Seismic performance of building with RC and Composite shear wall provided at side centre

[1] Mohammad Saqib Siddiqui, [2] Anurag Bajpai

[1] PG Student (M.Tech Structural Engineering), [2] Assistant Professor

[1][2] Civil Engineering Department, Institute of Engineering and Technology,

Lucknow- 226022 (India)

Abstract - This study compares the seismic behaviour of tall building with RC shear wall and Composite shear wall. To improve the strength and ductility of core walls in tall buildings which would be subjected to combined high axial compressive force and bending moment during the earthquake, an innovative concrete filled double skin steel plate composite (CFSDC) wall is proposed. Multi-partition composite shear walls have the strong points, such as high load-carrying capacity, good ductility, excellent energy dissipation capacity and fast construction speed. Composite shear walls are widely used in civil projects due to its high stiffness and deformability. RC shear wall building and CSW building are compared by providing both shear walls at side centre of building in X and Y direction using ETABS. The structural response in is investigated comparing various parameters that are time period, storey displacement, storey drift and stiffness. Multi storey building (G+24) is taken in Zone IV with medium soil.

Keywords: Composite shear wall, CFSDC wall, ETABS, Seismic behaviour.

INTRODUCTION

Steel shear walls, which are frequently used in seismic resistant structures against lateral loads, consist of a thin steel plate, two columns and two horizontal floor beams. The steel plate with two adjoining columns behaves as vertical plate girder with the columns acting as flanges and the steel sheet as web. The wall stiffness is provided through the diagonal tension field, generated in the steel sheat and accompanied by frame bending action.

In composite shear walls, a layer of in-situ or pre-cast reinforced concrete is connected to one or both sides of the steel plate to improve the shear capacity by increasing the number of diagonal tension field lines, and also to improve the panel bearing against destructive factors such as fire, impulses, and explosion. The Canadian steel structures standards have approved this system and the American codes also provided the necessary guidelines for design and analysis of such walls. The improvement of shear capacity is due to distribution of diagonal lines in steel plate obtained by using steel mesh as stiffners, connected to the steel plate, producing lateral stiffness, or by a concrete layer connected to the steel plate by shear connectors (studs) to delay buckling.

Structural shear walls have played an important role in resisting lateral force, imposed by the earthquake or wind in tall buildings. However, the application of RC shear walls has been limited because of Composite shear walls.

This research addresses the behaviour of 3 structures subjected to earthquakes in Zone IV. Multi storey building(G+24) without shear wall, with RC shear wall and with Composite shear wall are analysed and compared. Seismic parameters that are time period, storey displacement, storey drift, stiffness are compared of all the three bare frame structures.

Cross section of shear wall

RC shear wall of 250mm thickness is provided in Model 2. These are provided at corners/edges of building.

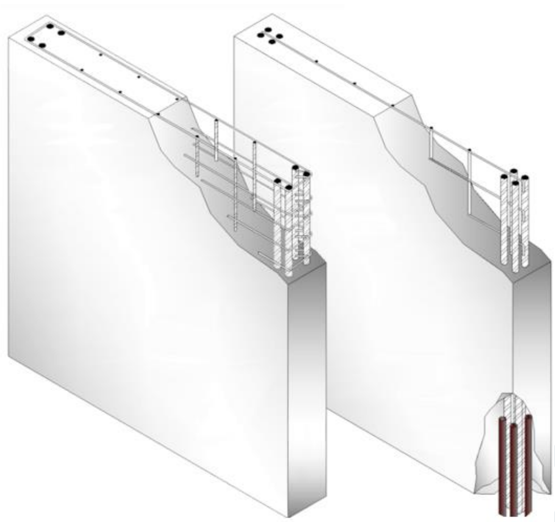

Fig 1 – RC shear wall design

Composite shear wall of 250mm thickness with two steel plates of 4mm thickness is provided in Model 3. These are provided at corners/edges of building.

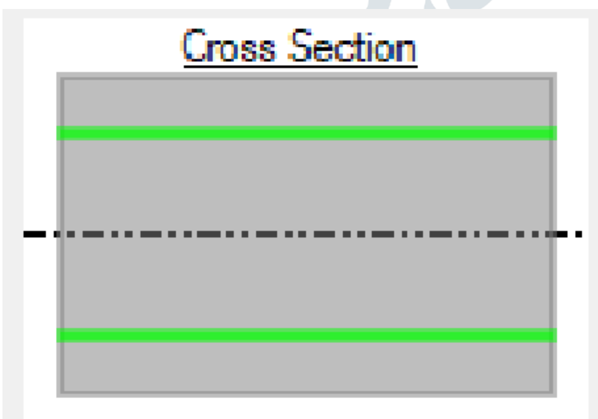

Fig 2 – Cross section of Composite shear wall provided

---- SHOWS STEEL PLATES(4mm)

Number of Layers: 3

Total Section Thickness: 250 mm

Sum of Layer Overlaps: 8 mm

Sum of Gaps Between Layer: 0 mm

2. OBJECTIVES OF WORK

1. To study the behaviour of building for regular plan under seismic loads and load combinations as per IS 1893:2016.
2. To evaluate the response of RC multi-storey building (G+24) with RC shear wall (RSW) and Composite shear wall (CSW).
3. To determine seismic parameters that are time period, storey displacement, storey drift, stiffness.

