Seismic Analysis of Structure Using Friction Damper

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Abstract—In the era of rapid urbanization and technological advancement, multi-storey high-rise buildings are common. As building height increases, they become more susceptible to wind and seismic loads, making structural stability crucial. Dampers, mechanical devices that dissipate energy, are used to enhance building flexibility and resist lateral forces. This study focuses on evaluating the seismic behavior of multi-storey RCC buildings with friction dampers to improve earthquake resistance and stability.

Index Terms: Friction dampers, Seismic analysis, Storey Drifts, Response Spectrum

I. INTRODUCTION

An earthquake is a significant seismic event caused by the sudden release of energy from tectonic plate movements, posing a threat to human life and infrastructure. Seismic waves transmit this energy, making earthquakes one of the most unpredictable and devastating natural disasters. To mitigate damage to civil structures during earthquakes and high winds, reducing the structural response to dynamic loads has become a crucial aspect of structural engineering. Mechanical damping of seismic energy in friction dampers prevents structural damage by converting kinetic energy to heat. This avoids repair costs, service disruptions in critical buildings like hospitals and schools, and saves time. Friction dampers enhance structural stiffness and ductility by absorbing energy during inelastic behavior, like bending and buckling.

II. LITERATURE SURVEY

Farnoosh Roshan-Tabari et al. (2024): This study found that standard CIIR rubber has insufficient damping for effective seismic mitigation above 0°C. The aim was to develop a modified CIIR with enhanced damping and compare it to standard CIIR. Viscoelastic properties were evaluated using DMTA, followed by cyclic shear tests on prototype dampers made from both materials. Results showed the modified CIIR had significantly better damping. Nonlinear time-history analyses confirmed its effectiveness in seismic response mitigation.

Anshul Malhotra et al. (2020): The effectiveness of friction dampers (FDs) is studied in dynamically similar and dissimilar steel buildings subjected to uncorrelated seismic and wind forces. Buildings range from five to twenty storeys, with various FD configurations connecting them. Buildings are modeled as plane frames with or without bracing, and FDs are modeled with elastic-perfectly plastic behavior. Results show FDs minimize gaps between connected buildings and are more effective in reducing responses in dissimilar buildings. However, effectiveness varies under different loading scenarios.
Hamid Radmard Rahmani and Carsten Konke (2019): The study explored optimal placement and properties of tuned mass dampers (TMDs) in tall buildings to control earthquake-induced vibrations. An algorithm was developed to distribute limited mass optimally across the building height, using an enhanced NSGA-II method. Results indicated that distributing TMDs throughout the building is more effective than using a single TMD, especially under earthquake excitations with significant higher mode amplitudes. TMD locations were influenced by earthquake frequency content and maximum modal displacements.

Xiaoqing Ning et al. (2018): A new damping method, consisting of a silicone damper and connecting elements, is introduced to protect stored cultural relics. This device is easy to install without altering the original structures, suitable for various new and existing relic cabinets. To validate its effectiveness, both numerical simulations and shaking table tests were conducted. Results indicate that this method significantly improves the seismic performance of the relic cabinets and reduces movement of the stored relics, demonstrating its effectiveness in seismic protection for cabinet-stored cultural relics.

Keck et al. (2017): They opted to exclude viscous friction from their model's Stribeck curve as it's accounted for by the σ2 parameter. To obtain constant velocity data, they conducted an experiment using a stepwise oscillating velocity function on the contacting surfaces. This function ensures constant velocities, eliminating acceleration effects on friction at the measurement point, as indicated between the dotted lines. The resulting Stribeck function is neither symmetric nor odd, making the positive and negative portions non-equivalent.

III. PROBLEM STATEMENT

Buildings' susceptibility to earthquakes poses significant risks to safety, infrastructure, and urban resilience. Conventional designs often fail to control earthquake-induced dynamic responses, leading to severe damage or collapse. There's an urgent need to explore innovative seismic mitigation strategies to enhance structural performance and reduce vulnerability. One promising solution is integrating friction dampers, which absorb energy and reduce structural vibrations, improving stability and resilience. However, comprehensive research on their effectiveness, optimal design, and economic viability in seismic applications is lacking.

IV. AIMS AND OBJECTIVES

a.To evaluate the effectiveness of friction dampers in reducing the seismic response and enhancing the seismic performance of a structure.

b.To understand the principles and mechanisms of friction dampers and their applications in seismic mitigation.

c.To incorporate friction dampers into the structural model accurately, representing their physical behavior and interaction with the structure.

d.To perform a dynamic analysis of the structure without friction dampers to determine its natural frequencies, mode shapes, and seismic response under various ground motion scenarios.

