Behaviour of Coupled Shear Wall with Damper in High Rise Building

Chetna Sahu[1] Bhavesh Kumar Jha[2]
[1]M. Tech Student [2]Assistant Professor
[1,2]Department Civil Engineering
[1,2]Government Engineering College, Jagdalpur, 494001, India

Abstract— The reinforced concrete shear wall is used in seismic prone zone to counter lateral forces & they are most appropriate structural component in high rise building. It provide the stiffness and strength during earthquake but the coupled shear wall gives more stiffness and strength and it is outstanding structure to resist gravity loads. The behavior of coupled shear wall is regulated by the coupling beam. The outcome of the above structure can be increased by providing a damper. Here a viscous damper has been used for the analysis along with the coupled shear wall. This study mainly focuses on the analysis and design of coupled shear wall with and without damper. Time history method is used for dynamic analysis. Parameters like storey drift, storey displacement, storey stiffness, storey shear and base shear of a structure are determined by using ETABS software. The comparative study of the above parameters for the models that is bare frame, shear wall, coupled shear wall without damper and coupled shear wall with damper have also been studied. In this study we found the coupled shear wall with damper reduces the response of structure like storey drift and displacement etc and increase the storey stiffness of the structure. The scope of present work is to study the effect of seismic loading on placement of coupled shear wall in building at different position of damper.

Keywords: High-rise building, bare frame, Shear wall, Coupled shear wall, Fluid viscous damper, ETABS

I. Introduction

In 21st century the demand of building constructions in increasing day by day because of rapid growth industrialization and population explosion, which is inviting the engineers to study, innovate and design new type of structure, which is extreme challenge for them especially in seismic zone. These natural calamities will bring along with it a very vast impact on mankind which is very difficult to deal with it. So for dealing this the engineers must designed seismic resistant building in this zone, which will counter the seismic force and minimize its effect to maximum possible effect. As we know no structure can be made fully seismic resistant but designing it will reduced the intensity of seismic force which will less hamper the humankind.

Now a day's high rise building or sky scrapper are popular on demand because its huge advantage like maximize space used in limited area also they are very attractive. Designing of these building are very challenging and engineers have to overcome many difficulties for erecting it. There are lots parameters taken for designing it but this project is about using coupled shear wall with damper for designing a 14th storey building & comparing it with normal building of same storey with coupled shear wall without damper.

A. *Coupled Shear Wall*

When two shear walls are interconnected by beams through their height then the shear wall is termed as Coupled shear wall. The coupling beams control the behavior of the coupled shear wall. This are designed for damping the structure in case of earthquake by dissipating the energy produced by earthquake due to their special characteristic known as ductile inelastic behavior. They are very effective in countering the seismic loads.

B. *Fluid Viscous Damper*

This is type of hydraulic damper which basically work on the principle of hydraulics. The working medium used here is hydraulic oil. It can be operated over temperature of -40˚ to 70˚C. The main parts of viscous damper are cylinder, piston, orifice, piston rod, accumulator and hydraulic fluid.

II. Objective

The work has been undertaken with the following objectives:

1) Modeling and analysis of 14-storey building for earthquake load in ETABS. Analysis of structure with shear wall.
2) To assess the behavior of structure with coupled shear wall.
3) Analysis of structure with coupled shear wall with damper.
4) Comparative study has been done on storey displacement, storey stiffness, storey drift, storey shear and base shear for the above four cases.

III. Description of Models

S. No	Parameters	Corresponding Data
1	Plan dimension	26 m × 14 m
2	Height of building	43.4 m
3	Height of each storey	3.1 m
4	Beam size	0.5 m× 0.5 m
5	Column size	0.7 m × 0.7 m
6	Coupling beam size	0.3 m × 0.5m
7	Slab thickness	0.15 m
8	Shear wall thickness	0.25 m
9	Grade of concrete & steel	M 20 & Fe 415
10	Density of concrete	25 kN/ m3
11	Soil Profile type	Medium
12	Response Reduction Factor	5.0
13	Seismic Zone factor	0.24 (Zone 4)
14	Importance Factor	1.5

15	Damping ratio	5%
16	Dead Load	Self Weight (Beam, Column, Wall, Slab)
17	Live Load	1.5 kN/m2
18	Load Combination	According to IS 1893(Part-1):2002

IV. CALCULATION

A. Shear Wall

$\tau_v = Vu/t_w d_w = 0.70$ N/mm^2.
$A_{s(min)} = 0.0025 \times 250 \times 1000$ per meter length = 625 mm^2
= 2 layers
$V_{us} = (0.70\text{-}0.36) \times 250 \times 4800 = 408$ kN
$S_v = \frac{0.87\, f_y\, A_h\, d_w}{S_v} = 667.21$ mm
M_{uv}=10440 kN-m
P_u= 6644.89 KN
Provide 20 bars of 25 mm diameter equally distributed on four sides of section.

