Seismic Response Control of Steel Composite Building with Shear Wall System Using Viscous Fluid Dampers

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Abstract— It is well understood fact that all structures inherently dissipate and absorbs energy induced due to external loading such as earthquake shaking by its ability to deform, flexibility and strength. The performance of the buildings can further be improved by controlling seismic response using viscous fluid dampers. Focused mainly on their nonlinear behavior; this study will demonstrate the advantages of viscous dampers on steel composite buildings subjected to few sets of ground motions. The analysis was carried out using ETABS software, using the nonlinear dynamic analysis (modal time-history) method for few sets of ground motions download from PEER database. Earthquakes have devastating impact on the dynamic response of buildings due to its unpredictability and random nature. In this study, two cases have been studied in order to make a significant comparison: the actual building without viscous dampers, and the building with dampers installed. Results were exported for both cases and shown in terms of story displacements, story accelerations and inter story drifts, and the plot of the cumulative energy of the system. The results show a significant reduction in ductility demand, as well as their response such as accelerations, displacements and drifts.

Index Terms- Viscous Fluid Damper, Energy Dissipation, Time-History, Ground Motions, Performance-Based Design, Seismic Response Control, Ground Motions.

I. INTRODUCTION

The widely used practice of earthquake resistant design procedures is based elastic analysis, even though the structures may sustain significant damage beyond their elastic limit due to earthquakes. To ensure the safety of the structures nonlinear behavior of some structures is required to be understood, i.e., dissipation of energy through inelastic cyclic deformation (hysteretic behavior). In this approach, the damage is expected to occur and depending on the magnitude of earthquake, damage may occur beyond the reparable extent, and thus sometimes retrofitting and strengthening of damaged members is not feasible or possible depending upon nature of damage, cost of repairing, time required, etc. Important structures such as hospitals, data centers, airports, railway stations play very important role after earthquakes and are expected to remain fully operational even after a major earthquake**.** Mostly retrofitting is done by increasing strength and stiffnesses of members to ensure safety however this is not always valid as due to increase in stiffness sometimes response of structure is also amplified and thus further increasing demand.

In order to demonstrate the advantages of using viscous dampers in buildings, a study of steel composite commercial building having composite steel beams with metal deck system, encased composite columns and shear walls as lateral load resisting systems is equipped with FVD, the building is designed as per Indian standard applicable for New Delhi. The structural design of the building is performed as per requirements of IS 1893:2016 as well as IS 16700:2017 for seismic hazard applicable for ZONE IV. FVDs are passive control devices and after properly configuring the dampers by installing at such locations to minimize the response lesser energies are transferred to structural members for dissipation.

II. VISCOUS FLUID DAMPERS (VFD) AS SEISMIC RESPONSE CONTROL DEVICES

These are passive control devices (velocity sensitive) gets activated at low displacements and produces damping effect through ‘to and fro’ medium and thus absorbing and kinetic energies and radiating the absorbed energies in the form of heat.

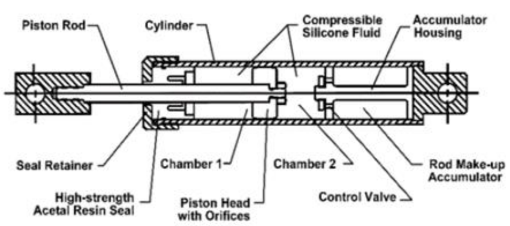


FIG 1 Typical arrangement of Viscous fluid damper.

The VFD devices dissipate energy through the relative velocities that occur between their connected joints. The nature of force-displacement response of the dampers depends on the frequency of the motion. During a seismic event, a piston compresses the fluid in the cylinder, resulting in the transfer of fluid from one chamber to another, thus damping force is generated. This is how internal displacement of the piston causes the conversionof kinetic energy into heat energy.

The conventional damping force of VFD is imposed by,

$$F = CV^{\alpha} \qquad \text{(i)}$$

Where F is the expected damping force, C is the damping coefficient, V is the velocity of the piston and α is the damping exponent.

