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Analysis of Multi-Storied Buildings with the Use of Coupled Shear Walls

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Abstract– The present study focuses on the use of coupled shear walls with and without dampers for resisting seismic loads. Multistory structures with and without shear walls are analysed. Different parameters, such as the structure's base shear, storey drift, storey displacement, storey stiffness, and storey shear, are evaluated, and a comparative study is performed. It is observed that coupled shear walls with fluid viscous dampers reduce storey drift by 24% and storey displacement by 45% when compared to buildings without shear walls. A coupled shear wall with a damper has a 29% higher stiffness than a coupled shear wall without a damper, thus performing effectively in resisting lateral forces induced by an earthquake.
Key Words: Multistoried building, Bare frame, Shear wall, Coupled shear wall, Fluid viscous damper.

1. INTRODUCTION

In the twenty-first century, the demand for multistory buildings is expanding day by day due to rapid industrialization and population growth, which makes it challenging for engineers to analyze, invent, and design new types of structures, particularly in seismic zones. As we know, no structure can be completely earthquake-resistant, but proper design minimises the intensity of seismic forces. Shear walls are important structural elements for resisting lateral forces and making structures earthquake-resistant. Various shear walls commonly used are concrete shear walls, masonry shear walls, steel shear walls, wood shear walls, coupled shear walls, etc. A shear wall is a vertical structural element typically made of reinforced concrete or masonry designed to resist lateral forces such as wind or seismic loads [3].A coupled shear wall is a structural system where multiple shear walls are interconnected horizontally using coupling beams or walls, working together to resist lateral loads like wind or seismic forces.This configuration enhances the overall stiffness and strength of the structure, reducing deformations and improving its resistance to lateral forces [5]. A fluid viscous damper is a device used in structural engineering to mitigate the effects of vibrations and reduce the impact of dynamic loads on a structure. It consists of a piston that moves through a fluid-filled chamber, generating resistance and dissipating energy. The fluid viscosity provides damping by absorbing and dissipating the kinetic energy of the structure, thereby reducing vibrations and improving structural performance [6].

2. OBJECTIVES

The objectives of the present study are:

1. To analyze multistoried building (G+14) with coupled shear wall with and without dampers using latest software and study the behavior of structure.
2. To evaluate various structural parameters such as stiffness, drift, storey shear and storey displacements.
3. To check effectiveness of coupled shear walls in resisting earthquake forces.

3. METHODOLOGY

Following methodology is adopted in carrying out the work:

a) Preparing plan of a multistoried structure for analysis.
b) Provision of coupled shear walls at peripheral locations along with dampers at corners

c) Modeling of the G+14 multistoried building having coupled shear wall with and without dampers.

d) Analyzing the building using equivalent static method comparing the results.

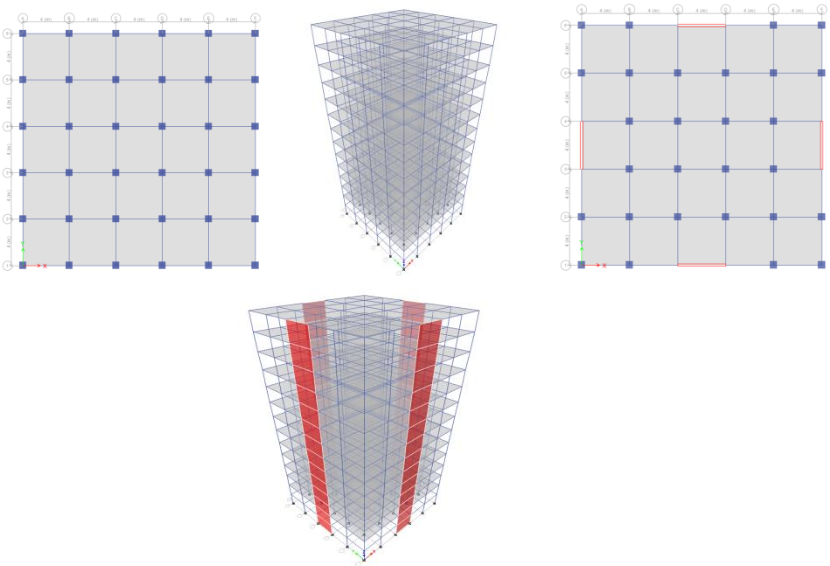
There are various seismic analysis techniques that provide varying levels of accuracy. Three variables can be used to categorise the analytical process: the type of external loads used, the behaviour of the structural materials, and the type of structural model selected. The analysis can be categorised as linear static analysis, linear dynamic analysis, non-linear static analysis, or nonlinear dynamic analysis depending on the kind of external action and structural behaviour. Regular structures with a maximum height can be subjected to equivalent or linear static analysis. Response spectrum analysis and elastic time history approach are two methods of analysis that fall within linear dynamic analysis. Structures with inelastic behaviour can be studied using nonlinear static analysis, often known as pushover analysis.