B. Coupled Shear Wall

$V_u = \frac{840.83 \times 10^3}{28} = 60.91$ kN
$A_{sd} = \frac{V_u}{1.74 f_y \sin\alpha} = 347.95$ kN
Provide 4 no. bar 10 mm diameter.

C. Damper

C_L = 180950kN-s/m
V_{max} =0.08 m/s
$F_{d,max}$ = 15894.96 kN
K_L = 1503892 kN/m

V. MODELING AND ANALYSIS

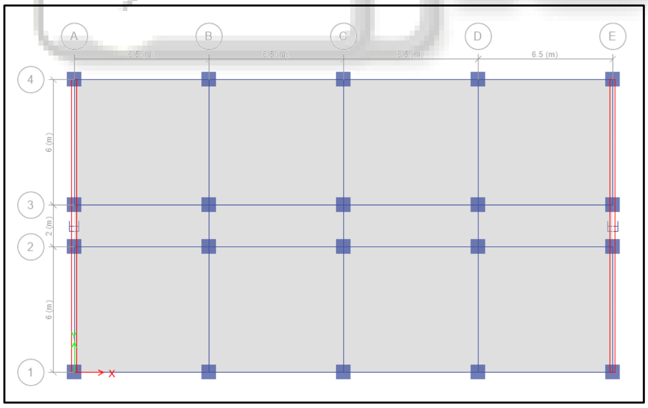

Fig. 5.1: Plan of G+13 storey building

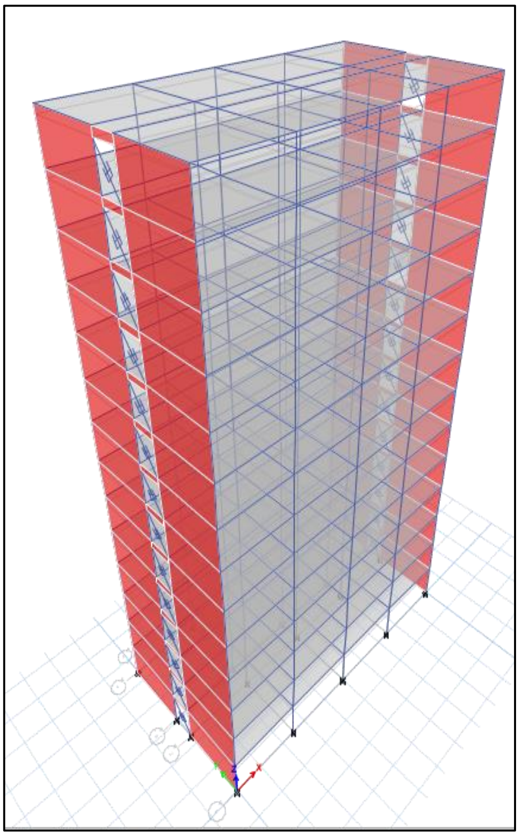

Fig. 5.2: 3D view of G+13 storey building

VI. RESULTS

A. Base Shear

Direction	Frame (kN)	Shear wall (kN)	Coupled shear wall (kN)	Coupled shear wall with damper (kN)
Y	1967.513	2418.281	2471.8139	2471.814

Table 6.1: Base shear in y direction due to EQY:

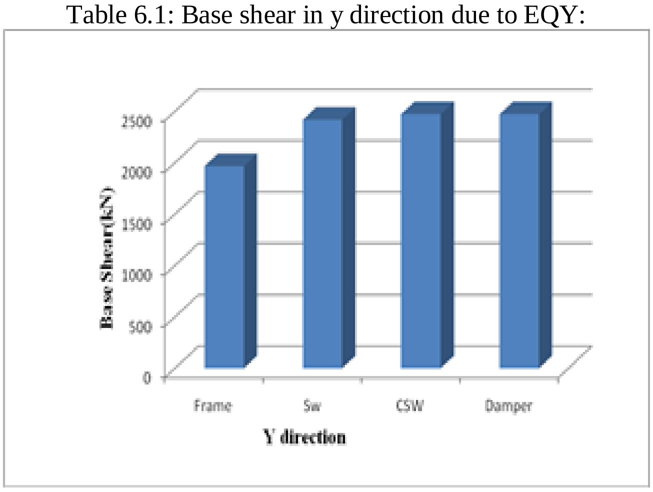

Fig. 6.1: Base shear in y direction due to EQY

From above fig. shows that the base shear of coupled shear wall with damper is slightly more than the coupled shear wall because it attracts more lateral forces and the base shear of frame is less than the other models because the weight of structure is decrease.

B. Storey Displacement:

No. of storey	Height (m)	Frame (mm)	Shear wall (mm)	Coupled shear wall (mm)	Coupled shear wall with damper(mm)
Storey 14	43.4	50.341	12.33	10.317	9.832
Storey 13	40.3	48.416	11.428	9.525	9.061
Storey 12	37.2	45.956	10.425	8.653	8.213
Storey 11	34.1	42.976	9.382	7.752	7.342
Storey 10	31.0	39.54	8.312	6.838	6.461
Storey 9	27.9	35.727	7.226	5.919	5.58
Storey 8	24.8	31.619	6.136	5.009	4.711
Storey 7	21.7	27.298	5.062	4.122	3.867
Storey 6	18.6	22.845	4.024	3.272	3.071
Storey 5	15.5	18.339	3.047	2.477	2.33
Storey 4	12.4	13.863	2.154	1.758	1.659
Storey 3	9.3	9.505	1.37	1.129	1.073
Storey 2	6.2	5.404	0.727	0.611	0.59
Storey 1	3.1	1.881	0.263	0.22	0.22

Table 6.2: Storey displacement in y direction due to EQY:

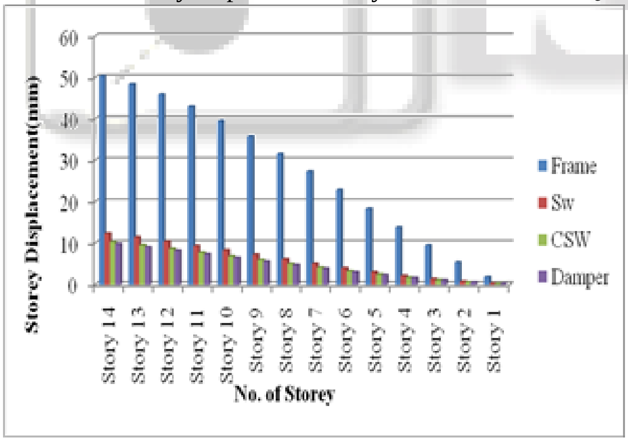

Fig. 6.2: Storey displacement in y direction due to EQY

From above fig. it was found that the storey displacement of building decrease with decrease the height of the building. Story displacement of frame is more than other model and the coupled shear wall with damper minimum because it counter more forces.

C. Storey Stiffness:

No. of storey	Height (m)	Frame (kN/m)	Shear wall (kN/m)	Coupled shear wall (kN/m)	Coupled shear wall with damper (kN/m)
Storey 14	43.4	180383	426871.54	495314.7	507622.4
Storey 13	40.3	277401	817379.77	957593.1	987831.5
Storey 12	37.2	324537	1129288.5	1336153	1383199
Storey 11	34.1	351063	1380014.3	1650307	1715065
Storey 10	31.0	368184	1585464.9	1918416	2002343
Storey 9	27.9	380742	1765262.8	2161413	2267264
Storey 8	24.8	391285	1937142.3	2401506	2530220
Storey 7	21.7	401452	2119513.4	2658204	2813386
Storey 6	18.6	412589	2335405.3	2959065	3146297
Storey 5	15.5	426246	2620487.4	3347017	3575065
Storey 4	12.4	445163	3039105.6	3903609	4186979
Storey 3	9.3	477158	3740888.8	4792443	5162005
Storey 2	6.2	557066	5116686.9	6517624	7068822
Storey 1	3.1	1050131	9935086.2	11786537	12688892

Table 6.3: Storey stiffness in y direction due to EQY:

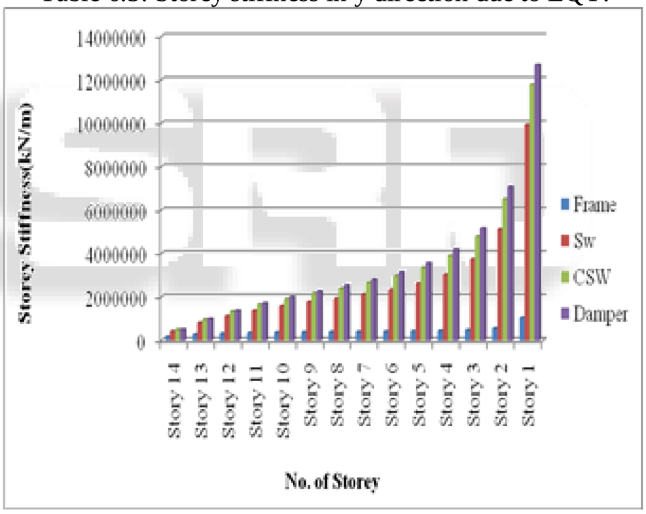

Fig. 6.3: Storey stiffness in y direction due to EQY

From above fig it was found that the storey stiffness of building increase with decrease the height of building. Story stiffness of frame is less than the shear wall and the shear wall model and it is less than coupled shear wall without damper and the stiffness of coupled shear wall with damper is more because it attracts more shear resistance so it is more stiffen than the other models.

D. Storey Drift:

No. of Storey	Height (m)	Frame	Shear wall	Coupled shear wall	Coupled shear wall with damper
Storey 14	43.4	0.00062	0.000309	0.00027	0.000264
Storey 13	40.3	0.00079	0.000336	0.000282	0.000274
Storey 12	37.2	0.00096	0.000345	0.00029	0.000281

Storey 11	34.1	0.00111	0.000345	0.000295	0.000284
Storey 10	31.0	0.00123	0.000351	0.000296	0.000284
Storey 9	27.9	0.00133	0.000351	0.000294	0.00028
Storey 8	24.8	0.00139	0.000346	0.000286	0.000272
Storey 7	21.7	0.00144	0.000335	0.000274	0.000259
Storey 6	18.6	0.00145	0.000316	0.000257	0.000242
Storey 5	15.5	0.00144	0.000289	0.000233	0.000219
Storey 4	12.4	0.00141	0.000253	0.000204	0.00019
Storey 3	9.3	0.00132	0.000208	0.000169	0.000157
Storey 2	6.2	0.00114	0.000155	0.000128	0.000119
Storey 1	3.1	0.00061	0.000085	0.000073	0.000073

Table 6.4: Storey drift in y direction due to EQY:

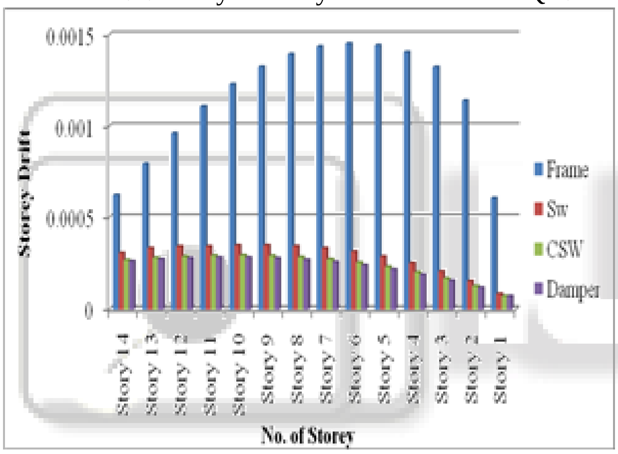

Fig. 6.4: Storey drifts in y direction due to EQY

From above fig it was found that the storey drift of coupled shear wall with damper is minimum and the frame is very high than the other. Storey drift is depend upon the relative displacement to its height.

