Non-Linear Dynamic Analysis of Multistorey Buildings with Dampers

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ABSTRACT

It is crucial for a structural engineer to save time in order to compete in the constantly expanding professional market. In response to this, an effort is made to use software to assess multistorey buildings. It is generally acknowledged that the most accurate method for modelling the reaction of structures exposed to high levels of seismic stimulation is nonlinear time-history analysis. The study compares the behaviour of rectangular structures with various fluid viscous damper (FVD) placements under dynamic loading. It was discovered that using FVD reduced storey displacement, and storey drift. In this study, a 28.5 m-storey RCC building is examined. The structure is rectangular in shape and lies in seismic zone V. Loading calculations for RC-framed buildings were performed in accordance with code rules, notably IS:1893-2002, IS:875(Part-III)-1987, and IS:456-2000. Using the seismic record from Imperial Valley, nonlinear time history analysis is conducted. The storey displacement, storey drifts, and storey shear characteristics are examined both with and without dampers.

***Keyword** - Dampers, Time-history analysis, Fluid Viscous damper, Imperial valley earthquake, Finite element modeling*

1. INTRODUCTION

In many parts of the world, reinforced concrete is a popular building material. RCC is frequently chosen over other construction materials such as steel, masonry, or timber in building projects due to the ease of availability of its constituent elements, the strength and economy it offers, and the flexibility of its forms.

RCC is an extremely complicated composite material from the perspective of structural analysis and design. It offers a distinct way to combine two materials with very contrasting mechanical properties. They combine to form a composite, which has the characteristics of an elasto - plastic material and reacts differentially to compressive and tensile stresses. Moreover, due to concrete's tendency to crack, both sectional and consequently structural qualities are influenced by the type of load applied on the structure and amount of the load applied. Many of these complications can become noticeable, especially when the building is exposed to dynamic loads like wind, waves, storms, and powerful ground motions like earthquakes. Despite the significance of material nonlinearities or time-varying qualities, they are infrequently taken into consideration during the analysis and design of RCC structures [1].

The input energy from the earth acceleration during a seismic event is converted into kinetic and potential energy, both of which must be absorbed or lost as heat. However, a significant amount of the input energy for powerful earthquakes will be absorbed by hysteretic action. Therefore, for many engineers, increasing the stiffness of the structures is the most traditional method of protecting them against the impacts of earthquakes. Using the passive control device FVD in buildings results in a very noticeable decrease in the structural response [2]. Dampers are most effective when installed in the lowest storeys [3].

1.1 Types of Dampers

1.1.1 Viscous Damper

Viscous damping is a technique for increasing energy release in a building structure's lateral system. By forcing fluid through an opening and creating a damping pressure that generates a force, a viscous damper releases energy. As a result, the power or energy of an earthquake is significantly reduced. Fig. 1 depicts the viscous damper for buildings.

Steel is a strong material, which is why it is composed of that. Silicone oil, which is inert, non-flammable, non-toxic, and steady for incredibly long periods of time, serves as the damping fluid. Viscous dampers have numerous uses in designing and retrofitting because of their simplicity of installation, adaptability, and variety in sizes.[2]

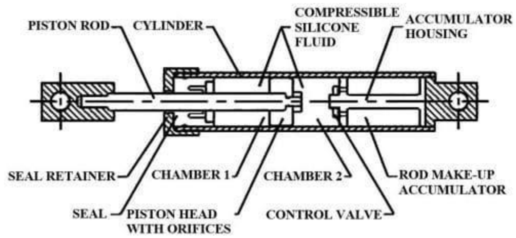

Fig -1: Viscous Damper [2]

1.1.2 Friction Damper

It is the most efficient, dependable, and cost-effective way to release energy. Here, the friction caused by the rubbing of surfaces against one another consumes the earthquake energy. Friction has a much higher energy dissipation rate than any other technique. The efficacy of a frictional damper is very little impacted by changes in temperature, velocity, etc. It has been transformed into one of the most popular types of dampers due to its straightforward behaviour and straightforward implementation. A spinning friction damper is shown in Fig. 2. It can be applied when seismic strengthening is being done on old structures. It is inexpensive and needs no upkeep.[2]

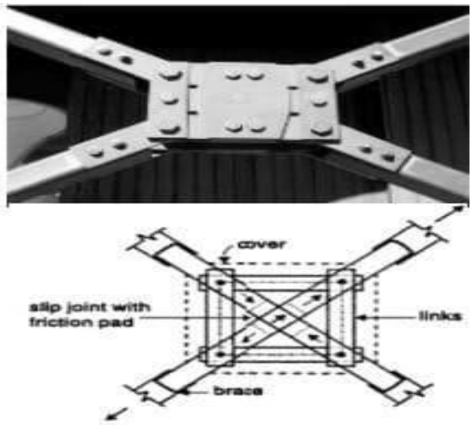

Fig -2: Friction Damper [2]

