

Comparative Study on Steel Frame Building with and without Damper

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Abstract- This paper presents comparative analysis of fifteen-storeyed steel frame building with and without damper. In this study, the proposed building is located in seismic zone 3. It is a rectangular shape building and its occupancy is residential. All steel structural members are designed according to AISC 360-05 and reinforced concrete is designed according to ACI 318-08. Dampers are designed by FEMA-356. Load consideration is based on UBC-97 and ASCE 7-05. The structural frame type of proposed building is special steel moment resisting frame (SMRF). The analysis and design of structure is carried out by using STAAD-Pro software. Dynamic behavior of the structure for wind and earthquake loading with respect to response spectrum analysis is carried out. Dampers help in reducing the vibrations caused by wind and earthquake. By using dampers we can improve the resistance of building. In this study, fluid viscous dampers are studied in details. Base on damper force, the numbers of required dampers are 64. Fluid viscous dampers are provided at the X and Z-direction bracing in model M-I. The other models M-II is provided at the Z-direction and M-III is provided at the Z-direction. The results of the maximum storey displacement of the structures due to the added dampers can be reduced. But the results of base shear are increased. Changes in response of storey drift, displacement and base shear for the damped structure are demonstrated illustrating the efficiency of dampers.

Keywords- Steel Frame Building, Viscous Damper, Storey Drift, Displacement, Base Shear

I. INTRODUCTION

Earthquake is one of the major natural hazards to the life on the earth and has affected countless cities and villages of almost every continent. The damaged caused by earthquakes are mostly to man-made structures. Hundreds of small earthquake occurs around the world every day and every year earthquakes take the lives of thousands of people. Therefore, it is necessary to design structures that are earthquake resistant. Nowadays, three basic technologies are used to protect buildings from damaging earthquakes effects. These are base isolation, passive energy dissipation devices and active control devices.

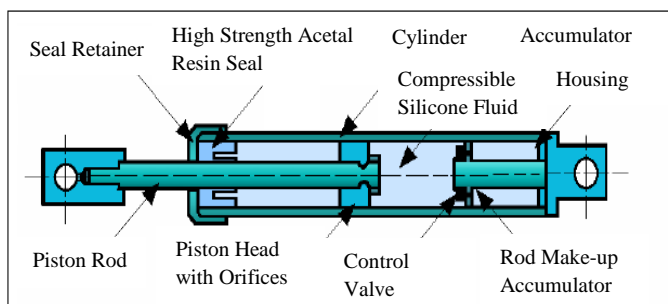


Fig.1 The orifice fluid viscous damper

In the past several decades, a variety of passive energy dissipation devices have been developed, such as fluid viscous dampers, viscoelastic dampers, metallic yield dampers, friction dampers and tuned mass dampers etc. Passive energy dissipation devices and, in particular, dampers incorporating fluid viscous materials have been introduced in civil engineering structures for seismic applications. Fluid viscous dampers can be successfully applied in buildings to reduce structural response and to dissipate seismic energy and they are added to the structure to increase the stiffness and damping of the structure.

The objectives of the study are to understand the analysis of earthquake resistant building and to realize the effectiveness of fluid viscous damper.

The fluid viscous dampers are used in high-rise building in seismic areas. It reduces the vibrations included by both strong wind and earthquake. The force generated in each viscous damper is characterized by the following constitutive expression;

$$F = CV^\alpha(1)$$

where,

F = the force of the damper

C = the damping coefficient

V = relative velocity between the two ends of damper

α = the velocity exponent

II. PREPARATION

A. Data for Proposed Structure

The structure is fifteen-storeyed, rectangular shaped steel framed residential building.

Type of Structure	= 15-storeyd Steel Frame Building
Type of Occupancy	= Residential Building
Shopping Mall Area	= 132x90 ft
Residential Area	= 102x60 ft
Typical Floor Height	= 15 ft
Overall Height	= 10 ft
Location	= Seismic Zone (3)

Typical floor plans, three dimensional view of the proposed structure, the elevation view of proposed structure and the elevation view of proposed damped structures are shown in Fig. 2, 3, 4, 5, 6, 7 and 8 respectively.

