Performance Evaluation of Viscous Damper for Tall Steel Structure

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Abstract: Tall steel building is increasing day by day, thus need for such building is in demand due to rapid growth in population and increase in competition to construct tall buildings. The building in earthquake prone area are frequently subjected to serious ground motion, the result of this is collapse of structure. The various effects of earthquake are landslide, tsunami, rock fall, etc. such that in this area tall building is not allowed to construct unless properly analyzed for seismic behavior. But however tall building is constructed necessarily due to increase in demand. The design of building in earthquake zone should be such that they must resist moderate earthquake. The main the objective is to control the major part of energy that is getting into the structure and to avoid the collapse of structure, thus analysis of building is done in nonlinear domain. To take care of response viscous damper is used in the building. The analysis and design viscous damper is discussed in this paper. The analysis is carried out using ETABs software.

Index Terms - Tall building, nonlinear dynamic analysis, viscous damper, ETABS.

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1. INTRODUCTION

Increase in population has lead in growth of tall structure for the propose of accommodation. Also, a competition around the world to construct tall buildings is going on as the symbol of power and technology. Tall structures are subjected to vibration due to wind effect, earthquake, and other source of vibrations. These vibrations can cause serious harm to the structure and can lead to collapse of structure. Earthquake is the most serious phenomenon that engineers are extremely concerned about. The place and time of occurrence of an earthquake are unpredictable and therefore, this categorizes them as a disaster phenomenon. During an earthquake, a large amount of energy is absorbed by the structure. The damage of the structure is determined by the amount of energy consumed.

The most dangerous effects of earthquake are collapse of structure, especially in case of tall buildings due to high displacement of stories. The main problem is to reduce the structural response by decreasing the dissipation of input energy due to earthquake. The objective is to control a portion of energy that is getting into the structure, so that the seismic response of the structure and damage control potential could be improved. The main goal is to study and analyse the seismic behavior of tall steel structure using viscous dampers. Different nonlinear computer programs are now capable of modelling viscous dampers. Some of these programs are SAP2000, ETABS, ANSYS, etc. Use of EATBs in analyzing is user friendly and we can model and analyse the building quickly.

1.1 Proposed work

This work is focused on the analysis of steel building and to find the performance of the steel building with viscous damper. The nonlinear time history analysis is to be done to check the performance for different earthquake.

The use of viscous damper in the building and to check the performance for different damping and different position of damper is to be done. The building performance in terms of displacement, drift and base shear is to be find out.

2. DAMPING

Damping is event in which mechanical energy is dissipated in dynamic systems and it is converted into thermal energy. Damping reduces the system response, especially for near resonance conditions, where damping controls the response. Damping values depends on various factors such as, vibration amplitude, material of construction, fundamental periods of vibration, mode shapes and structural configurations.

2.1 Types of damping

Three primary damping are

- Internal Damping – due to material
- Structural Damping - at joints and interface
- Fluid Damping – through fluid-structure interaction.

Two types of external dampers can be added to enhance its energy dissipation characteristics:

- Active Dampers: require external source of power.
- Passive Dampers: does not require external source of power.

2.2 Passive Energy Dissipation Devices

Passive energy dissipations have been under development for a number of years. The main function of passive energy dissipation devices in a building is to absorb a portion of the earthquake input energy. The result is to reduce damage to the structure system. A high number of passive energy dissipation devices are available and others are under development. The various passive devices that have most commonly been used for seismic protection of structures include viscous fluid dampers, viscoelastic solid dampers, friction dampers, and metallic dampers.

2.3 Viscous Damper

Viscous dampers as shown in fig. is same as the action of shock absorber in automobile but performs better with high force. These dampers are larger than automotive damper and are more durable to serve for long time. The fluid use is of silicone oil which is inert, non-toxic.

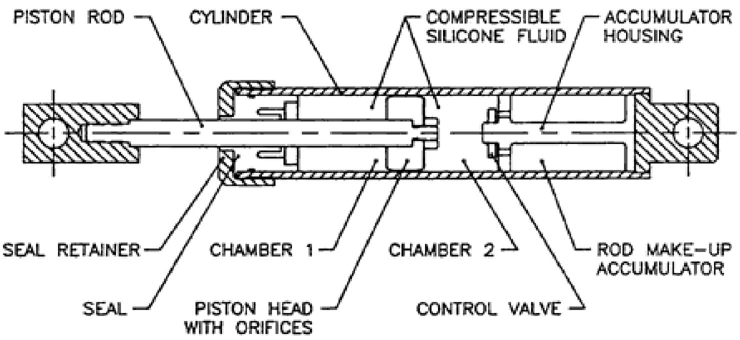

Fig.1 Viscous Damper [3]