1.1.3 Yielding Dampers

This damper uses the energy that is transmitted to the structure to cause it to submit and exhibit non-linear behaviour in its employed components. These dampers use metal inelastic deformation, which is useful for energy release in formable metals like steel and lead. Utilizing submission metallic dampers in supports is more typical. Several parallel steel slabs are frequently used to make these dampers. Additionally, they take on the roles of absorption and energy reduction when used in conjunction with a bracing system. Fig. 3 is the metallic type of yielding dampers.[2]

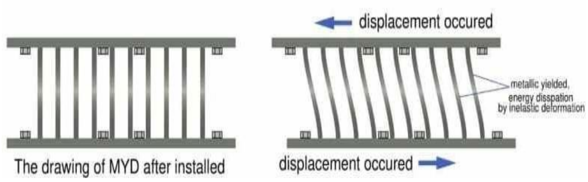

Fig -3: Yielding Dampers [2]

1.1.4 Magnetic Dampers

Electromagnetic damping is inexpensive and climate independent. It is tidy, incredibly simple to modify, and highly efficient. Because the magnetic damping is not as powerful, it works well in dynamic vibration absorbers even though they need less damping. Two racks, two pinions, a copper disc, and rare-earth magnets make up the damper. The racks and pinions allow the copper disc to spin when a relative linear motion is made between two rod ends. Fig. 4 represents magnetic damper. [2]

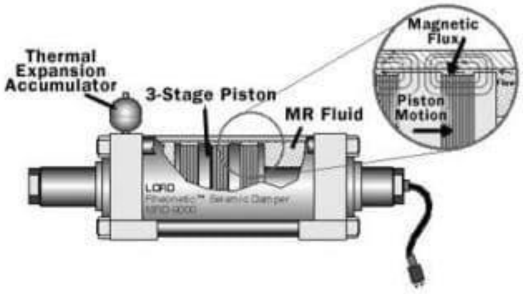

Fig -4: Magnetic Damper [2]

1.1.4 Tuned mass Dampers

It consists of a mass and a spring that is fastened to the structure. It functions according to the harmonic motion or frequency principle. Resonance frequency is resisted, which lessens mechanical vibrations. It consists of Large oscillating mass, Spring, Visco-damper. Because the parts are lightweight, they serve as a spring and significantly lower the amplitude of big vibrations. Fig. 4 represents tuned mass damper.[2]

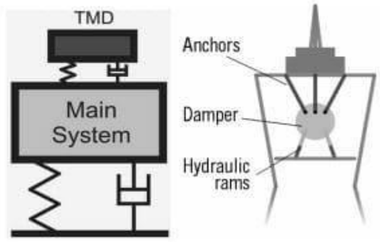

Fig -5: Tuned mass Damper [2]

2. METHODOLOGY

2.1 Modeling

For understanding the seismic behaviour of the structures, a rectangular building model with nine stories was considered for analysis of building under seismic vibration in the software. Each level is 3.0 m tall. It is regarded as being situated in seismic zone V. The columns are fixed at a depth of 1.5 m below the surface of the ground and soil structure interaction has not been taken into account. The building's physical characteristics are assigned. Beam and column members are referred to as frame elements with dimensions of 350*500 mm and 450*450 mm respectively. Slabs are characterised as area elements with 150 mm of thickness and the characteristics of shell elements. Fig.7 depicts the study's construction plan. The software takes into account the self- weight of the beams, columns, and slabs automatically. User defined load combinations were considered.