3.1 Equivalent Static Analysis:

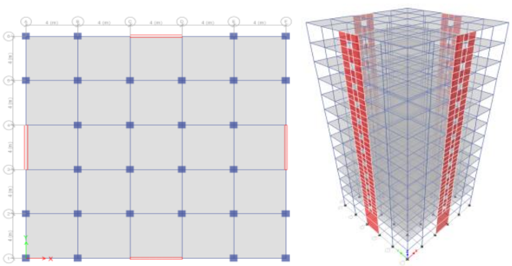
Most structures are still subject to earthquake analysis based on the presumption that horizontal load equals actual loading. The mass of the structure, the fundamental period of vibration, and the associated mode shape are used to compute the base shear, which is the total horizontal force acting on the structure. Based on horizontal forces and the code formula, the base shear is applied along the height of the structure. This method is applicable to buildings of low to medium height with a regular plan.

4. MODELING

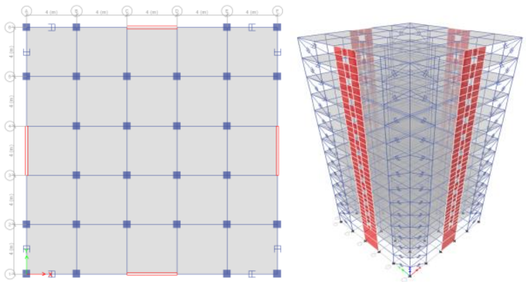
In the present study, four models are considered for seismic analysis. Each of them has 14 stories with a 3.1m storey height. The total height of each building is 43.40 m. These are used as input for ETABS software. Each type has a square 20m × 20m floor layout with five bays on each side. Seismic analysis is carried out. Shear walls on the building's outer frames resist lateral loads in all the models. The shear wall's window openings are 1m x 1m.



Model 1: Moment Resisting frame Model 2: Structure with a shear wall



Model 3: Structure with a Coupled shear wall



Model 4: Structure with a Coupled shear wall with Damper

4.1 Material Properties:

Table 1: Material Properties of Structure

Material properties	Values
Grade of concrete	M 30
Grade of steel	Fe 500
Density of concrete	25kN/m3

4.2 Section Properties:

Table 2: Section Properties of Structure

Column size	600 mm x 600 mm
Beam size	230 mm x 600 mm
Slab size	150 mm
Shear wall thickness	200 mm

4.3 Building Loads:

Table 3: Loads on Structure

Live load	1.5 kN/m2
Dead load	Self-weight (Beam, Column, Slab, Wall)
Soil type	Medium
Response Reduction Factor	5
Seismic Zone factor	0.24 (Zone4)
Importance Factor	1
Damping ratio	5%

5. RESULTS AND DISCUSSION

All the models are analysed by the equivalent static method using ETABS software. The results obtained are presented in tabular format below. A comparative study is made.