3. DESCRIPTION OF BUILDING

3.1 Dimensions of building

Commercial building with 25 storey located in Zone IV (Delhi)

S. No.	Structural part	Dimension
1	Length in X-direction	48m
2	Length in y-direction	48m
3	No of bay in X-direction	8No.@6m
4	No of bay in Y-direction	8No.@6m
5	Floor to floor height	3m
6	Total height of building	75m
7	Thickness of slab	150 mm
8	Thickness of RC shear wall	250 mm
9	Thickness of Composite shear wall	250 mm
10	Column size	(600x600)mm

11	Beam size	(350x500) mm

3.2 Material properties-

S.No.	Material	Grade (N/mm^2)
1	Column	M35
2	Beam, Slab	M30
3	Rebar	Fe-500

3.3 Seismic data-

1	Zone Factor	0.24 (clause 6.4.2)
2	Damping ratio	5%
3	Importance factor (I)	1.2 (clause 7.2.3)
4	Response reduction factor (R)	5 (SMRF) (clause 7.2.6)
5	Type of soil	Medium soil (II)

3.4 Loading

- Live load 4kN/m^2 as per IS 875 (II)
- Earthquake load as per IS 1893-2016 (I)

4. PROBLEM DESCRIPTION

Model 1 – Multi storey building without shear wall

Model 2 – Multi storey building with RC shear wall

Model 3 – Multi storey building with Composite shear wall

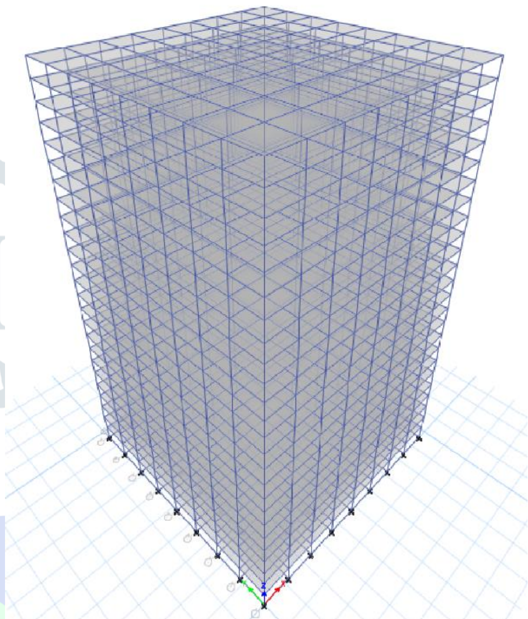

Fig 4.1 – 3-D view of structure without shear wall

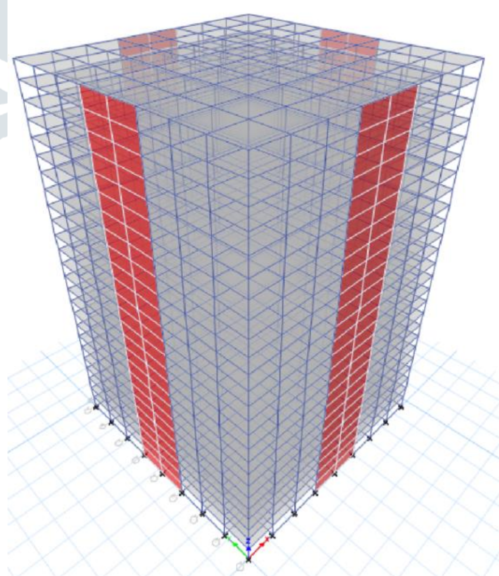

Fig 4.2 – 3-D view of structure with RC shear wall provided at side centre

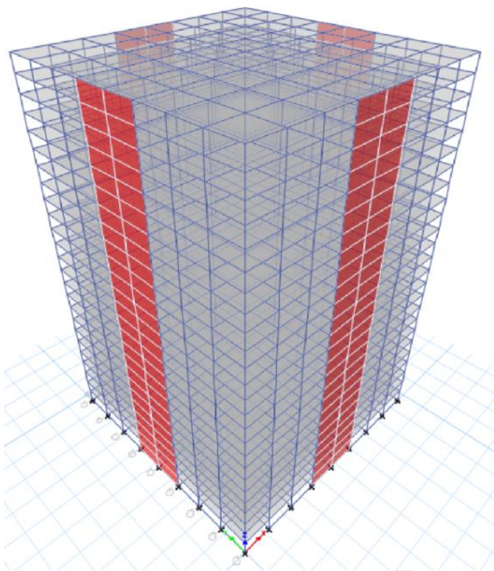

Fig 4.3 – 3-D view of structure with Composite shear wall provided at side centre