V. MATERIALS AND METHODOLOGY

In this project report an attempt to investigate the RCC structure model with friction damper at various positions in a building under the seismic loading is considered. This project mainly emphasizes comparison of models having dampers with the bare frame model by means of displacement, storey drift, time period and base shear using E-tabs software for analysis. In this study response spectrum method is used for seismic analysis, after the analysis results are carried out and these results are compared and discussed by plotting the graphs.

In this study following models considered for the analysis

MODEL 1. Building with Fixed Base(No damper) .

MODEL 2. Building with Friction Damper at Middle bays of alternate storeys .

MODEL 3. Building with Friction Damper at both Edges of alternate storeys.tables may span both columns.

Response spectrum Analysis: A response spectrum is a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. The science of strong ground motion may use some values from the ground response spectrum (calculated from recordings of surface ground motion from seismographs) for correlation with seismic damage.

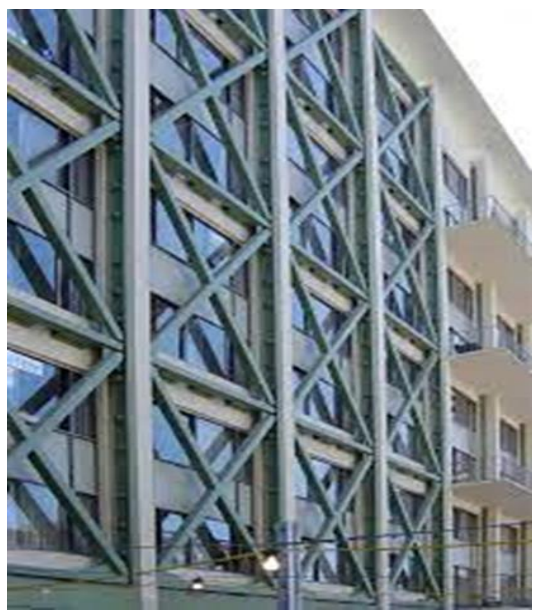


fig.1. Use of friction dampers in building

STRUCTURAL MODELLING

For these study, two buildings of same floor plan are taken in which columns are equally placed at the distance of 4m in both directions.

First building is modeled without damper, second building is modeled with dampers at all the four corners of building and the third one with dampers at the middlemost span i.e. at middle two bays of the each side of the building, all at the alternate storeys.

Each building is a 10- storey building and height of each story is 3.15m.

There is a comparison between these three buildings and the dampers considered are Friction Dampers.

