narkhede et al. [12]

compared mathematical formulas for short period excitations, the properties and behavior of FVD under shock vibrations were evaluated. Since nonlinear dampers perform better in shock vibration experiments (half sine), they were selected for additional testing. Research has been done on the impact of various damping coefficients and damping exponents. Nonlinear FVD performed remarkably effectively for shocks with a large magnitude and short duration since the damping coefficient was substantially smaller and the displacement was less.

M. A.K. Sinha et al. [13]

used 3D accelerograms to compare two models of a 12-story high moment-resisting frame that had and did not have FVD. Nonlinear time history analysis and ETABS picking nonlinear damper properties were used in the analysis. As recommended by earlier research, the velocity exponent was set at 0.5 to limit the damping force.With the exception of the base shear values, all other study factors produced good response reduction outcomes. Base shear values increased as a result of the damper weight increasing the frame's overall seismic mass by a considerable amount.

N. X.L. Lu et al. [14]

completed the renovation of an eight-story reinforced concrete building in China that had been damaged in the Wenchuan earthquake. Three different types of dampers viscous, steel, and viscoelastic were employed for the building's retrofitting. Their effects on the building's seismic response were compared in terms of shear forces and storey drifts under various earthquake levels. In ETABS, an analytical analysis of the building model structure was carried out. To analyze the seismic response of the retrofitted structure utilizing the three types of dampers stated above, a dynamic analysis of the building was conducted using two artificial accelerograms and three earthquake records. The viscous, steel, and viscoelastic dampers' hysteresis curves, which were taken from El Centro data, demonstrate how much energy these dampers dissipated, protecting the frame structure from serious damage. The inter-story drifts and shear in the columns were approximately 1.5 times less in the damper-equipped frame than in the damper-free frame. The initial setting is correct, as indicated by the chosen damping force ratio of actual to predicted.

O. Farzad Hejazi et al. [15]

examined how two three-story building frame models with shear walls at the corner and core positions responded. ETABS software was utilized in this investigation to create models that were ready for testing. In four distinct locations the bottom, middle, top, and throughout the storey of the shear wall frame viscous damper was positioned diagonally in the cutout aperture of the shear wall. The primary goal of this work was to examine, using three-dimensional seismic excitations, how well building frames with viscous dampers function inside shear walls. Three-dimensional seismic data from El Centro's 1940-time series was utilized for both models. The best location for shear wall dampers to prevent 3-dimensional seismic excitation was determined to be at the top.

P. Wen-Hsiung Lin et al. [16]

Investigated seismic response of a one-story, single-degree-of-freedom system equipped with nonlinear fluid viscous dampers. effectively studying the supplemental damping ratio ζsd and the velocity exponent α as independent parameters. The results show that the response of the structure varies linearly with the intensity of the excitation applied to the system. In the spectral velocity sensitive region, the nonlinearity of the damper does not influence the peak response of the system, while in other spectral regions, a 14% difference was observed. Supplemental damping can achieve a 25% to 60% reduction in the deformation of the structure at ζsd equal to 5% and 30%, respectively. However, the same values of reduction in system response can be achieved by using nonlinear FVDs with a lower value of the damping force. Finally, a practical procedure was provided to calculate the designed structural deformation and forces values for nonlinear FVD systems from design spectra.

 DOI : 10.35291/2454-9150.2024.0281

III. FINDINGS

The paper has been summarized, focusing on its main parameters, and a comprehensive conclusion of the work has been provided.

1. compared to other kinds of dampers things that reduce movement or vibration, it can last as long as or even longer than the building it's in. This means you don't have to spend much money maintaining the dampers because they last so long.
2. to make buildings safer during earthquakes, FVD probably a type of damping system is really helpful. It helps by reducing how much the floors of the building move, as well as the force at the base, the twisting force, and the pushing force on the building's columns. And it does all this while keeping the costs under control.
3. Different methods of bracing for FVD chevron, toggle, base plate, K-type provide ease of installation in any desired shapes and position of the bare frame models with effective functioning.
4. Dampers are put in the best spots to work well; more research needs to be done. This research would help figure out exactly where to put dampers and how many are needed. Doing this would make dampers more effective and cost less, which is good for saving money.
5. Tall buildings during earthquakes, dampers called nonlinear FVDs with a symbol "α" less than 1 are better than linear ones. This is because the nonlinear ones have a special property called hysteresis, which helps them absorb more energy when the building shakes. So, they're more effective at reducing the impact of earthquakes on tall buildings.