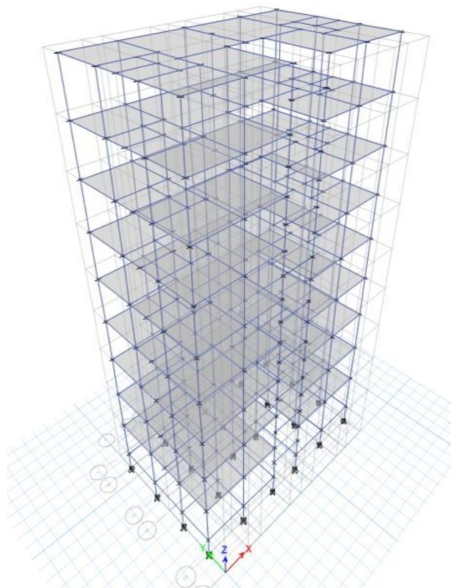

Fig -6: Model in software

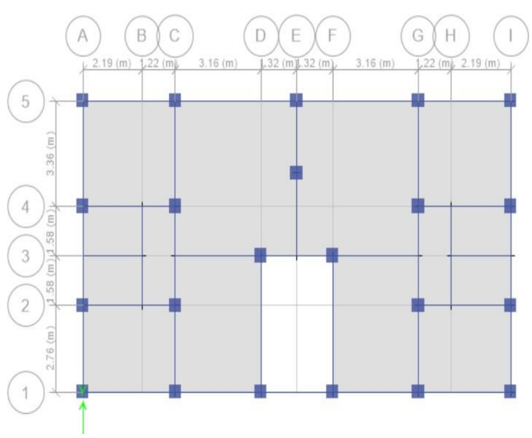

Fig -7: Plan of Building

For the seismic design of structures with dampers fluid viscous dampers was considered. The damping coefficient C value is what the programme uses to analyse the structure. The damping exponent and damping coefficient is constant.

For analysis three vertical arrangement of dampers was considered as shown in the fig. 8.

Placement 1 – Dampers placed on the alternate storey levels

Placement 2 – Dampers placed at corner of first 3 storey levels and last 3 storey level

Placement 3 – Dampers placed at corner of first 3 storey level

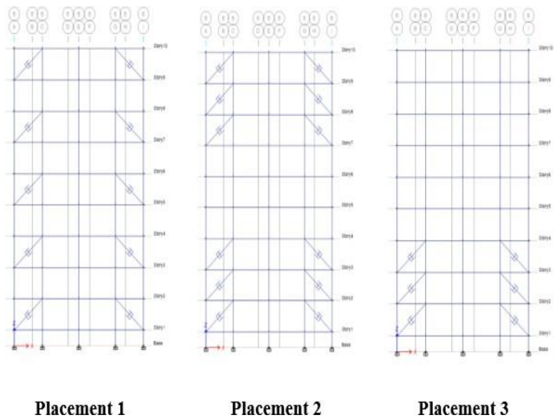

Fig -8: Placement of the Dampers

2.2 Time History Analysis

The most effective technique for analysing the structures under a particular earthquake record is time-history analysis. During the analysis, the precise earthquake record is entered at the foot of the building. In this case, the duration of the imperial valley signal is 54 and the time step size is 0.01 seconds. The fig 9 and 10 below shows time history signal in both the direction.

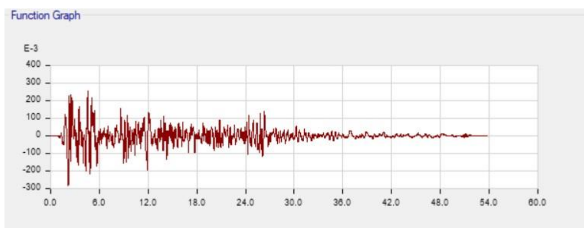

Fig -9: Earthquake along X- Direction

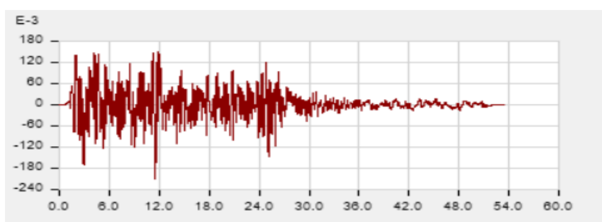

Fig -10: Earthquake along Y- Direction

3. RESULT

To assess the efficiency of horizontal dampers in the structure subjected to seismic excitation, a numerical analysis is conducted. The design parameters, which were derived from the study findings and analysed, include top story displacement, inter-story drift, and Storey shear.

3.1 Storey displacement

Analysis of storey displacement for three different placement of damper was caried out. Table 1 shows the percentage decrease in displacement at each storey level for the maximum critical load condition along X direction. As per the fig.11 model with no dampers show maximum displacement of 66.2 mm, which is reduced by 12%,11%

and 6% for placement 1, placement 2 and placement 3 respectively. Similarly, along Y direction 66.63 was reduced by 11%, 12%, 5% for placement 1, placement 2 and placement 3 respectively.