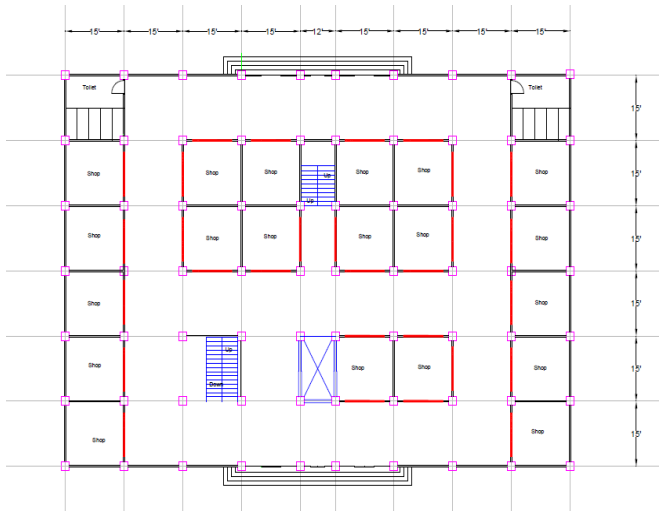


Fig.2 Ground Floor Plan of Proposed Structure

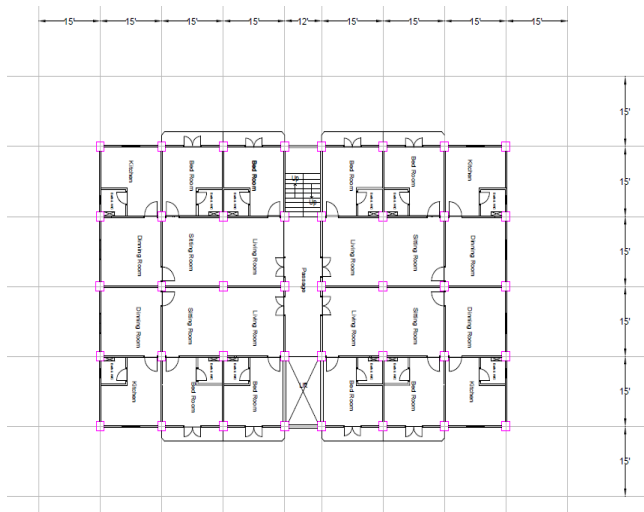


Fig.3 Typical Floor Plan of Proposed Structure

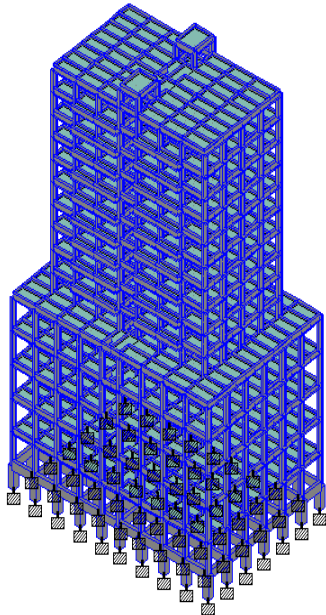


Fig.4 3D View of Proposed Structure

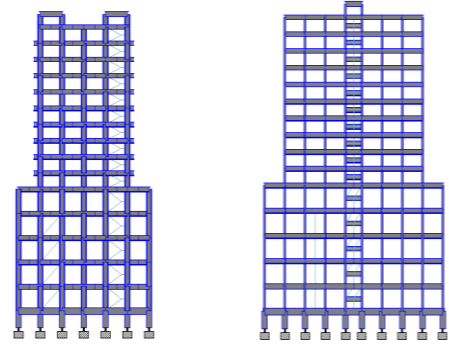


Fig.5 Elevation View of Proposed Structure (Without Damper M)

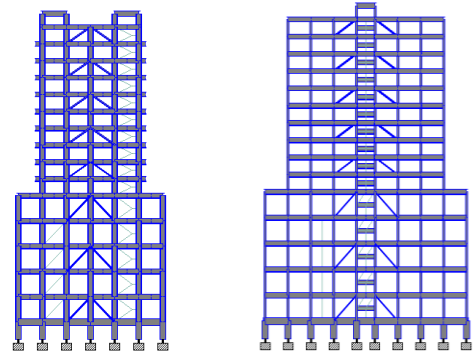


Fig.6 Elevation View of Proposed Structure M-I (X & Z-Direction)

