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Comparative Study on Seismic Behavior of High–Rise Steel Building with and Without Friction Damper and Fluid Viscous Damper: A Review

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Abstract: Seismic forces are induced on the structure present in earthquake prone areas. These are induced due to the movement of tectonic plates. Multi-storey buildings are those that have more than two stories, hence undergo large amount of deflection due to their slender structure. Due to the deflection caused by the ground accelerations during earthquakes, the structure is unstable and the structure undergoes damage which is not safe. Passive energy dissipation devices are gaining significance in design of earthquake resistant structures because of their effective performance in controlling seismic effects on structures during earthquake. Friction dampers and fluid viscous damper are passive energy dissipating devices which are used widely as seismic control devices.

The present study was conducted analytically on a 15-storey steel frame with regular and irregular configuration and performance of structure against non-linear time history ground movement with and without friction damper and fluid viscous damper. Time history ground acceleration data of Bhuj earthquake (2001) were applied on the structure and the response of friction damper and fluid viscous damper was analyzed and compared. The analysis of the structure for the non-linear dynamic ground acceleration was conducted using ETABS software. The results show that when a friction damper is used instead of a fluid viscus damper, storey displacement is greatly reduced by 25.52%. whereas results shows that storey shear, storey drift, and storey acceleration are greatly reduced by 27.75%, 30.39% and 15.27%, when fluid viscous damper is used instead of a friction damper.

Index Terms: Friction damper; Fluid viscous damper; storey shear; storey displacement; storey drift; Storey acceleration.

I. INTRODUCTION

Earthquake is a wave-like motion induced by tectonic plate vibration, which is triggered by the abrupt release of strain energy caused by tectonic plate movement in the Earth's mantle. Seismic waves are formed when parts of the Earth's crust dislocate, resulting in devastating earthquakes. These seismic waves propagate outward from the source at varied speeds, causing tremor on the surface of the Earth. Because the intensity of earthquakes near fault zones is higher, they are even more devastating. The majority of structures are intended to withstand gravity loads and cannot withstand lateral loads. Seismic loads are non-deterministic and transient, and the damage they produce is determined by their intensity, duration, frequency, soil-geological state, and structure quality. In today's world, structural engineers must create earthquake-resistant structures that are both stable and attractive. Because of the increased need for irregular structures, both plan irregular and vertical irregular structures, structural engineers are responsible for ensuring that the structure is safe from lateral and seismic pressures, which is a difficult task. Therefore, to build the earthquake resistance structure floating column, shock absorption, dampers and rocking core wall technique are used [1].

Dampers are devices that can be easily installed, are flexible, and need limited space. They have stable energy dissipating behaviour based on the rotational friction concept. Damping reduces the free vibrations of a vibrating body. It converts the mechanical energy of a free vibrating frame caused due to ground motions because of seismically induced forces into thermal energy and reduces the amplitude of vibration. In friction dampers, the structure is joined by bolts or rivets. Due to the vibration induced on the structure by the ground motion, the joined braces, slide relative to each other, and energy is dissipated by friction.

A piston with small annular orifices is used in hydraulic devices known as viscous fluid dampers. Fluid viscous dampers are based on the effective principle of high-velocity fluid flows through orifices. When a structure is seismically excited, the piston head moves, causing viscous fluid to flow through orifices. The damping effect is provided by the movement of fluid across the piston head.

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A. Friction Damper

Friction dampers work by generating friction between two solid plates sliding relative to each other to provide necessary energy dissipation. Pall is the inventor of friction damper devices. The friction damper is the most effective passive energy dissipater, as it operates on displacement criteria. This results in a steady, big, rectangular hysteresis loop that demonstrates the significant energy dissipation capacity. After the earthquake, they don't need to be replaced or repaired, and their functional efficiency is quite good. Different types of friction damping devices, such as Sumintomo, Fitzgerald, Pall, Dorka, Constantinou, Girgorian, and others, have been tested experimentally. Some of these have practical applications, but Pall friction dampers are used all over the world [2].