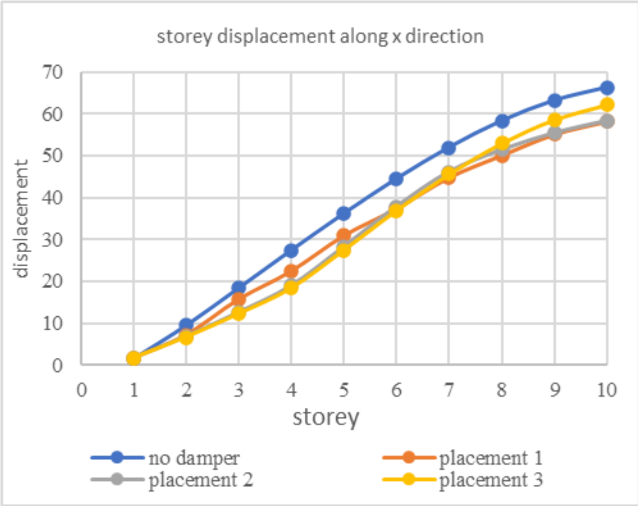

Chart -1: Maximum storey displacement along X-direction

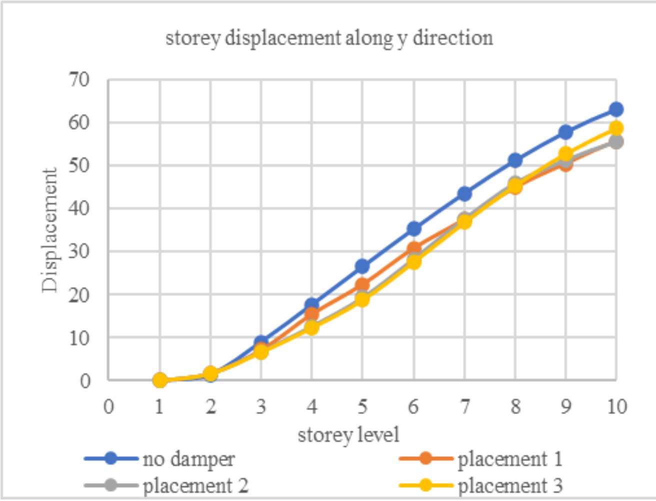

Chart -2: Maximum storey displacement along Y-direction

Table -1: Displacement along X-direction

storey	no damper	placement 1	% decrease	placement 2	% decrease	placement 3	% decrease
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Story1	1.53	1.69	-10.12	1.67	-9.21	1.65	-7.45
Story2	9.46	7.14	24.50	6.80	28.14	6.63	29.89
Story3	18.38	15.66	14.80	12.55	31.72	12.20	33.61
Story4	27.38	22.40	18.21	18.92	30.92	18.34	33.02
Story5	36.15	30.86	14.63	28.20	22.00	27.41	24.18
Story6	44.43	37.36	15.91	37.78	14.96	36.85	17.04
Story7	51.91	44.76	13.77	46.11	11.17	45.53	12.29
Story8	58.25	50.07	14.05	51.36	11.82	52.91	9.17
Story9	63.09	55.09	12.69	55.37	12.24	58.55	7.20
Story10	66.20	58.19	12.10	58.30	11.93	62.18	6.07

Table -2: Displacement along Y-direction

storey	no damper	placement 1	% decrease	placement 2	% decrease	placement 3	% decrease
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Story1	1.43	1.69	-17.85	1.70	-18.69	1.68	-17.09
Story2	9.01	7.15	20.67	6.78	24.74	6.64	26.33
Story3	17.66	15.48	12.38	12.63	28.51	12.32	30.23
Story4	26.49	22.36	15.57	19.31	27.10	18.81	29.00
Story5	35.19	30.72	12.69	28.23	19.77	27.57	21.64
Story6	43.51	37.44	13.94	37.55	13.68	36.82	15.38
Story7	51.14	44.85	12.30	45.88	10.29	45.40	11.23
Story8	57.76	50.43	12.69	51.27	11.23	52.83	8.53
Story9	62.99	55.58	11.76	55.56	11.80	58.69	6.83
Story10	66.63	59.04	11.40	58.85	11.68	62.74	5.85

3.2 Storey drift

For all the situations that were taken into consideration, storey drift results were obtained from the analysis. The graph of storey vs. drift for each level is shown in Fig. 13 & 14. The unitless number known as drift is the difference in deflection between the storeys. We can see the variation in the drift at each storey based on the damper's arrangement.