5.1 Base Shear:

Table 4: Base shear in the X and Y directions as a result of an earthquake:

Direction	Model 1: Base shear of bare frame (without shear wall) (kN)	Model 2: Base shear of frame with RC Shear wall (kN)	Model 3: Base shear of frame with Coupled shear wall (kN)	Model 4: Base shear of frame with Coupled shear wall with damper (kN)
X & Y	1256.29	804.1166	799.9862	611.7375

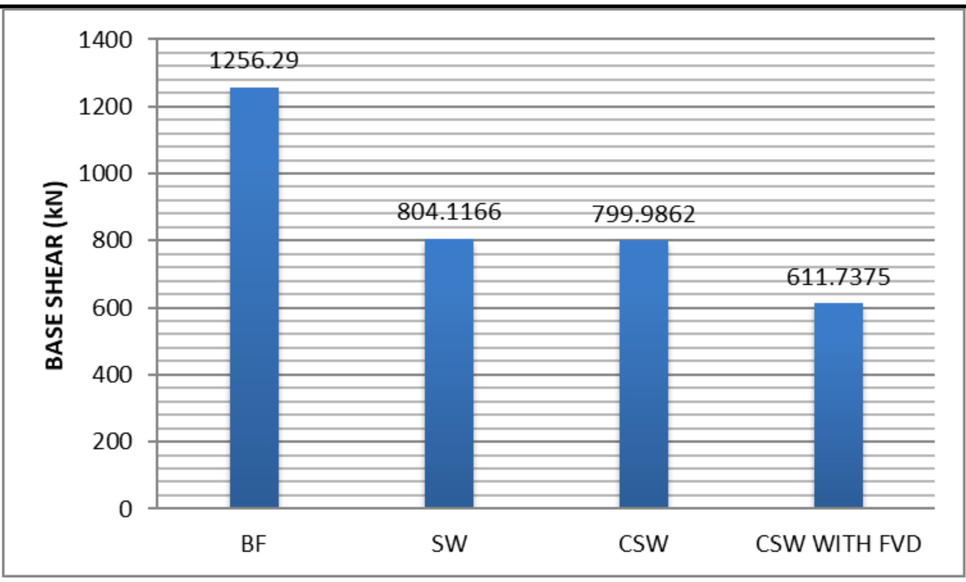


Fig 1: Base shear in X & Y Direction

Fig. 1 shows a comparison of model base shear values for both x- and y-direction loading. The base shear values are shown in Table 4. The coupled shear wall's base shear with the damper is observed to be reduced by 24% compared to a coupled shear wall without a damper. This reduction is found to be 51% as compared to a bare frame without a shear wall. The base shear value depends on the seismic weight of the structure and its time period. A low base shear value indicates a flexible structure, while a high base shear value indicates a stiff structure.

5.2 Storey Displacement:

Table 5: Storey displacement in the X and Y directions as a result of an earthquake:

Storey number from ground	Height from ground (m)	Model 1: Storey displacement of bare frame (without shear wall) (mm)	Model 2: Storey displacement of frame with RC Shear wall (mm)	Model 3: Storey displacement of frame with Coupled shear wall (mm)	Model 4: Storey displacement of frame with Coupled shear wall with damper (mm)
14	43.4	18.004	9.863	10.166	9.856
13	40.3	17.518	9.475	9.768	9.164
12	37.2	16.802	9.002	9.276	8.437
11	34.1	15.862	8.432	8.684	7.666
10	31.0	14.727	7.768	7.995	6.851
9	27.9	13.432	7.018	7.22	5.998
8	24.8	12.01	6.198	6.372	5.12
7	21.7	10.49	5.324	5.468	4.235
6	18.6	8.9	4.414	4.528	3.362
5	15.5	7.264	3.487	3.571	2.528
4	12.4	5.603	2.569	2.623	1.762
3	9.3	3.94	1.692	1.716	1.101
2	6.2	2.314	0.906	0.903	0.585
1	3.1	0.843	0.316	0.311	0.257