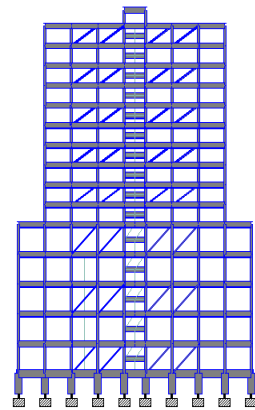


Fig.7 Elevation View of Proposed Structure M-II (Z-Direction)

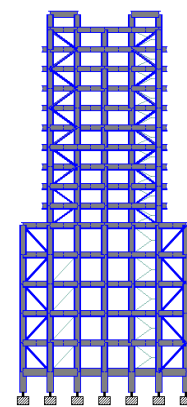


Fig.8 Elevation View of Proposed Structure M-III (X-Direction)

B. Material Properties of Proposed Structure

Material properties of the existing building are as shown in following.

For Concrete;	
Compressive Strength (f_c')	- 4000 psi
Yield Strength (f_y)	- 60000 psi
Poisson's Ratio	- 0.17
Density	- 150 pcf
For Steel;	
Minimum Yield Strength (f_y)	- 36000 psi
Ultimate Tensile Strength (f_u)	- 58000 psi
Poisson's Ratio	- 0.3
Density	- 490 pcf

C. Loading Consideration of Proposed Structure

The applied loads considered in this structural analysis are dead load, live load, wind load and earthquake load.

Dead Load;	
Superimposed Dead Load	- 35 psf
Walling Load	- 55 psf
Live Load;	
Floor Load	- 40 psf
Stair	- 100 psf
Water Tank	- 222 psf
Wind Load;	
Wind Velocity	- 120 mph
Wind Pressure	- 70.77
Exposure Type	- B
Importance Factor, I_w	- 1
Earthquake Load;	
Seismic Zone	- 3
Seismic Zone Factor	- 0.3
Importance Factor, I	- 1
Soil Type	- S_D
Response Modification Coefficient, R	- 8.5 (SMRF)
Numerical Coefficient, C_t	- 0.035
Seismic Coefficient, C_a	- 0.36
Seismic Coefficient, C_v	- 0.54
Damping Ratio	- 5%

D. Load Combinations of Proposed Structure

Design codes applied are UBC-97 and ASCE 7-05. There are 23rd numbers of load considerations. Load combinations of proposed structure which are used in the structural dynamic analysis.

1. 1.4 DL
2. 1.2 DL + 1.6 LL
3. 1.2 DL + 1.0 LL
4. 1.2 DL + 0.8 WLX
5. 1.2 DL - 0.8 WLX
6. 1.2 DL + 0.8 WLZ
7. 1.2 DL - 0.8 WLZ
8. 1.2 DL + 1.0 LL + 1.6 WLX
9. 1.2 DL + 1.0 LL - 1.6 WLX
10. 1.2 DL + 1.0 LL + 1.6 WLZ
11. 1.2 DL + 1.0 LL - 1.6 WLZ
12. 1.2 DL + 1.0 LL + 1.0 EQX
13. 1.2 DL + 1.0 LL - 1.0 EQX
14. 1.2 DL + 1.0 LL + 1.0 EQZ
15. 1.2 DL + 1.0 LL - 1.0 EQZ
16. 0.9 DL + 1.6 WLX
17. 0.9 DL - 1.6 WLX
18. 0.9 DL + 1.6 WLZ
19. 0.9 DL - 1.6 WLZ
20. 0.9 DL + 1.0 EQX
21. 0.9 DL - 1.0 EQX
22. 0.9 DL + 1.0 EQZ
23. 0.9 DL - 1.0 EQZ

E. Damper Parameters

Damper elements are assigned in STAAD-Pro software. The properties of fluid viscous damper used in this study are $C=1384$ kip-sec/in, $V=15.28$ in-rad/sec and $F=94137$ KN. Base on damper force, the number of required dampers are 64. Fluid viscous dampers are provided at the X and Z-direction bracing in model M-I. The other models M-II is provided at the Z-direction and M-III is provided at the X-direction.