III. CASE STUDY

A G+14+Terrace -story steel composite building having encased composite columns designed as per provisions of AISC 360-16, steel composite beams with metal deck designed as per provisions of AISC 360-16 and RC shear walls designed as per requirements of IS 456:2000, IS 1893:2016, and IS 13920:2016 modelled as 3D and analyzed with and without VFDusing ETABS software.

The dampers were modelled as nonlinear link element with "Damper-Exponential" option. Piston dampers works in the axis direction of the device and thus accordingly modelled after determining the properties of dampers such as stiffness, damping and damping exponent, for this study the value of damping exponent (α) is chosen as 0.3 and dampers are placed in diagonal configuration only.

The ground motions are applied directly to the base of the model (grade level) to study the behavior.

3.1 Ground Motions

Following table provides information on ground motions records used for this study for 2475-year return period earthquakes.

GROUND MOTION RECORDS FOR 2475 YEAR RETURN PERIOD EARTHQUAKE					
S.NO.	EARTHQUAKE NAME	DATE OF OCCURANCE	MAGNITUDE	STATION NAME	SCALING FACTOR
1	Big Bear-01	28-06-1992	6.46	Ferndale City Hall	1.22
2	Coalinga-01	02-05-1983	6.36	Cantua Creek	1.02
3	Chi-Chi_Taiwan-02	20-09-1999	5.9	Parkfiled-Fault	1.68
4	Chi-Chi_Taiwan-05	22-09-1999	6.2	CHY028	1.61
5	Chi-Chi_Taiwan-05	22-09-1999	6.2	TCU065	1.83
6	Chi-Chi_Taiwan-05	22-09-1999	6.2	TCU138	1.59
7	Chi-Chi_Taiwan-05	22-09-1999	6.2	CHY101	0.76

Dynamic loading applied on the structure was simulated by nonlinear time-history analyses (FNA) of the above earthquakes.

For analysis and design using nonlinear FVD maximum considered earthquake (MCE) shall be used.

3.2 Dampers location

To determine the suitable locations of dampers, few initial trials are required to be performed in which various arrangements and locations are considered.

In this study the dampers are placed in both X and Y directions, initially dampers were placed in all storey levels and relative velocities between joints of the dampers were determined by putting C and α as 1. Dampers experiencing velocities less than 0.05 m/sec² were then removed as viscous dampers are velocity dependent devices and the final placing of dampers throughout the building was based upon the joints having higher velocities. calculated parameters for nonlinear viscous dampers were then provided as input parameter in the program for analysis and results were obtained.