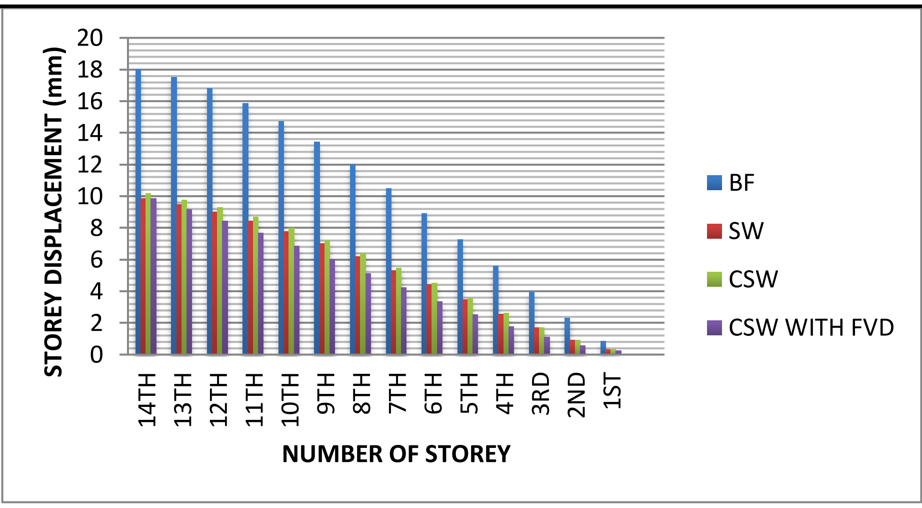


Fig. 2 Storey displacement in X & Y direction

Fig. 2 shows the maximum storey displacements in both x- and y-direction loading for each of the four models. Table 5 shows the maximum displacement values along both the x and y directions. From Figure 2, we can observe that the storey displacement of a coupled shear wall with a damper is reduced by 3% compared to a coupled shear wall without a damper and by 45% compared to a bare frame at the top storey. Each model's displacement value falls within the codal provision's limits, which is 5% of the building's height.

5.3 Storey Stiffness:

Table 6 Storey stiffness in the X and Y directions as a result of an earthquake:

Storey number from ground	Height from ground (m)	Model 1: Storey stiffness of bare frame (without shear wall) (kN/m)	Model 2: Storey stiffness of frame with RC Shear wall (kN/m)	Model 3: Storey stiffness of frame with coupled shear wall (kN/m)	Model 4: Storey stiffness of frame with coupled shear wall with damper (kN/m)
14	43.4	440572.4	351595.53	314591.5	676190.9
13	40.3	599644.5	578932.43	515742	545853.1
12	37.2	651049.6	687753.62	621309.9	604029.3
11	34.1	675515.5	738089.63	676991.4	632459.3
10	31.0	690421.6	763406.26	709429.1	660386.9
9	27.9	701119.3	778268.87	731236.1	684564.4
8	24.8	709787.6	789749.06	749220.6	709989
7	21.7	717580.7	802217.49	767064.1	736735.3
6	18.6	725290	819944.05	793101.4	769209.9
5	15.5	733809.7	849508.34	832630.1	809821.4
4	12.4	745349.2	904114.39	906102.3	867542
3	9.3	768824.5	1019026.6	979063.7	627395.5
2	6.2	851165.2	1327863.9	1323793	1059954
1	3.1	1498488	2670878.3	2677847	3447123