Design of viscous damper is done by the formula derived by Levy (2008).

$$C_d Total = 2 * \zeta * \omega_n \frac{[\phi^T][M][\phi]}{[\phi^T][\phi]} \text{ -- (1)}$$

Where

ζ = Damping in %

ω_n =Natural frequency of the structure (rad/sec)

ϕ = Modal displacement matrix

M= Mass matrix

C_d =Coefficient of Damping

3. NONLINEAR TIME HISTORY ANALYSIS

The nonlinear dynamic analysis consists of the non-linearity of the structure. It is a very complex model to analyze the effect of dynamic loading and it can be used for any no. of degrees of freedom. In non-linear dynamic analysis, force is considered as time dependent. So, the governing equation is now also function of time apart from function of dimensions. Other assumption in this analysis is that the material is non-linearly elastic. This can be addressed by changing the strain-displacement equation and adding higher order terms in the equation. This method consists of performing a time-history analysis in the non-linear domain. The seismic action is directly applied, by means of accelerogram, at the base of the structure.

4. MODLING OF BUILDING

For this study a 30-storey steel frame building is considered. The steel building consists of 5 bays in X-direction and 5 bays in Y-direction. Each bay is of dimension of 4 x 4 m, having total plan area of 20 m X 20 m. The building is considered to be located in zone V and designed according to IS 1893 2016. The structure is considered to be fixed at the base. The structure is modeled using software ETABS 2016. Models are studied for comparing maximum story displacement, maximum story drift and base shear.

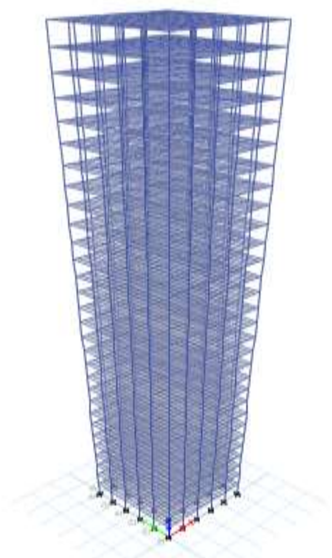

Fig 1 3-D view of Building

The common data used for modelling of building is as follows:

Table 1 Details of Building

No. of Storey	30
Storey height	4000 mm
Total height of building	120 m
Thickness of Slab	150 mm
Grade of concrete	M25
Grade of steel	Fe500
Number of bays	5 (X and Y direction)
Column Size	Outer=PISHB450-2-400/40, Inner= PISWB600-2-400/40
Beam Size	M25
Grade of steel	ISWB300
Zone	V
Response reduction factor	5
Soil Type	Medium (Type II)

The loads considered for the modelling of building are given in table below.

Table 2 Loading details

Sr no.	Load type	Value (kN/m^2)
1	Live load	3
2	Floor finished	1

Fig 2 Building with Viscous damper

4.1 Time history data

Various time history taken from ETABs 2016 for analysis are:

- Imperial valley
- North west California
- Sylmar-country hospital
- Friuli Italy

- Gazli USSAR
- El Centro

5. RESULT AND DISCUSSION

The complete analysis of building is done first linearly and then time history are applied to building to check the performance for different earthquakes taken from ETABs. The result is divided into two forms, first the building is linearly analysed without application of time history, then the building is analysed for seven different time history data. Then the results are showns with use of viscous damper to show its effect of change in storey response.

5.1 Displacement and inter-story drift of building without damper

The first analysis is linear static analysis, in which the building is analysed for static forces and the results are plotted for displacement and inter-storey drift.

Table 3 Displacement and Inter-storey values without damper

Time history	Displacement(mm)	Inter-storey drift
Regular building	215.55	0.0025
Imperial valley	246.68	0.0036
NW California	215.56	0.0028
Sylmar country	257.03	0.0033
Friuli Italy	190.20	0.0025
Gazli USSAR	265.70	0.0034
El Centro	272.96	0.0038

The figure below shows the graph of top displacement of the building for various time history. The graph shows the behaviour of building for different time history.