F. Structural Stability

The superstructure is needed to check the followings for stability of proposed building.

1. Check for overturning moment
2. Check for sliding
3. Check for storey drift
4. Check for torsional irregularity
5. Check for P- Δ effects

In checking for overturning moment, the ratio of resisting moment to overturning moment of the proposed damped structure (the factor of safety) is greater than 1.5. So, overturning moment checking is safety. The factor of safety for sliding is greater than 1.5. Therefore, there is no sliding occur in the structure. In checking for storey drift, it is found that storey drift for all storey do not exceed limit. And the torsional irregularity and P- Δ effects are satisfied for all check. Therefore, the proposed building is satisfied for all stability check.

III. SECTIONAL PROPERTIES OF PROPOSED STRUCTURE

Column sizes of proposed structure are W40x328, W40x298, W40x215, W40x167, W36x135 and W12x30. Beam sizes are W40x199, W40x183, W36x160, W36x135, W33x130, W30x108, W8x18, W6x15, W6x12 and W6x9 respectively.

IV. COMPARISON OF DYNAMIC ANALYSIS RESULTS

Analysis results of proposed structure are compared in this paper. Comparisons of storey drift in X and Z-direction are as shown in Table 1, Fig.9 and Table 2, Fig.10 respectively.

TABLE 1: STOREY DRIFT IN X-DIRECTION

Storey	Storey Drift in X-Direction (in)			
	M-I	M-II	M-III	Without Damper M
14	0.002	0.0031	0.0028	0.0044
13	0.0032	0.0033	0.0029	0.0049
12	0.0024	0.0034	0.0031	0.0047
11	0.0029	0.0031	0.0029	0.0044
10	0.0025	0.0029	0.003	0.0039
9	0.0027	0.0029	0.0027	0.0038
8	0.0023	0.0028	0.0027	0.0038
7	0.0026	0.0027	0.0025	0.0039
6	0.0022	0.0026	0.0025	0.0048
5	0.0025	0.0028	0.0018	0.0053
4	0.0028	0.0019	0.0025	0.0038
3	0.0025	0.0025	0.0026	0.0038

2	0.0019	0.0025	0.0026	0.004
1	0.0024	0.0025	0.0032	0.0028
GF	0.0013	0.0015	0.0014	0.0022

TABLE 2: STOREY DRIFT IN Z-DIRECTION

Storey	Storey Drift in Z-Direction (in)			
	M-I	M-II	M-III	Without Damper M
14	0.001	0.0004	0.0017	0.0037
13	0.0017	0.0019	0.0023	0.0034
12	0.0012	0.0005	0.0027	0.0032
11	0.0022	0.0024	0.0029	0.003
10	0.0012	0.0035	0.0032	0.003
9	0.0023	0.0026	0.0033	0.003
8	0.0013	0.0007	0.0032	0.003
7	0.0023	0.0024	0.0033	0.0029
6	0.0013	0.0009	0.0033	0.0059
5	0.0023	0.002	0.0029	0.0053
4	0.0026	0.0007	0.0031	0.0037
3	0.0024	0.0023	0.0028	0.0036
2	0.0015	0.0009	0.0028	0.0035
1	0.0024	0.0024	0.0028	0.0028
GF	0.008	0.0005	0.0016	0.0014

TABLE 3: STOREY DRIFT IN X-DIRECTION

Storey	Displacement in X-Direction (in)			
	M-I	M-II	M-III	Without Damper M
14	4.86	5.571	5.371	7.881
13	4.616	5.201	5.031	7.348
12	4.227	4.8	4.674	6.76
11	3.936	4.398	4.303	6.197
10	3.583	4.024	3.953	5.672
9	3.289	3.667	3.588	5.202
8	2.968	3.325	3.262	4.752
7	2.693	2.991	2.924	4.302
6	2.377	2.663	2.624	3.83
5	2.116	2.346	2.32	3.256
4	1.813	2.006	2.1	2.615
3	1.481	1.647	1.642	1.936
2	1.04	1.189	1.17	1.258
1	0.692	0.747	0.695	0.546
GF	0.269	0.305	0.32	0.4