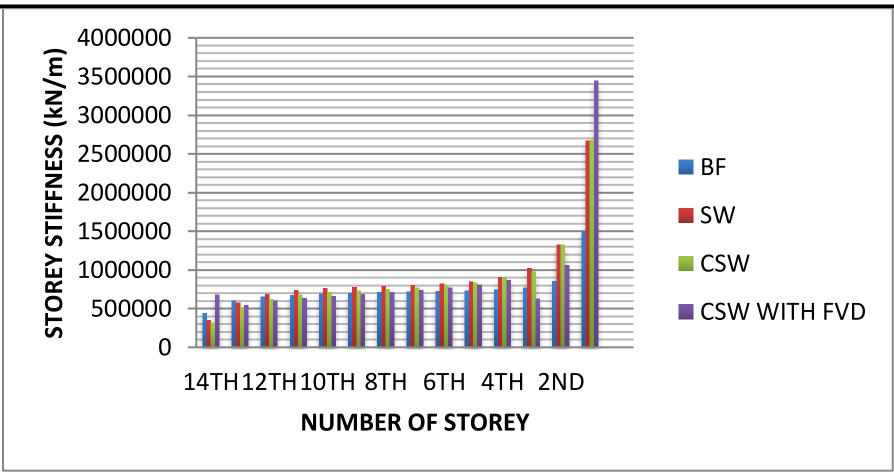


Fig.3 Storey stiffness in X & Y direction

Fig. 3 shows a comparison of the storey stiffness in both x- and y-direction loading for all four models. Table 6 shows the maximum stiffness values in both the x and y directions at the bottom.. From the above fig. 3, the storey stiffness of a coupled shear wall with a damper is increased by 29% compared to a coupled shear wall without a damper at the ground floor because it has higher shear resistance and is more stiffened than the other models.

5.4 Storey drift:

Table 7: Storey drift in the X and Y directions as a result of an earthquake:

Storey number from ground	Height from ground (m)	Model 1: Storey drift of bare frame (without shear wall)	Model 2: Storey drift of frame with RC Shear wall	Model 3: Storey drift of frame with coupled shear wall	Model 4: Storey drift of frame with coupled shear wall with damper
14	43.4	0.000157	0.000125	0.000128	0.00012
13	40.3	0.000231	0.000153	0.000159	0.000149
12	37.2	0.000303	0.000184	0.000191	0.000181
11	34.1	0.000366	0.000214	0.000222	0.000209
10	31.0	0.000418	0.000242	0.00025	0.000238
9	27.9	0.000459	0.000264	0.000274	0.000261
8	24.8	0.00049	0.000282	0.000291	0.000286
7	21.7	0.000513	0.000294	0.000303	0.000281
6	18.6	0.000528	0.000299	0.000309	0.000269
5	15.5	0.000536	0.000296	0.000306	0.000247
4	12.4	0.000536	0.000283	0.000293	0.000214
3	9.3	0.000525	0.000253	0.000262	0.000166
2	6.2	0.000477	0.0002	0.000199	0.000157
1	3.1	0.000272	0.000102	0.0001	8.30E-05

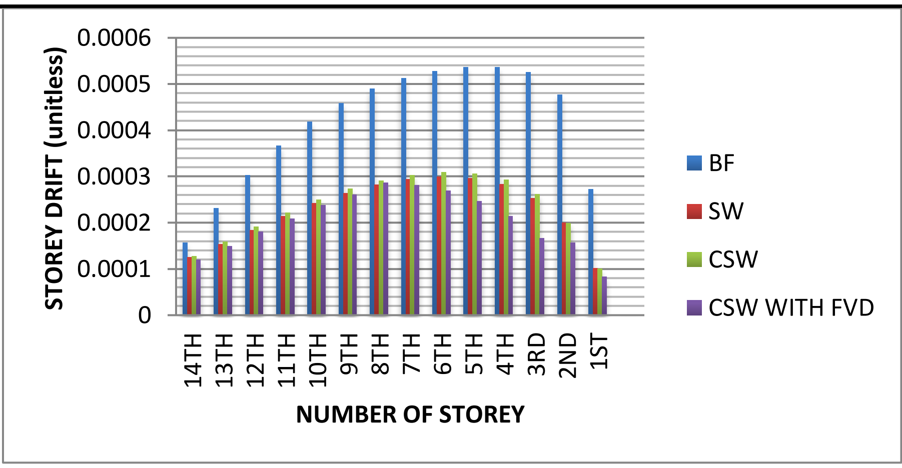


Fig 4 Storey drift in X & Y direction

Fig. 4 shows a comparison of the maximum storey drift in both the x and y directions. From the figure, As we can see, model 3 (a building with a coupled shear wall) shows a high drift value in both the x and y directions, while model 4 (a building with a coupled shear wall and damper) shows the least drift when compared to other models. The max drift values of model 4 have occurred at the 8th storey, i.e., 0.000286. The max drift value for model 3, i.e., 0.000291 occurred at the same 8th storey. The acceptable drift value is 0.004 times the structure's height; so, the maximum drift allowed is 0.004x3.1 = 0.0124. The drift values in all models are less than the maximum drift value.