E. Storey Shear:

No. of Storey	Height (m)	Frame (kN)	Shear wall (kN)	Coupled shear wall (kN)	Coupled shear wallwith damper (kN)
Storey 14	43.4	347.546	397.0387	403.1304	403.1304
Storey 13	40.3	681.825	814.1204	830.0016	830.0016
Storey 12	37.2	966.654	1169.5036	1193.726	1193.726
Storey 11	34.1	1205.99	1468.1242	1499.356	1499.356
Storey 10	31.0	1403.79	1714.9181	1751.942	1751.942
Storey 9	27.9	1564	1914.8212	1956.537	1956.537
Storey 8	24.8	1690.6	2072.7693	2118.193	2118.193
Storey 7	21.7	1787.52	2193.6983	2241.96	2241.96
Storey 6	18.6	1858.72	2282.5441	2332.891	2332.891
Storey 5	15.5	1908.17	2344.2425	2396.038	2396.038
Storey 4	12.4	1939.82	2383.7296	2436.452	2436.452
Storey 3	9.3	1957.62	2405.941	2459.185	2459.185
Storey 2	6.2	1965.54	2415.8128	2469.288	2469.288
Storey 1	3.1	1967.51	2418.2807	2471.814	2471.814

Table 6.5: Storey shear in y direction due to EQY:

Fig. 6.5: Storey shear in y direction due to EQY

From above fig, it shows the comparison between four models. The storey shear of building increase with decrease the height of building. Story shear of frame is minimum and the coupled shear wall with damper is maximum because it have more shear resistance as compare to other models.

VII. Conclusions

After the analysis of 14 storey building structure the result obtained and compare the conclusion are as follows:

1) In multi storey building, provision of coupled shear wall with damper is found to be effective in increasing the overall seismic response and characteristics of the structure.
2) The presence of coupled shear wall with damper can significantly affects the seismic behavior of the structure; it increases the stiffness and strength of structure.
3) Damper is a energy dissipation device so it is more effective with coupled shear wall to dissipate the vibration energy.
4) If we decrease seismic zone than no need to provide damper because the seismic response will be decrease.
5) To consider the coupled shear wall with damper in the seismic analysis of structure, it decreases the probability of damage of the structure.
6) Storey drift is minimum in the coupled shear wall with damper as compare to other model it means the structure is more stable.

VIII. Future Scope

The present study is based on comparison of four types models model one is moment resisting frame structure, second is structure with shear wall, third is the structure with couple shear wall without damper and fourth introduces structure with coupled shear wall with damper. These models are generated in ETABS and analyzed.

1) The position of damper can be changed and then the result shall be compared.
2) For further experimentation relation can be established between the strength and stiffness along with economic structure.
3) To study the structure in different earthquake zones and finding the best suitable position of coupled shear wall with damper in each zone.
4) To change position of shear wall with openings can be done by different openings.
5) Using different methods of dynamic analysis and comparing the results with manual calculation.

References

[1] IS 1893 (Part I): 2002 Criteria for Earthquake Resistant Design of Structures
[2] IS 13920:1993, Indian Standard code of Practice-Ductile Detailing of Reinforced Concrete Structure, Bureau of Indian Standards, New Delhi
[3] IS 456: (2000) Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards,New Delhi
[4] Pankaj Agrawal and Manish Shrikhande "Earthquake resistant design of structures", chapter 22 pp. 392-403.
[5] S.K. Duggal "Earthquake resistant design of structures" Second edition, Oxford University Press, chapter 5 pp.36-3375.
[6] P.C. Varghese "Advanced reinforced concrete design" Second edition, chapter 19 pp. 337-339.
[7] Nutan Kumar Subedi "Rc coupled shear wall structure I: Analysis of coupling beams" Journal of Structural Engineering, Vol. 117, March, 1991.
[8] Bahram M. Shahrooz, Mark E. Remmetter, and Fei Qin, "Seismic design and performance of coupled walls" Journal of Structural Engineering, Vol. 119, November, 1993.
[9] Deepak R. Pant; Michael Montgomery, and Constantin Christopoulos "Analytical Study on the Dynamic Properties of Viscoelastically Coupled Shear Walls in High-Rise Buildings" Journal of Engineering Mechanics, March 22,2017.
[10] Teasang Ahn, Youngju Kim, Sang dae Kim, Intae Hwang "Seismic performance of coupling beam damper system" Structural Engineering, 2011 .
[11] Jenn-Shin Hwang, "Seismic design of structutrs with viscous dampers" January 2002.
[12] Ruixue Chen, Guolei Xing. "Seismic Analysis of high-rise buildings with composite metal damper". 2015.
[13] O. Lavan "Viscously coupled shear walls: Concept, simplified analysis, and a design procedure" 2012.