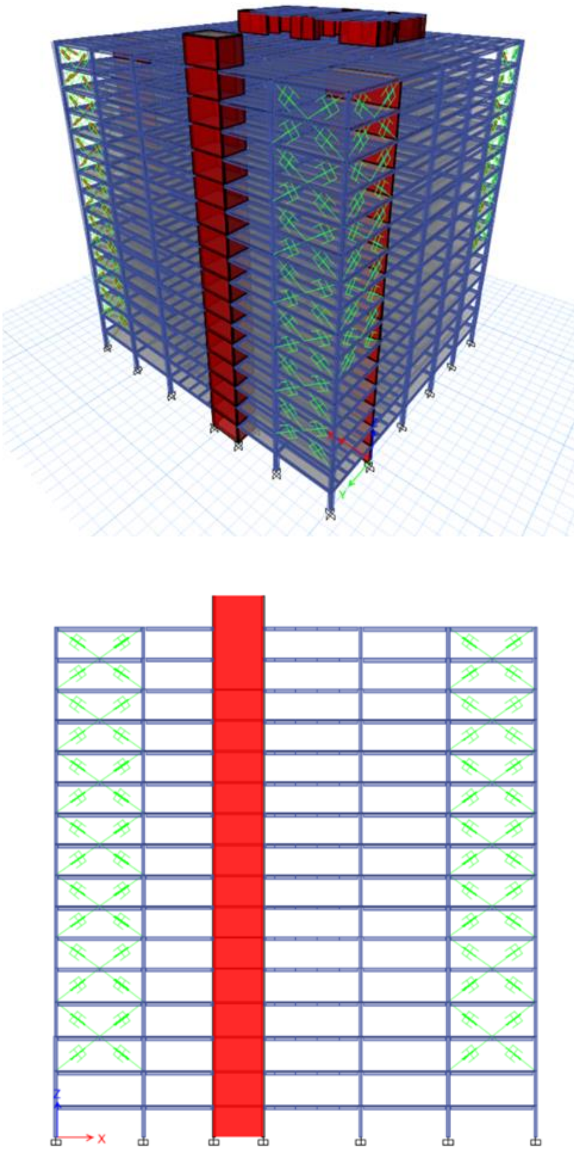


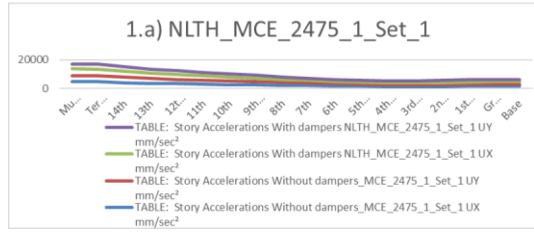
Fig. 2. a) 3D Model with VFDs, b) *Z*-X view, Elevation

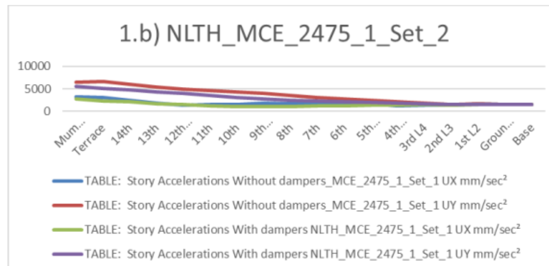
Before final configuration of dampers in building, few of them located near higher density of shear walls were present were removed due to higher rigidity because of shear to enhance the performance of dampers ensuring maximum effectiveness.

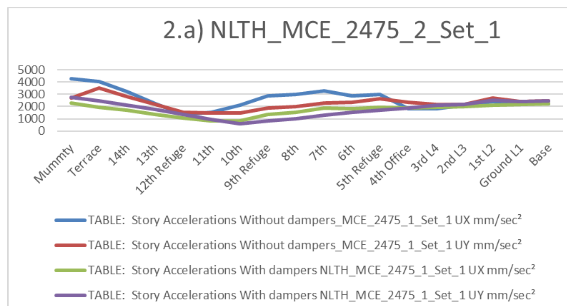
IV. RESULTS

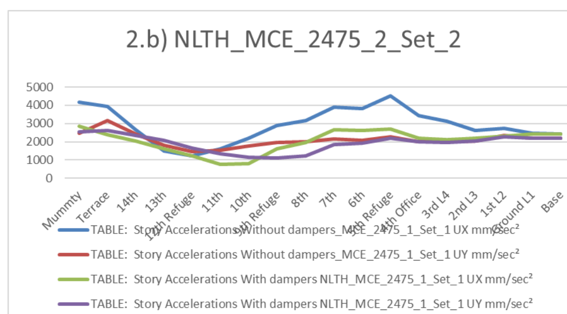
1.1. Structural response (floor accelerations, displacements).

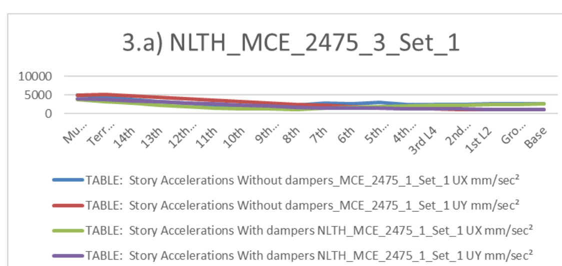
The results obtained from analysis are shown in the form of graphs showing the reduction in Story acceleration response of the structure.