5.4 Storey Shear:

Table 8 Storey shear in the X and Y directions as a result of an earthquake:

Storey number from ground	Height from ground (m)	Model 1: Storey shear bare frame (without shear wall) (kN)	Model 2: Storey shear of frame with RC Shear wall (kN)	Model 3: Storey shear of frame with coupled shear wall (kN)	Model 4: Storey shear of frame with coupled shear wall with damper (kN)
14	43.4	213.8878	136.404	135.9568	134.4
13	40.3	429.1215	274.2725	273.0623	271.1
12	37.2	612.5159	391.7462	389.886	388.785
11	34.1	766.6181	490.4568	488.0503	486.456
10	31.0	893.9754	572.0358	569.1778	569.1309
9	27.9	997.1347	638.1147	634.8911	603.4563
8	24.8	1078.643	690.3253	686.8127	625.323
7	21.7	1141.048	730.299	726.5652	632.2729
6	18.6	1186.897	759.6674	755.7711	622.0226
5	15.5	1218.736	780.0622	776.053	588.6254
4	12.4	1239.113	793.1148	789.0334	528.6138
3	9.3	1250.576	800.4569	796.3348	323.5031
2	6.2	1255.67	803.7201	799.5896	431.8743
1	3.1	1256.29	804.1166	799.9862	611.7375

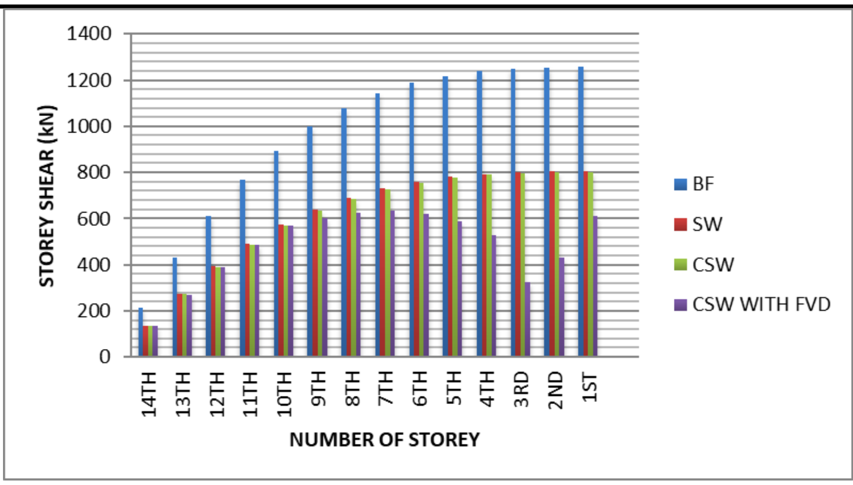


Fig 5 Storey shear in X & Y direction

Fig. 5 shows the comparison of storey shear for all four models in both x-direction and y-direction loading. Table 8 shows the storey shear values at the bottom along both the x and y directions. From above Fig. 5, it is found that the storey shear of a coupled shear wall with a damper is less compared to a coupled shear wall without a damper and a bare frame. It means that the building experiences lower levels of lateral force or shear compared to the upper floors.

6. CONCLUSIONS

The following conclusion are drawn from the present study:

- The base shear of a structure with coupled shear wall with damper is observed to get reduced by 24% compared to a structure with coupled shear wall without damper. This reduction is found to be 51% as compared to structure without any shear wall i.e. (bare frame).
- The storey displacement of a structure with coupled shear wall with damper is observed to get reduced by 3% compared to a structure with coupled shear wall without damper. This reduction is found to be 45% as compared to structure without any shear wall i.e. (bare frame).
- The storey stiffness of a structure with coupled shear wall with damper is observed to get increased by 29% compared to a structure with coupled shear wall without damper at ground floor.
- The storey drift of a structure with a coupled shear wall with a damper is observed to get reduced by 6% compared to a structure with a coupled shear wall without a damper and by 24% compared to a bare frame at the top of the structure.

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