TABLE 4: STOREY DRIFT IN Z-DIRECTION

Storey	Displacement in Z-Direction (in)			
	M-I	M-II	M-III	Without Damper M
14	3.594	2.929	5.574	6.833
13	3.473	2.886	5.667	6.395
12	3.271	2.656	5.395	5.988
11	3.132	2.597	5.067	5.605
10	2.874	2.311	4.713	5.243
9	2.733	2.24	4.328	4.888
8	2.462	1.925	3.931	4.528
7	2.311	1.844	3.543	4.164
6	2.038	1.574	3.147	3.807
5	1.881	1.466	2.75	3.103
4	1.601	1.226	2.395	2.464
3	1.292	1.094	1.836	1.807
2	0.865	0.686	1.333	1.162
1	0.594	0.528	0.835	0.528
GF	0.158	0.099	0.335	0.25

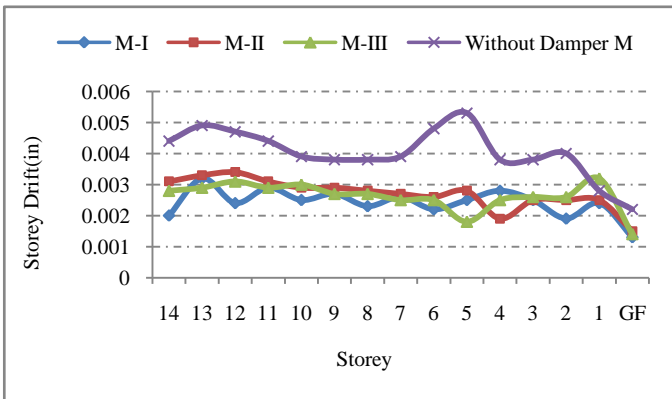


Fig.9 Comparison of Storey Drift in X-Direction

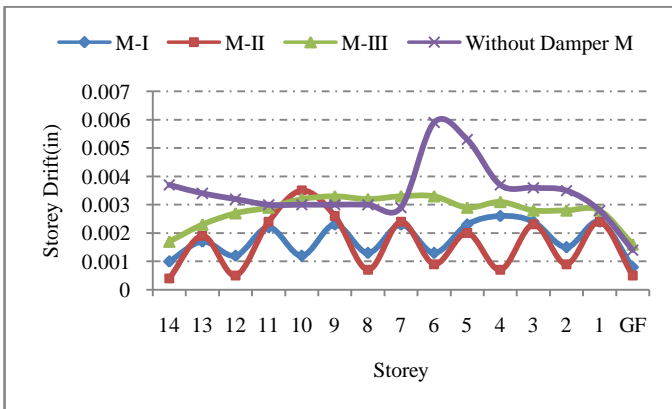


Fig.10 Comparison of Storey Drift in Z-Direction

Comparisons of displacements in X and Z-direction are shown in Table 3, Fig.11 and Table 4, Fig.12 respectively. Base shear are as shown in Table 5, Fig.14 and Fig.15 respectively.