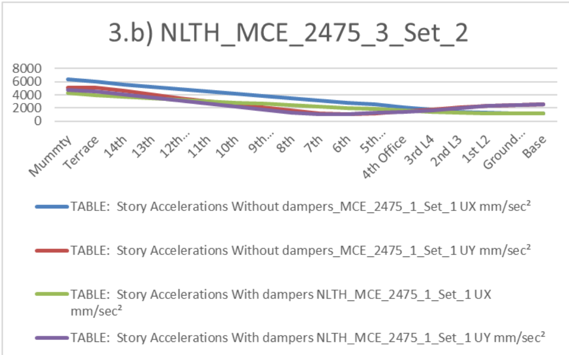


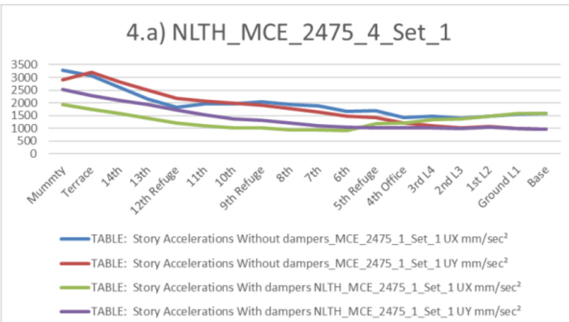


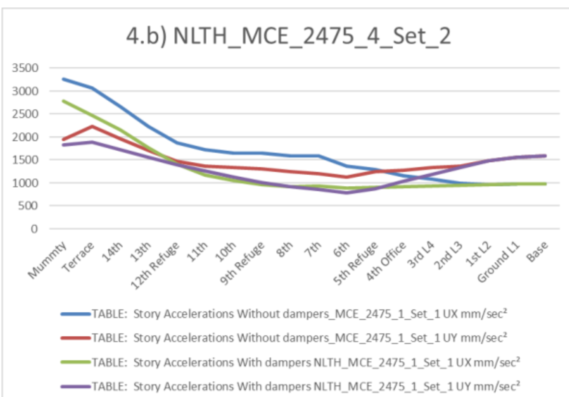


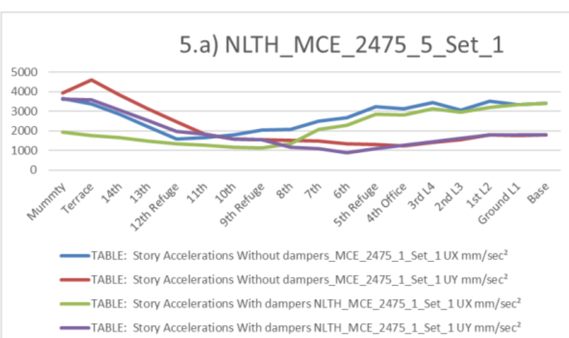


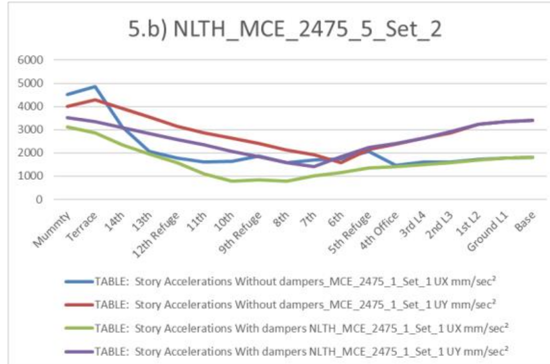




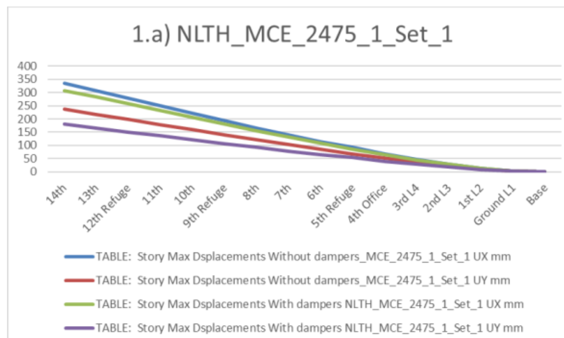


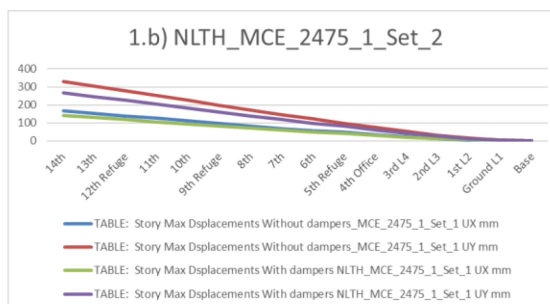


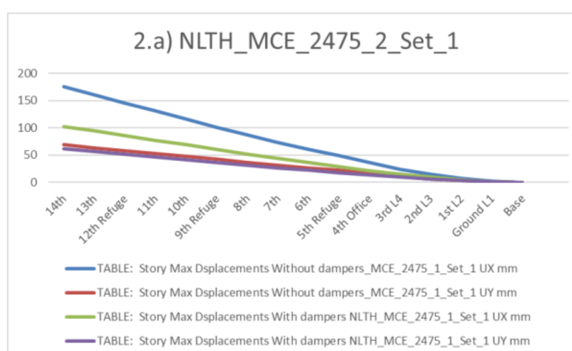