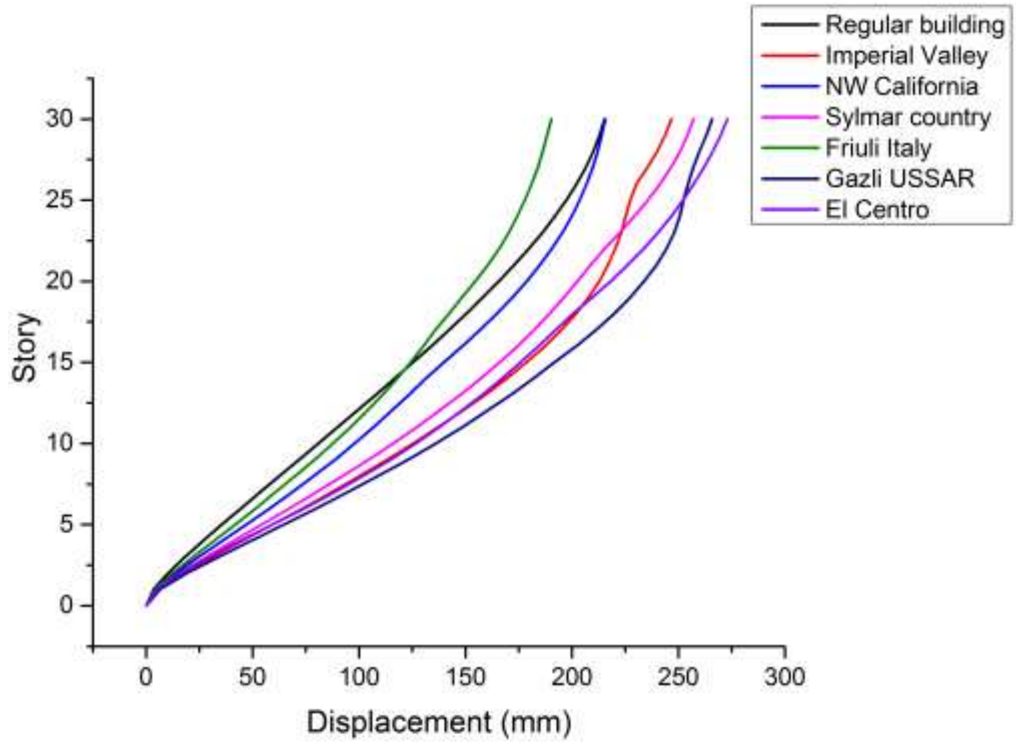

Fig 3 Top deflection of building

The above figure shows that the building behaves differently for different time history. The black colour line shows the displcement of building which is subjected to static force and all other colour line in the graph shows the displacement for different time history. The displacement are shown in milimeters, it is seen that for El centro the building has maximum displcaement.

The figure below shows the graph of inter storey drift of the building for various time history. The graph changes for different time history.

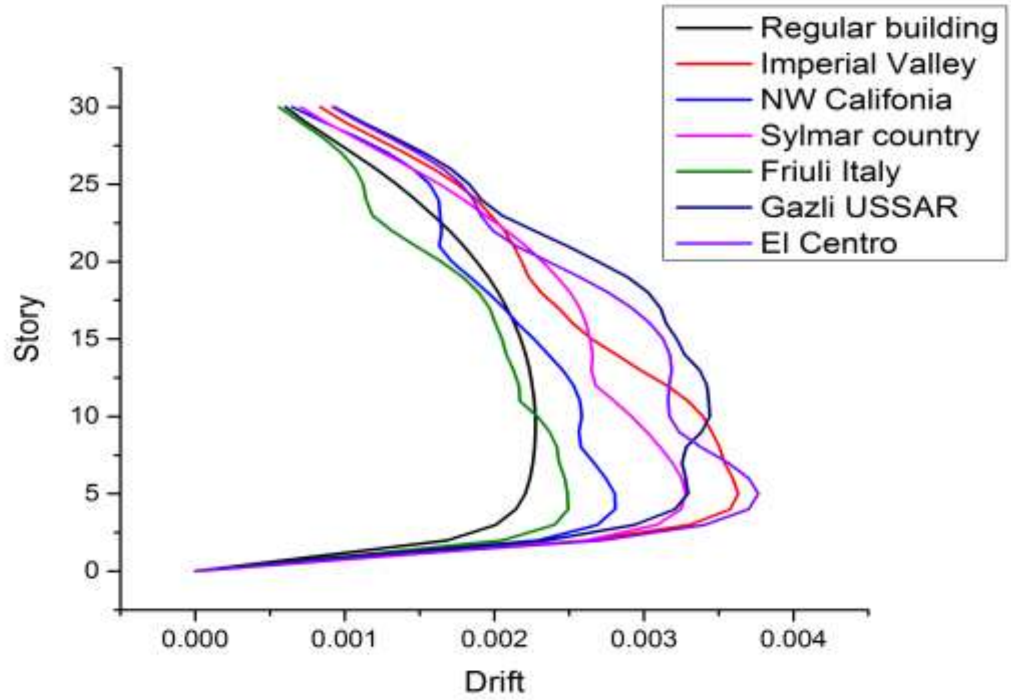

Fig 4 inter-storey drift

The figure above shows the variation in inter storey drift for different earthquakes. The black colour line shows that building behaves linearly for static force, when the time history is applied the other curves shows that the building behaves non linearly.