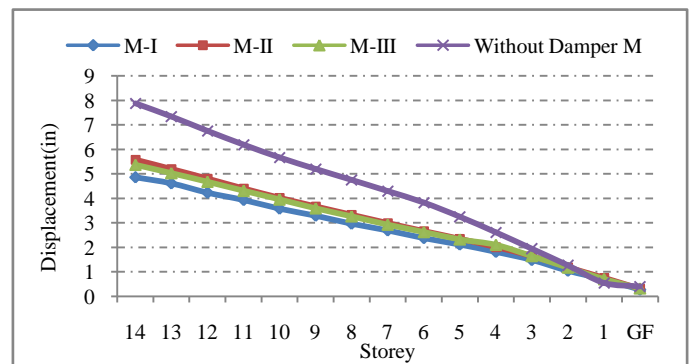


Fig.11 Displacement in X-Direction

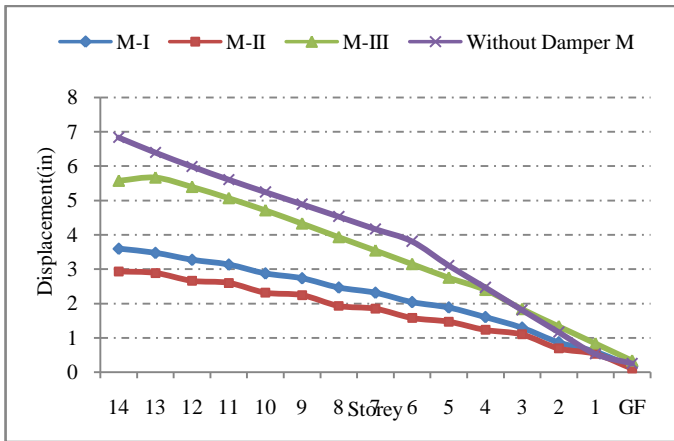


Fig.12 Displacement in Z-Direction

TABLE 5: BASE SHEAR IN X AND Z-DIRECTION

Model	Base Shear (Kip)	
	X-Direction	Z-Direction
Model M-I	27559.83	23540.99
Model M-II	27679.40	23733.46
Model M-III	27372.69	23261.21
Without Damper M	27354.00	23159.44

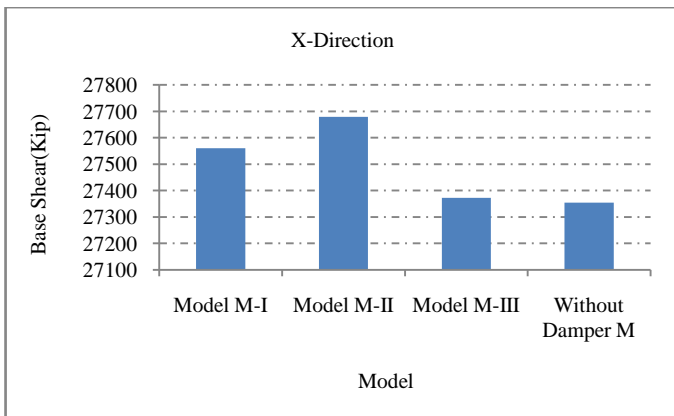


Fig.13 Base Shear in X-Direction

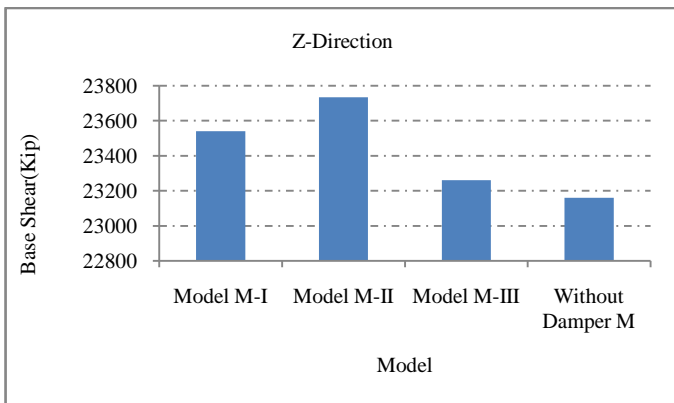


Fig.14 Base Shear in Z-Direction

DISCUSSIONS AND CONCLUSIONS

In this study, fluid viscous dampers are used to reduce seismic response of the structure subjected to the earthquake loads. The result shown that, storey drift gets reduced considerably as storey displacement is reduced after application of damper.

In the comparison of results of the structure with and without damper, reduction in storey drift ranges are 38% in M-I, 36% in M-II and 33% in M-III of X-direction. For Z-direction, reductions in storey drift ranges are 38% in M-I, 39% in M-II and 21% in M-III.

In the comparison of results of the structure with and without damper, reduction in displacement ranges are 38% in M-I, 29% in M-II and 32% in M-III of X-direction. For Z-direction, reductions in displacement ranges are 47% in M-I, 57% in M-II and 18% in M-III respectively.

By comparing base reactions which are obtained by with and without damper, usage of dampers shows considerable effects on increase in base shear. As the base shear increase the building will be able to resist the earthquake.

The result shown that, adding fluid viscous damper to the structure reduces not only deformation but also the storey drift and displacement. It can be concluded that seismic response of steel frame is considerably reduced with added fluid viscous damper placed by bracing.

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