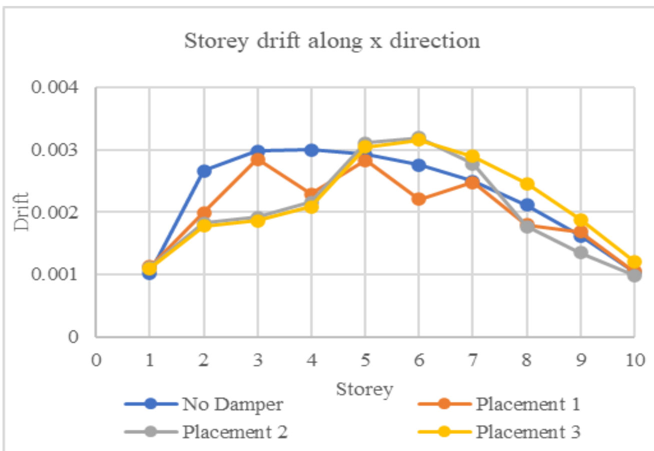

Chart 3: Storey drift along x direction

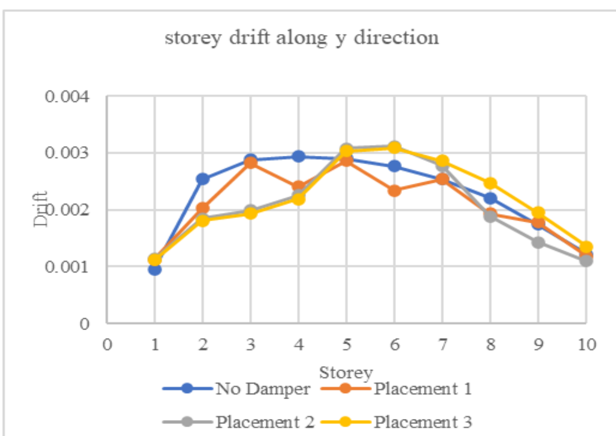

Chart -4: Storey drift along y direction

3.3 Storey drift

The resistance offered at various storey against storey displacement may be studied using the storey shear plot, which is a crucial parameter. For all placements and without damper, the plots of storey shear for all cases have been compared. Each scenario shows that the maximum value of story shear at the specified storeys is higher for buildings with dampers along both directions.

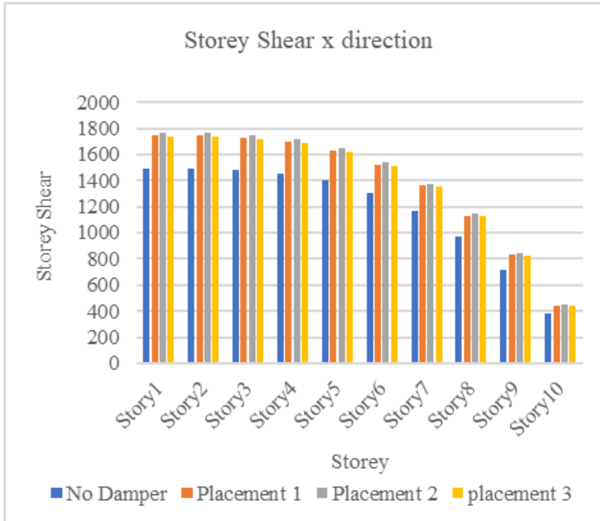

Chart -5: Storey Shear in X- direction

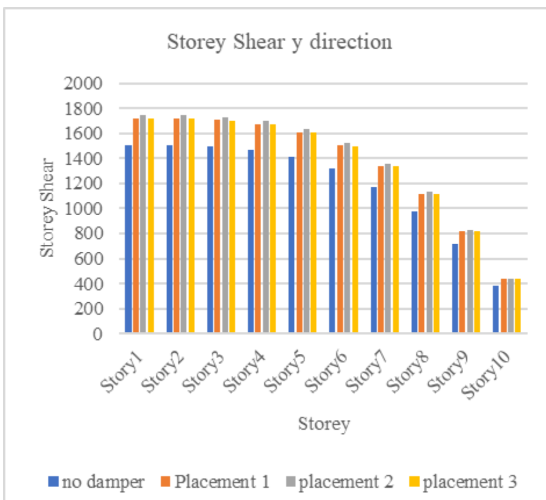

Chart -6: Storey Shear in Y- direction

4. CONCLUSIONS

The outputs of a non-linear time history study performed on a nine-story RC frame structure with and without FD, illustrated by story responses and time history plots for different parameters, show that the structure's story response has been significantly decreased by the application of dampers.

From the analysis result following conclusions are made:

1) The placement 1 and placement 2 show same amount of percentage reduction of the displacement.
2) While considering the efficiency of the placements, the highest storey shear was obtained by placing dampers at bottom and top storey.
3) By comparing the results obtained, Placement 1 and 2 shows higher reduction in displacement as compared to Placement 3.

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