REFERENCES

[1] Chen, Xue Wei, Jia Xuan Li, and Jack Cheang. "Seismic performance analysis of Wenchuan hospital structure with viscous dampers." The Structural Design of Tall and Special Buildings 19.4 (2010): 397-419.

[2] Munir, A., and P. Warnitchai. "Optimal reduction of inelastic seismic demands in high rise reinforced concrete core wall buildings using energy-dissipating devices." The Structural Design of Tall and Special Buildings 22.7 (2013): 543- 568..

[3] Whittle, J. K., et al. "A comparison of viscous damper placement methods for improving seismic building design." Journal of Earthquake Engineering 16.4 (2012): 540-560.

[4] Kim, Jinkoo, Hyunhoon Choi, and Kyung-Won Min. "Performance-based design of added viscous dampers using capacity spectrum method." Journal of Earthquake Engineering 7.01 (2003): 1-24.

[5] Brando, Giuseppe, Federica D'Agostino, and Gianfranco De Matteis. "Seismic performance of MR frames protected by viscous or hysteretic dampers." The Structural Design of Tall and Special Buildings 24.9 (2015): 653-671.

[6] Goel, Rakesh K. "Seismic response of linear and nonlinear asymmetric systems with nonlinear fluid viscous dampers." Earthquake engineering & structural dynamics 34.7 (2005): 825-846.

[7] Bahnasy, A., and O. Lavan. "Linear or nonlinear fluid viscous dampers? A seismic point of view." Structures Congress 2013: Bridging Your Passion with Your Profession. 2013.Lee, David, and Douglas P. Taylor. "Viscous damper development and future trends." The Structural Design of Tall Buildings 10.5 (2001): 311-320.

[8] Lee, David, and Douglas P. Taylor. "Viscous damper development and future trends." The Structural Design of Tall Buildings 10.5 (2001): 311-320.

[9] Ras, A., and N. Boumechra. "Seismic energy dissipation study of linear fluid viscous dampers in steel structure design." Alexandria Engineering Journal 55.3 (2016): 2821-2832.

[10] Hwang, Amy. Viscous dampers: practical application issues for the structural engineer. Diss. Massachusetts Institute of Technology, 1998.

[11] Kargahi, Mohsen, and C. Ekwueme. "Optimization of viscous damper properties for reduction of seismic risk in concrete buildings." 13th World Conference on Earthquake Engineering. 2004.

[12] Narkhede, D. I., and R. Sinha. "Shock Vibration Control of Structures Using Fluid Viscous Dampers." 15 WCEE (World Conference on Earthquake Engineering). 2012.

[13] Sinha, A. K., and Sharad Singh. "Structural Response Control of RCC Moment Resisting Frame Using Fluid Viscous Dampers." Technology 8.1 (2017): 900-910.

[14] Ras, Abdelouahab, and Nadir Boumechra. "Study of nonlinear fluid viscous dampers behavior in seismic steel structures design." Arabian Journal for Science and Engineering 39.12 (2014): 8635- 8648.

[15] Hejazi, Farzad, Nima Ostovar, and Abdilahi Bashir. "Seismic Response of Shear Wall with Viscous Damping System." Global Civil Engineering Conference. Springer, Singapore, 2017.

[16] Lin, Wen Hsiung, and Anil K. Chopra. "Earthquake response of elastic SDF systems with non linear fluid viscous dampers." Earthquake engineering & structural dynamics 31.9 (2002): 1623-1642.

 DOI : 10.35291/2454-9150.2024.0281