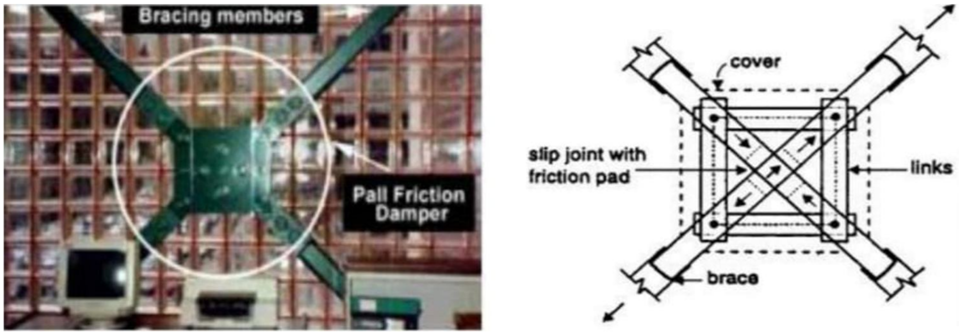

Figure 1.2 Pall Friction Damper

Friction damper data

Friction damper properties used in modelling	
Link-type	plastic(wen)
Mass	44 kg
Weight	0.43 kN
Effective stiffness	103030.3 kN/m
Yield strength	200 kN
Post yield stiffness ratio	0.0001
Yielding exponent	10
Maximum slip load of the damper	410.14

B. Viscous Fluid Damper

Figure 1.3 Viscous fluid damper

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The hydraulic devices known as viscous fluid dampers have a piston with small annular orifices. The effective principle of fluid flows at high velocity through orifices is the basis for fluid viscous dampers. When a structure is subjected to seismic excitations, the piston head moves, which causes the viscous fluid to flow through orifices. The movement of fluid across the piston head thus provides the damping effect. The input energy is dissipated by forcing a highly viscous fluid through an opening, which causes a force and damping pressure. They are adaptable and designed to provide regulated damping of a structure in response to seismic, wind, and thermal motions. The forces exerted by viscous dampers will vary depending on the earthquake ground motion because they are velocity dependent. Viscous dampers only provide damping, not rigidity. As a result, the structure is prone to failure [7].

A viscous damper's hysteresis loop is oval or elliptical, whereas a friction damper's hysteresis loop is rectangular. The area of a viscous damper's hysteresis loop (energy dissipation or damping) is roughly 70% that of a friction damper, implying that 70 friction dampers will achieve the same damping as 100 viscous dampers with the same force. Friction dampers, on the other hand, exert only 70% of the forces exerted by viscous dampers for the same number and damping value. Dampers, bracing, connections, columns, and foundation costs are significantly reduced as a result of this.

Fluid viscous damper data

Fluid viscous damper properties used in modelling	
Link-type	Damper - exponential
Mass	2200 kg
Weight	0.225 kN
Stiffness	20000 kN/m
Damping	4000 kN-s/m
Damping exponent	1

II. CRITICAL REVIEW ON DESIGN OF EARTHQUAKE RESISTANT STRUCTURE USING FRICTION DAMPER AND FLUID VISCOUS DAMPER

S.S. Pathan, D.N. Kakade, and A.P. Wadekar [2018]: They have proposed the Seismic Response Control of a Steel Building Using Friction Dampers from the method of time history analysis of G+12 structures using E-TABS 2015 software. The performance of a building is better in the case of a plan with a friction damper because the displacement is reduced as compared to a shear wall. The stiffness of the building is increased by using dampers and shear walls, but the effect is greater using the shear wall. The performance of the building is increased on the periphery along the damper and shear wall.

T. Tabassum and K.S. Ahmed [2018]: This research paper describes the results of the analysis of the seismic behaviour of a thirty-story steel building with and without a damper under different earthquake acceleration signals. The proposed procedure placed the various types of dampers like friction damper, bilinear damper, and exponential damper on the top three floors of the building. The study compares the different performances such as the joint displacement, joint acceleration, and the base force of structure with and without damper for a thirty-story steel building using ETAB2015. The study further performs time history analysis for different seismic accelerograms to observe the actual time-domain responses of the structure. Linear time-history analysis of this steel building structure indicates that maximum displacement, maximum base force, and maximum acceleration are effectively reduced in the presence of a damper on the top three floors of the building.

A Ras, N. Boumechra [2016]: Research paper based on seismic energy dissipation study of linear fluid viscous dampers in steel structure design using the SAP2000 software, this paper focused on increasingly used to provide better seismic protection for existing as well as new buildings and bridges. A 3D numerical investigation is done considering the seismic response of a twelve-story steel building moment frame with diagonal FVD that have linear force versus velocity behaviour. Nonlinear time history, which is being calculated by Fast nonlinear analysis (FNA), of the Boumerdes earthquake (Algeria, May 2003) is considered for the analysis.