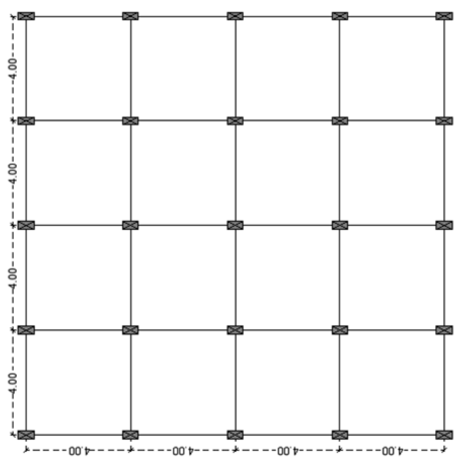


Fig. 02. Layout showing building without dampers

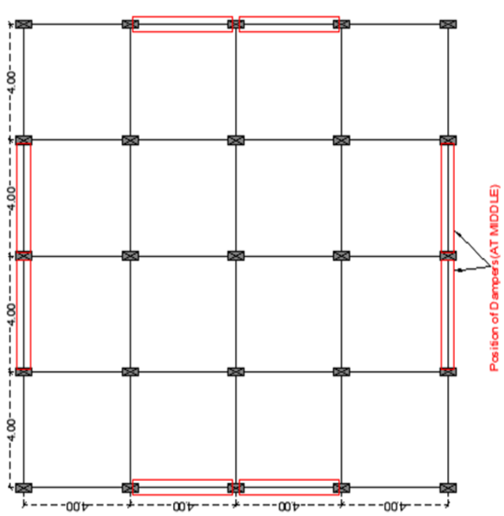


Fig. 03. Layout of Building with dampers at center

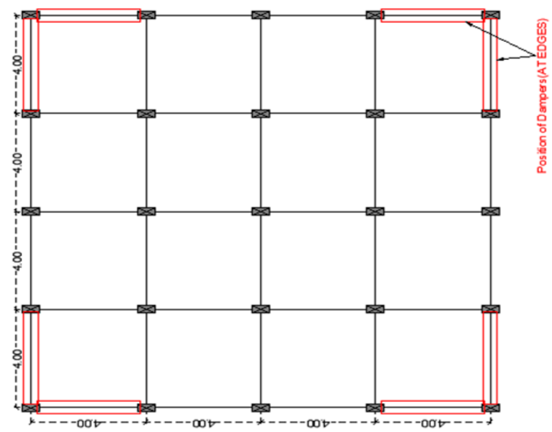


Fig.04. Layout of building showing dampers at edges

Table 01. Specification for Seismic Analysis

Sr.no	Parameters	Dimensions
DETAILS OF BUILDING		
1	Storey height for ground floor	3.15 m
2	Storey height	3.15 m
3	Column sizes	300 mm X 600 mm
4	Beam sizes	300 mm x 500 mm
5	Depth of slab	150 mm
6	Thickness of wall	230 mm
MATERIAL PROPERTIES		
7	Unit weight of concrete	25 KN /m3
8	Grade of concrete	M30
9	Grade of steel	Fe500D
10	Floor finish	1 KN /m2
	Earthquake Load	
11	Dead load from slab	5 kN
12	Weight of wall	10.26 KN /m2
13	Weight of parapet wall	4 kN
FOR SEISMIC ANALYSIS		
14	Types of soil	Medium
15	Seismic zone	V

16	Zone factor(Z)	0.36
17	Importance factor	1
18	Response reduction factor	5
19	Damping ratio	5 %
20	Analysis Method	Response spectrum analysis
21	Software Used	ETABS
LINK PROPERTIES		
22	Link type	Damper Exponential
23	Mass	2200 kg
24	Weight	0.225 KN
25	Slip Load	100 kN
26	Friction Co-efficient	0.02
27	Effective Stiffness	20,000 KN/M
28	Effective Damping	4000 KN-S/M

Distribution of dampers in frames:
The X-braced friction dampers are applied to a 10 storey building model with bays at a distance of 4 m in both the direction i.e. in X and Y direction and floor to floor height of 3.15 m..

These dampers are applied on the alternate floors in each of model 2 and model 3 of the bulding which is assumed to be in Zone V.

Model 2 consist of X-braced friction dampers at the center of each side i.e. at the middle two bays while in Model 2 it is located at the edges of each side or at the corners.

Of all, total 40 X-braced friction dampers are applied to each model and analysis is done to derive the results.

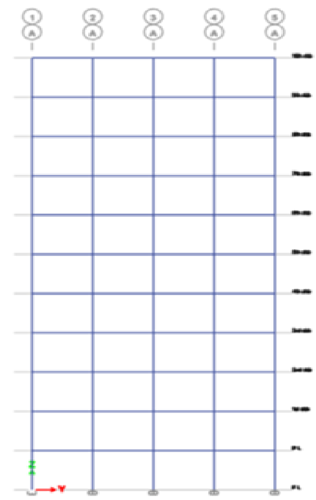


Fig.05. Layout of building in Etabs building without damper

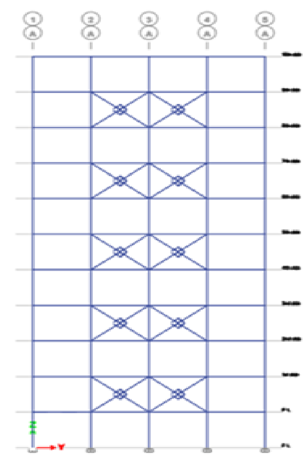


Fig.06. Layout of building with central damper in Etabs

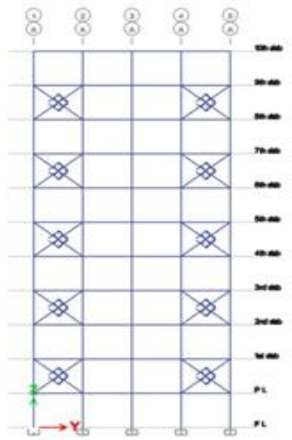
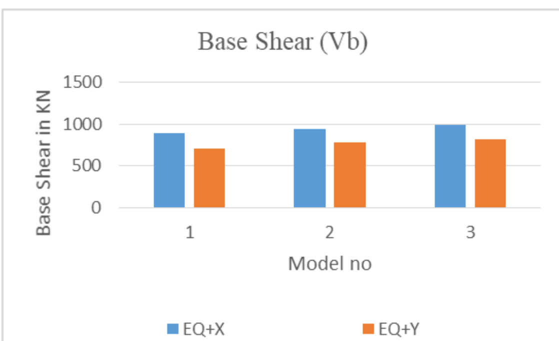


