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Hybrid Model for Building Retrofitting

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***Abstract*— Beam-column joint is considered as a crucial zone in moment resisting frames. During an earthquake, structures are subjected to large forces due to ground shaking and the response of the building depends on the behavior of the beam-column joint. In normal analysis, the joints are usually treated as rigid and due to which the effects of various shear forces developed within the joint are not considered. To avoid the failures during earth quake, seismic upgrading is required, for structural deterioration, change in functions or increased performance requirements. Damping is one of the commonly adopted methods proposed for achieving optimal performance of the building subjected to seismic actions. In the present study, an economical approach towards the use of dampers in buildings to reduce the seismic effect is studied. A hybrid combination of dampers with steel bracings for retrofitting is studied in this paper. A cost effective hybrid configuration is presented which can simultaneously reduce the seismic effect and the overall cost for retrofitting.**

Keywords*— *Seismic retrofit, dampers, steel bracings, hybrid configuration

I. INTRODUCTION

Earthquakes are considered as one of the greatest hazards to life and property. The damage is commonly associated with man-made structures. The study on the damages during earthquakes clearly demonstrates that shape of the building have a crucial role in seismic effect. The building should be simple, regular and symmetric in plan and elevation. When designing the buildings in seismic zones, design philosophy aims to provide sufficient ductility to the structure for effective dissipation of seismic energy. In ordinary moment-resisting frames, the principle of "strong column-weak beam" is followed. This ensures the formation of plastic hinge in the beam itself thus making it capable of dissipating energy while remaining in inelastic region. But many already existing buildings are not constructed following this principle. Seismic retrofitting is required in such buildings especially if the buildings are in seismic zone. In order to achieve sufficient seismic response of the building, three methods are commonly adopted. These are isolation, energy absorption at plastic hinges, and use of mechanical devices for structural control. The use of mechanical dampers for seismic retrofitting is studied in this paper.

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The structural control obtained using mechanical devices can be of two types: active and passive control. Active control requires a power supply to activate the dampers. During earthquake it is not practicable as power supply could be disrupted. Hence, active devices are incorporated in buildings subjected to wind induced loading. Therefore passive energy dissipation systems are commonly adopted to absorb seismic energy.

Types of Passive energy dissipation devices are:

- Viscous fluid dampers
- Friction dampers
- Metallic dampers
- Visco-elastic dampers
- Tuned mass dampers

Several buildings have been studied in the past to understand the effect of added dampers to the structure. From the analysis it became clear that the most effective device distribution depends on the configuration of the structure. Damping devices are added to the structure to increase the damping ratio. Analysis is then done to check the percentage of reduction of response of structure. However due to oversimplification of original system, the neglected higher mode may play an important in the structural response[1].

The damping ratio has an influence on the damper performance. If the damping ratios are increased, it was found that displacements get reduced. Further studies proved that, for single degree of freedom structures, fitting more dampers at places of maximum inter-storey drift optimized the structural response. For multi degree of freedom structures, higher damping ratios can increase the seismic response. [2]

A study was conducted at Buffalo university [2001] which included analyzing a four degree of freedom structures embedded with viscous dampers. Dampers were arranged in different configurations and different damping ratios. From various configurations, most effective configuration was obtained. Also limitations in using damping ratio as sesmic response reduction measurement were emphasized.

Seismic behavior of steel frame structures with viscous damper was studied by Chang.et.al., [3]. A design guideline was also proposed in the study. In order to establish the effect of different damper positions in a building, it was required to obtain the optimum damping coefficient for supplemental dampers. Hahn et al.,[4] developed a parametric analysis to determine the optimum damping coefficient. The results showed that if the structure are of uniform storey stiffness then dampers must be placed in lower storey of the building for efficient seismic response.

Zhang et al.,[5] and Wu et al.,[6] proposed another method for optimum damper positions in buildings with specified storey stiffness. In their study, additional dampers where placed sequentially on storey with maximum storey drift. The results showed that damper can be said to be optimally placed

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if they are installed at places of maximum displacement across damper.

Pong et al.,[7] introduced a finite element model for fluid dampers in study. This model was used in the analysis of a ten-storey frame. The conclusion drawn from the experiment was that addition of fluid dampers to the first floor absorbs more energy than installing in other floors.

A new method was introduced by Henry et al.,[8] to determine the number of dampers and their optimal placement. In his study, dampers were placed between every storey of building. Then analysis was done and damper with minimum gains were eliminated first as they contribute nothing to overall seismic performance of building's performance.

A comparative study of an existing retrofit of a mid rise steel building with additional steel bracings against an alternate retrofit using ADAS(Added Damping And Stiffness) passive energy dissipation device was conducted by Henry A[9]. He concluded from the studies that dynamic response of existing steel bracings was inferior to ADAS retrofit but considering the economic aspect, steel bracings was proved to be effective. Further studies on steel bracings was conducted by Luigi DI SARNO[10]. He studied the seismic performance of steel moment resisting frames retrofitted with different bracing systems and found that mega bracing system was more economical.

From the study conducted on various journals, the effectiveness in using dampers and bracings for retrofitting became clear. But the conventional method of going for any particular type of retrofitting, namely damper or bracings was found to be uneconomical as number of dampers in each case could not be controlled. The research on the hybrid model has its importance in this condition, to make the retrofitting economical.