A. Ravitheja [2016]: Research paper focused on Seismic evaluation of multi-story RC buildings with and without fluid viscous dampers and the building was analysed by using SAP2000 Software, the paper shows that fluid viscous dampers to building can effectively reduce the building responses by selecting optimum damping coefficient i.e. when the building is connected to the fluid viscous dampers (FVD) can control both displacements and accelerations of the building, and conclusion drawn by the author was base shear and storey displacement is less in buildings with fluid viscous damper.

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J. Premalatha, M. Mrinalini, M. Palanisamy [2018]: Research paper based on a 20-Storey benchmark steel moment-resisting frame is taken for the study of seismic response reduction by providing viscous fluid dampers for chevron mechanisms using SAP 2000 Software, the model time history analysis of the frame subjected to four types of earthquakes loads with chevron dampers is carried out. The Linear time history analysis (LTHA) was carried out and responses such as absolute acceleration, displacements, drifts, damper displacements, and damper forces are found for all six models of chevron mechanism dampers for four different time histories considered for analysis such as El Centro, Kobe, Northridge and S Monica with PGAs normalized to of 0.35g. LTHA was carried out for six different types of chevron mechanism damper with a 40% damping coefficient.

Mahdi Hosseini and N.V. Ramana Rao [2016]: Research paper based on reducing the seismic response using fluid viscous dampers using SAP 2000 software, these building connected to steel bracing for 12 floors when subjected to a seismic excitation of Bhuj 2001 earthquake ground motion.

It is considered a regular steel structure with 3 variants of confirmation: Normal Steel Building, Steel Building with 'X' Bracing, and Steel Building with Dampers. Nonlinear time history analysis has been performed for structures and observed the reduction in seismic response. Parameters studied are roof displacements, storey drifts, and base shears. Roof displacements decreased highly to an extent of 50% and 38% compared to normal steel building and building with X bracings respectively. The result analysis shows a reduction of 55-60% in base shear and 35-9% in storey drift for structures equipped with fluid viscous when compared to normal steel building and building with X bracings respectively. It expresses that providing bracings with a damper in the outer frame of the structure is more efficient than the structure with only dampers.

Manisha, Mr. Eshwar Reddy H. N and Dr. H. M. Rajashekar Swamy[2021]: Research paper focused on Seismic rehabilitation of structure by the performance of friction damper using ETABS2016 Software, results from this paper was modelling and analysis of RCC structure by non-linear time history analysis of structure during Burj earthquake, and conclusion drawn by the author was in a ten-story building, displacement was reduced by 9.68%, and acceleration was reduced by 30% when compared to a fifteen-story building. The friction damper performed better in a ten-story structure than in a fifteen-story building.

Ankit Jain and Dr. R. S. Talikoti [2016]: Research paper focused on the Performance of High Rise structures with dampers at a different location by a performance of viscous fluid damper using SAP2000 Software, the paper found out the seismic performance of the building can be improved by providing energy dissipating device (damper), which absorb input energy during an earthquake, the frame is safer when the damper is provided up to floor from the base as compared with another arrangement, and conclusion drawn by the author was the application of dampers in different floors of the building effectively reduces base shear.

Kavya dias et al. [2015]: They investigated the efficacy of retrofitting two types of existing three-story RC structures with passive energy dissipative devices. The friction damper was installed on the ground level, supported by chevron bracing assemblies, to minimize the soft story weakness without causing problems on the upper floors. The reaction of the RC structures was examined for seven compatible earthquake data before and after retrofitting using nonlinear time history analysis. Dampers and braces were developed with base shear capacities of 5% and 10%, respectively. The analyses showed the ductility demand of the ground floor was greatly reduced to a 10% base shear capacity design. The paper concluded that the seismic response of the structure was improved by retrofitting the structures with a friction damper supported by chevron braces.

Saiful Islam, [2012]: Focused on the effectiveness of base isolation in multi-story RC frame buildings with a plan irregular and vertical irregular layout. The time history study was performed using the ETABS 2013 program on a 15-story RC building. The base isolation system was constructed according to the UBC 97 code. The application of LRB was discovered to extend the time period of the structure. Furthermore, in plan irregular buildings, the rise in the time period was greater than in vertical irregular buildings. It was concluded that plan irregular building gives better performance by use of isolators at the base of the building as compared to plan irregular building at higher seismic prone.