5.2 Result of building with viscous damper

After the application of viscous damper in the building the results of displacement and inter storey drift are as follows

1) Displacement data for various damping

For the building with viscous damper the results are checked for various damping effects such as 2%, 5%, 10% and 20%, in this the top displacement of the building is shown for various time history which are taken from ETABs 2016.

Table 4 Displacement table

	Regular building	Imperial valley	NW California	Sylmar country	Friuli Italy	Gazli USSAR	El Centro
2%	215.55	180.53	167.51	179.65	145.55	180.46	182.56
5%	215.55	178.53	165.51	177.65	145.22	179.98	180.25
10%	215.55	176.53	166.51	171.65	143.55	175.46	172.56
20%	215.55	175.53	164.51	170.65	142.22	172.98	172.25

2) Inter storey for various damping

For the building with viscous damper the results are checked for various damping effects such as 2%, 5%, 10% and 20%, in this inter storey drift of the building is shown for various time history which are taken from ETABs 2016.

Table 5 Inter storey drift

	Regular building	Imperial valley	NW California	Sylmar country	Friuli Italy	Gazli USSAR	El Centro
2%	0.0025	0.0026	0.0024	0.0027	0.0021	0.0029	0.0030
5%	0.0025	0.0025	0.0023	0.0025	0.0023	0.0028	0.0029
10%	0.0024	0.0025	0.0025	0.0024	0.0020	0.0027	0.0028
20%	0.0023	0.0024	0.0022	0.0023	0.0019	0.0026	0.0027

3) Base shear curve

This graph shows the base shear for various time history and the values are changed for different accelerations. The building subjected to time history shows increase in base shear that which is not subjected to time history.

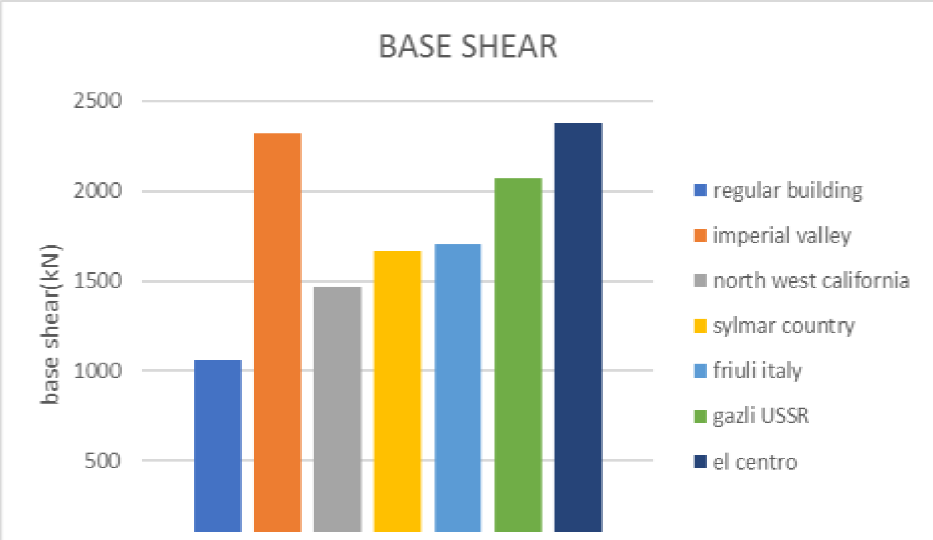

Fig 5 Base shear

6. CONCLUSION

The modelling of building is done in ETABs for analysis. The first static analysis shows that there is more deflection in building than required, thus to reduce the response of the building there is need of energy dissipating device like viscous damper. The design of viscous damper is done and it is applied in building to check the performance in terms of deflection, inter storey drift and base shear. The nonlinear time history analysis is also done to check the nonlinearity of the building. Various time history taken from ETABs 2016 are applied to the considered building model. The result for seven different time history is found out.

The analysis results show that there is more deflection of building for different time history. After application of viscous damper in the building, it shows great results in terms of reduced response of the structure. The use of viscous damper shows about 15% to 20% reduction in the response of structure in terms of deflection, inter storey drift and base. This shows that the use of viscous damper helps in reducing the response of the structure, thus ultimately prevent the collapse of the structure.

7. REFERENCES

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