This paper presents an attempt to study the hybrid model for retrofitting the buildings. Validation is done analytically and the objectives of the project are

1. To study the effect of dampers in retrofitting of building.
2. To study the effect of various damper configurations in building
3. Economical optimization of number of dampers using a hybrid model.

II. VALIDATION

A 3-storey building was modeled in ANSYS. All columns were assumed to be fixed at the base. The validation problem was selected from a study conducted by F.Hejazi.[12]. Damper properties and the earthquake data were taken from the journal. The maximum deformation and the shear force value of the building obtained after analysis was compared with journal values as shown in table1.

Table.1: Results Comparison

	Analysis Results	Journal Value
Total Deformation	2.308mm	2.6mm
Shear Force	2.5kN	2.7kN

III. TIME HISTORY ANALYSIS

A non-linear time history analysis was conducted on reinforced building models retrofitted with dampers. This type of analysis is used to determine the response of structure under the action of El-Centro earthquake data. This analysis also helps to determine the time-varying displacements, strains, stresses, and forces in the structure as it responds to the transient loads. The building considered is a 5storey building.

For conducting the study a 5 storey building was considered (Fig 1). Building details are given in Table 2. In the initial stage dampers were installed in different configurations and analyzed.

In this study, dampers are provided in 6 configurations. They are:

(i) All 4 sides
(ii) Centre only
(iii) 4 sides with centre
(iv) 4 corners
(v) 4corners with centre
(vi) Alternative storey
(vii)Alternative storey with centre

The same building was then analyzed by retrofitting with steel bracings. The results were then analyzed to obtain an efficient configuration which can reduce seismic effect on the structure and be economical in retrofitting process. The results obtained for dampers and steel bracings are shown in Table 2 and Table3.

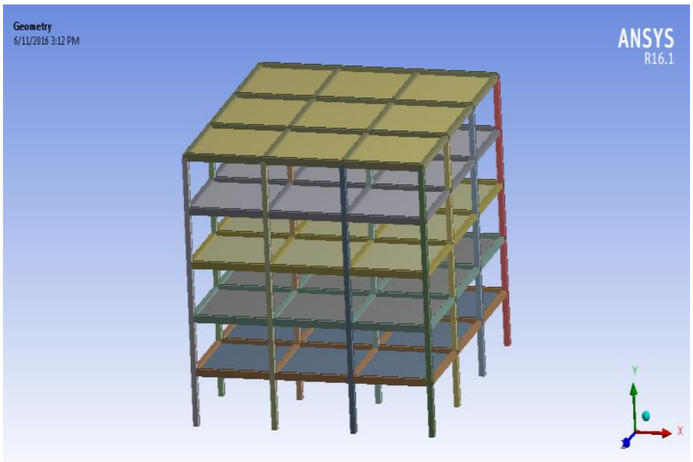

Fig. 1: Model of the building in ANSYS

Table 2 : Analysis results of dampers

Damper alone				
Sl. No	Configuration	Deformation (mm)	Stress (MPa)	No: of dampers
1	All 4 sides	9.62	8.25	60
2	Centre only	20.961	3.56	20
3	4 sides with centre	10.5	3.65	80
4	4 corners	13.4	4.5	40
5	4 corners with centre	10.63	3.45	60
6	Alternative storey	19.06	4.56	36
7	Alternative storey with centre	12	3	56

Table 3 : Analysis results of steel bracings

Steel Bracing alone			
Sl. No.	Configuration	Deformation (mm)	Stress (MPa)
1	All 4 sides	37.478	6.3
2	Centre only	43.04	7.76
3	4 sides with centre	32.73	5.72
4	4 corners	41.7	6.9
5	4 corners with centre	37.5	6.28
6	Alternative storey	42.8	7.6
7	Alternative storey with centre	39.7	7

By studying the various configurations, alternative storey with centre was found to be the efficient configuration as stress and deformation value is less for this configuration. It can be observed that stress value is even lesser in case of 4 sides with centre configuration but the number of dampers is very high in that case. So considering the economic aspects, dampers provided at alternative storey along with centre was selected as optimum configuration.

III. HYBRID MODEL ANALYSIS

In order to introduce economic concept into design, the number of dampers were required to be reduced. For attaining this objective a hybrid design is introduced. The study is conducted with dampers placed at the center in zigzag way (2 in each floor) and steel bracings placed on outside wall in alternative storey. Analysis results of the hybrid model is compared with other results and is shown in Table 4.

Table 4: Tabulated Comparison Results

	Deformation	Stress	No. of dampers
Without dampers	56.50	9.77	-
Damper only	12	3	56
Hybrid model	29.6	5	10
% reduction	47.6%	48.8%	82.1%

It was observed that the hybrid model could efficiently reduce the stress value by 48.8% and deformation by 47.6%. Considering the economic side, the hybrid model reduced the number of dampers by 82.1% making the retrofitting much economical.

IV. CONCLUSION

A hybrid model for retrofitting of building is studied in this paper. Conventional method is to either completely retrofit the building using damper or completely using bracing. In this hybrid model, both dampers and steel bracings are used together so that advantages of both the retrofitting techniques can be achieved. And the most important outcome is that this hybrid model can reduce the retrofitting cost of the building by reducing the number of dampers. It was found that the damper reduction is almost by 82% which is quite economical.

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