III. CONCLUSION

1) Seismic performance of a building can be improved, by placing passive energy dissipating devices in the structure as it absorbs and dissipates the strain energy induced.
2) Installation of passive energy dissipating devices like dampers significantly reduces amplitude of vibration, forces on the structure and also reduces the acceleration of the floors.
3) Friction dampers reduce the effect of high input energy on the structure.
4) Friction dampers are durable and require less maintenance, hence they do not need to be replaced after an earthquake.
5) Performance of a building is better in case of plan with friction damper the displacement is reduced as compared to the without damper.

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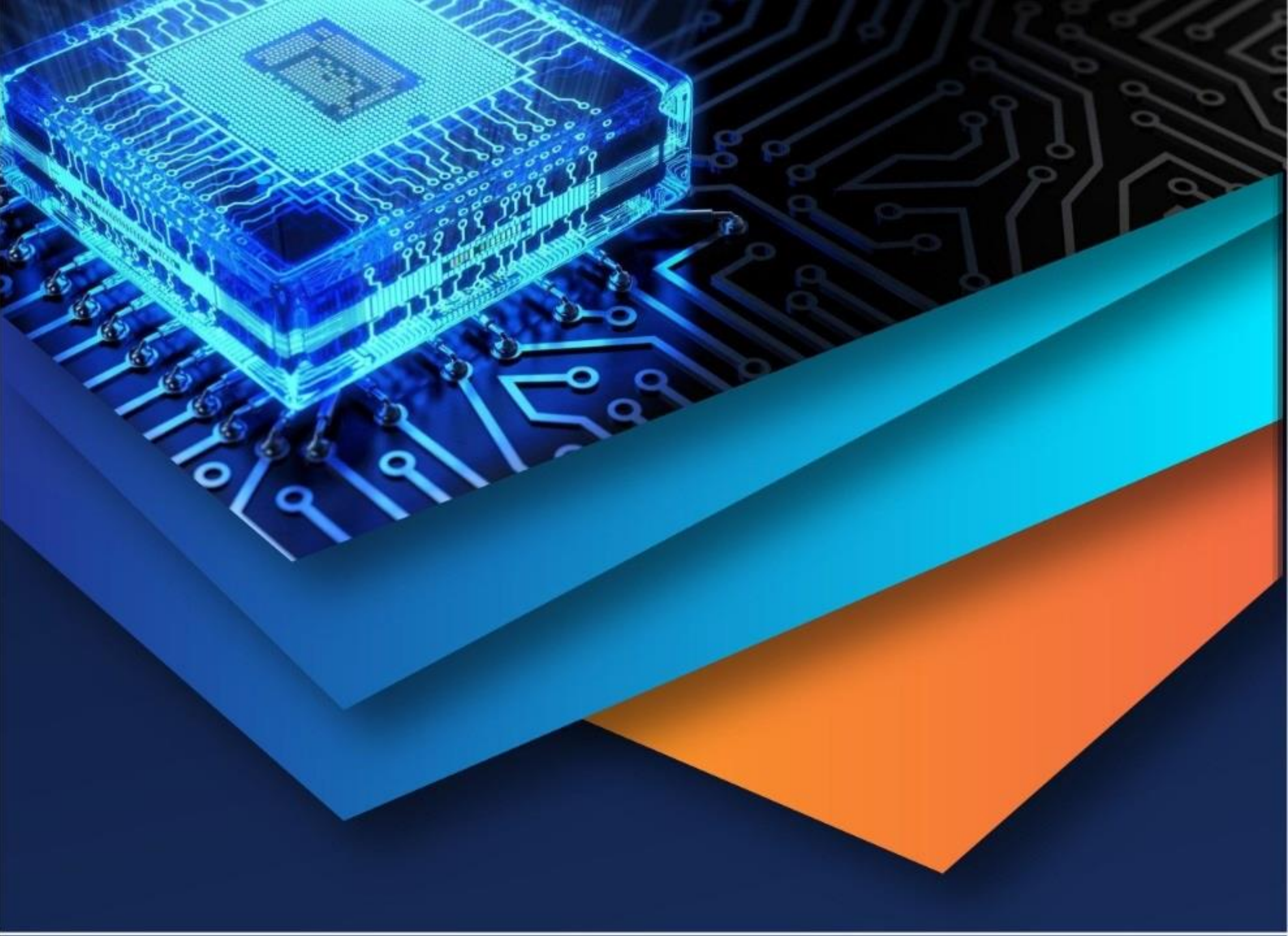

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