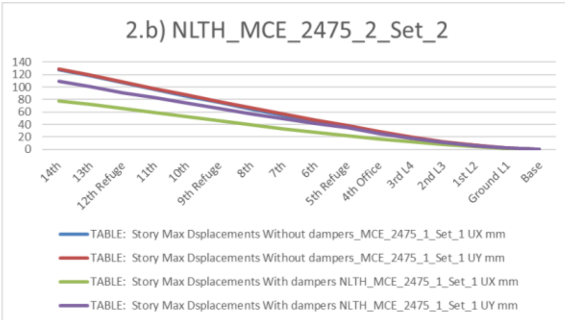


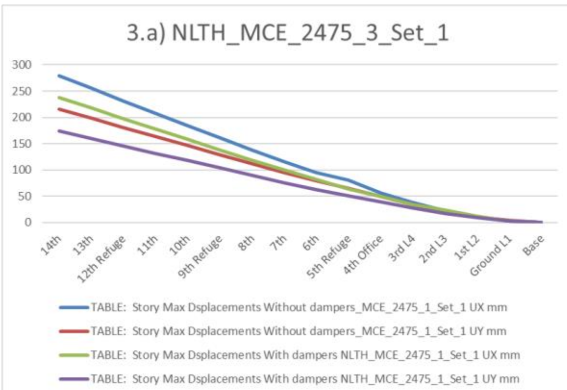
Story displacements comparison of building with viscous dampers and building without viscous dampers. The results obtained from analysis are shown in the form of graphs showing the reduction in Story maximum displacement response of the structure.