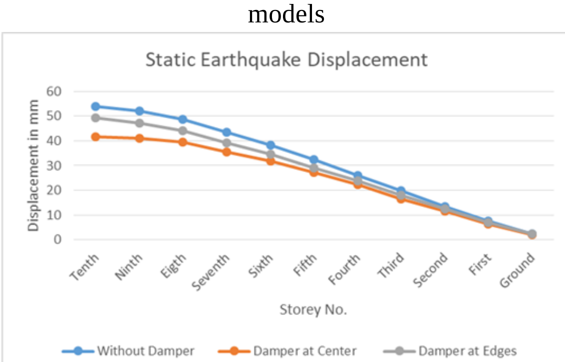
Fig.07. Layout building with edge damper in Etabs

VI. RESULTS AND DISCUSSION

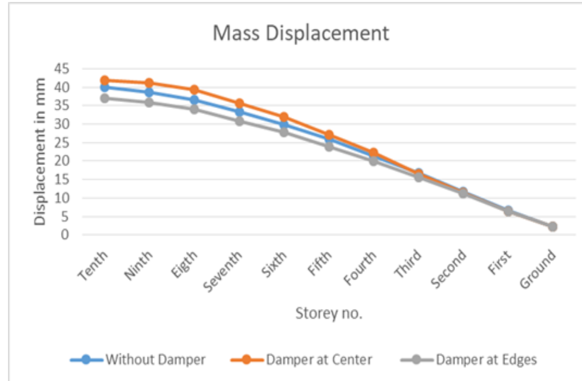
For the above layouts seismic analysis was done in Etabs software by use of Response Spectrum Method and results are obtained for base shear, static earthquake displacement, dynamic earthquake displacement and modal time period.



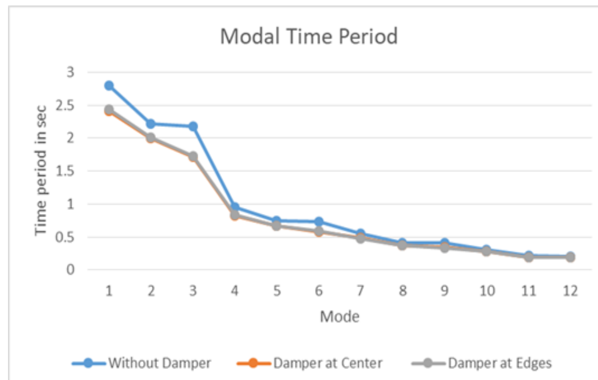
Graph 01.Comparative study of base shear for all 3 models



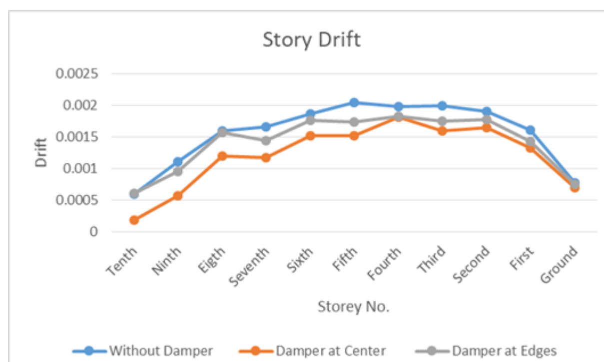
Graph 02. Comparative study of static eq displacement for all 3 models



Graph 03. Comparative study of dynamic eq displacement for all 3 models



Graph 04. Comparative study of modal time period for all 3 models



Graph 05. Comparative study of storey drift for all 3 models

CONCLUSION

In this project we studied the behaviour of RC 10 Storey Building in seismic zone V of India by following Indian seismic code in Etab software. We analysed the structure using friction damper at edges of bays in building as well as at the centre of each bay in building.

It is concluded that :

•The results of this investigation show that the response of the structure i.e, time period, storey displacement, storey drift and storey acceleration can be reduced by using friction damper..

•All the damper arrangements are effective to reduce the base shear of the structure fixed at the base. However among all the types of damper arrangement, the central arrangement gives most economic ans effictive results.It thus has maximum effect to reduce the response of structure at the base.

•The Damper technique effectively reduces stress on concrete and reinforcement

•Seismic performance of building after applying dampers is efficient than in that of building without dampers.

•The considerable amount of reduction in lateral displacement is seen due to inclusion of friction dampers in frame.

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