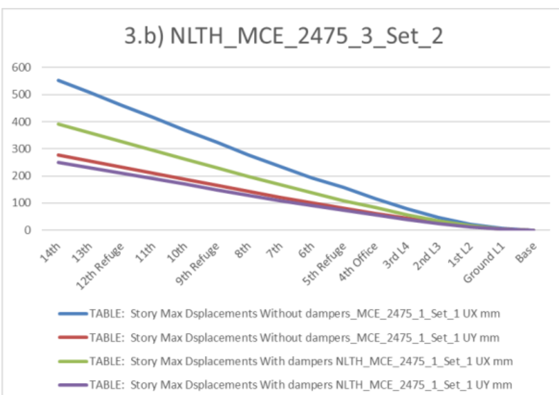


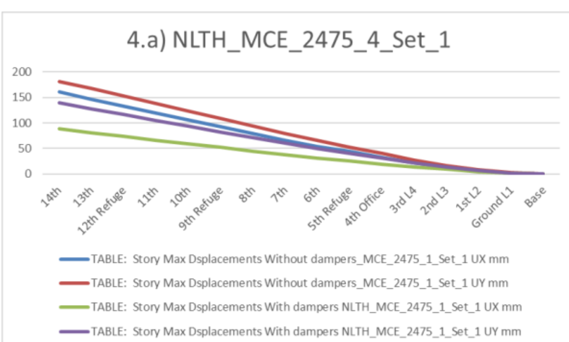


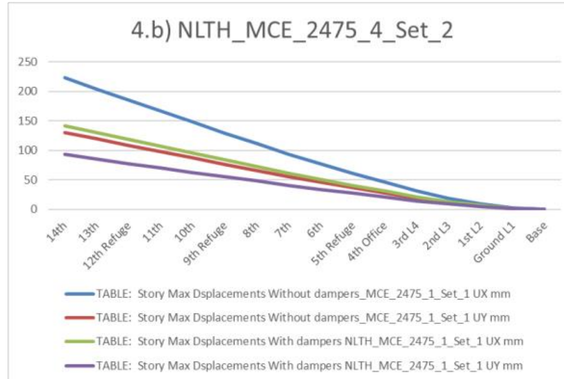


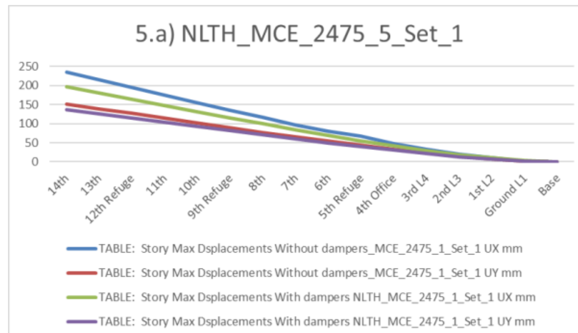


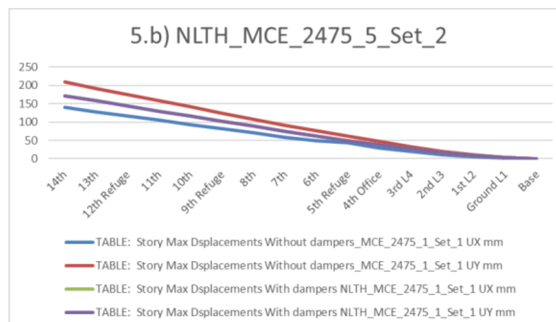








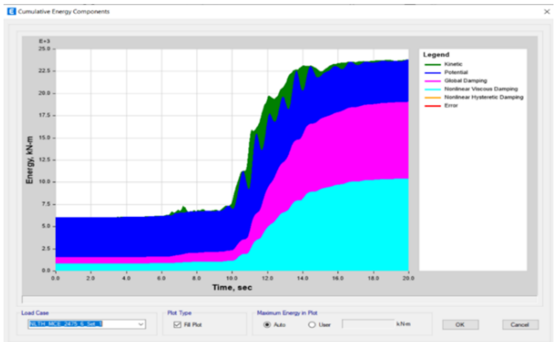




1.2. Structural system energy

The energy balance plot is particularly useful in order to see how energy is transferred to the supplemental damping systems. For the two different α, the energy variation is shown in Fig.

Since the purpose of adding supplemental damping is to dissipate energy, it is natural to consider the migration of energy quantities. The difference when using different α can be observed. For α = 0.50, the amount of energy dissipated by the devices is higher than the one obtained for α = 0.25.



Energy variation in direction
NLTH_MCE_2475_6_Set_1

FORCE -DISPLACEMENT PLOT

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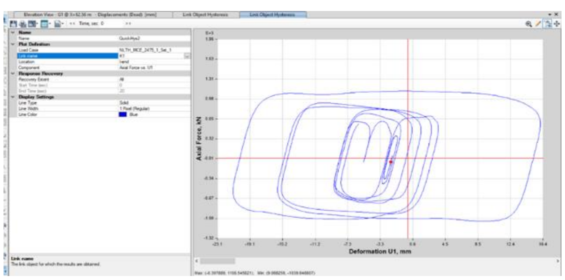
Figure below represents the force-displacement relation for one of the dampers on the fourth floor. For this acceleration record, the maximum damper force is approximately 1108 kN. As seen in the figure, the dampers dissipate a large amount of seismic energy (cumulative area in the loops).



CONCLUSION

VFD reduces the structural response such as displacements, floor accelerations, etc.

A reduction in the ductility requirements occurs with the use of dampers. This can be verified through the energy graph.

Significant amount of energy is absorbed by FVD and lesser energy is transferred to the structure, thus with reduced seismic response of structure the seismic demand on the structure is also reduced.

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