5. ANALYSIS AND RESULTS

5.1 TIME PERIOD

As per **IS 1893 2016 clause 7.6.2**, the approximate fundamental translational natural period'T_s'of oscillation in seconds shall be estimated by following expression:

$T_s = 0.075h^{0.75}$(for moment resisting frame)
Where, h = height of building in meter

MODE	TIME PERIOD (seconds)		
	MODEL 1	MODEL 2	MODEL 3
Mode1	3.438	2.364	2.365
Mode2	3.438	2.364	2.365
Mode3	3.154	1.706	1.708
Mode4	1.133	0.633	0.634
Mode5	1.133	0.633	0.634
Mode6	1.041	0.42	0.421
Mode7	0.661	0.302	0.303
Mode8	0.661	0.302	0.303
Mode9	0.612	0.194	0.195
Mode10	0.461	0.194	0.195
Mode11	0.461	0.189	0.19
Mode12	0.428	0.148	0.149

TABLE 5.1 – Time Period in seconds

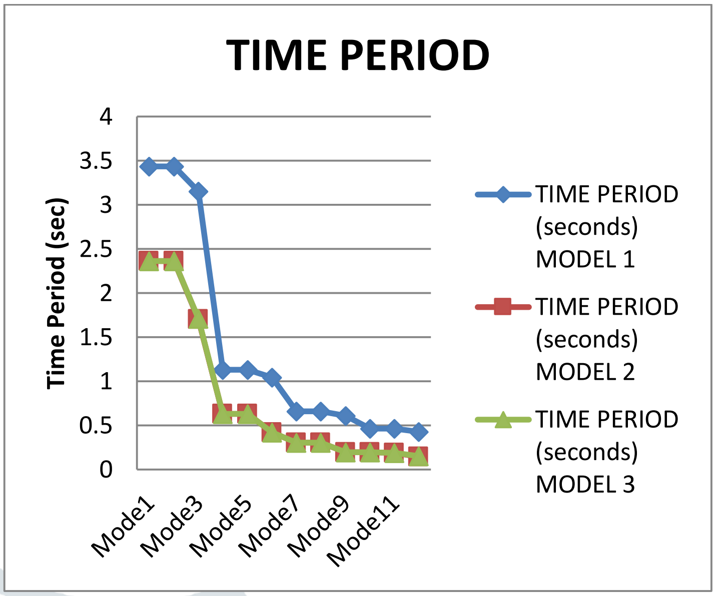

Fig 5.1 – Graph showing Time period

Time period of model 1 is maximum and decreases rapidly at each interval of 3 modes.

Time period of model 2 and model 3 is almost same.

5.2 STOREY DISPLACEMENT

According to EURO CODE, the maximum allowable deflection is calculated as **h/250**,

Where,

h= height of the storey above ground level

5.2.1 STOREY DISPLACEMENT IN X DIRECTION

STORY	STOREY DISPLACEMENT (mm)			
	MODEL 1	MODEL 2	MODEL 3	IS Code Limit
Story25	363.844	212.571	146.078	300
Story24	352.672	204.751	140.7	288
Story23	337.284	196.731	135.197	276
Story22	320.05	188.29	129.39	264
Story21	302.172	179.67	123.467	252
Story20	284.168	170.87	117.419	240
Story19	266.174	161.882	111.243	228
Story18	248.726	152.709	104.94	216
Story17	231.886	143.363	98.52	204
Story16	215.395	133.859	91.991	192
Story15	199.476	124.213	85.367	180
Story14	183.598	114.444	78.659	168

Story13	168.597	104.577	71.885	156
Story12	154.043	106.854	73.441	144
Story11	139.994	95.845	65.88	132
Story10	126.034	84.794	58.292	120
Story9	112.46	73.773	50.724	108
Story8	99.461	62.871	43.238	96
Story7	87.184	52.197	35.908	84
Story6	75.064	41.885	28.826	72
Story5	63.086	32.099	22.103	60
Story4	51.881	23.037	15.876	48
Story3	42.056	14.947	10.311	36
Story2	33.951	8.081	5.581	24
Story1	27.874	2.808	1.957	12

TABLE 5.2.1 – Storey displacement in X Direction

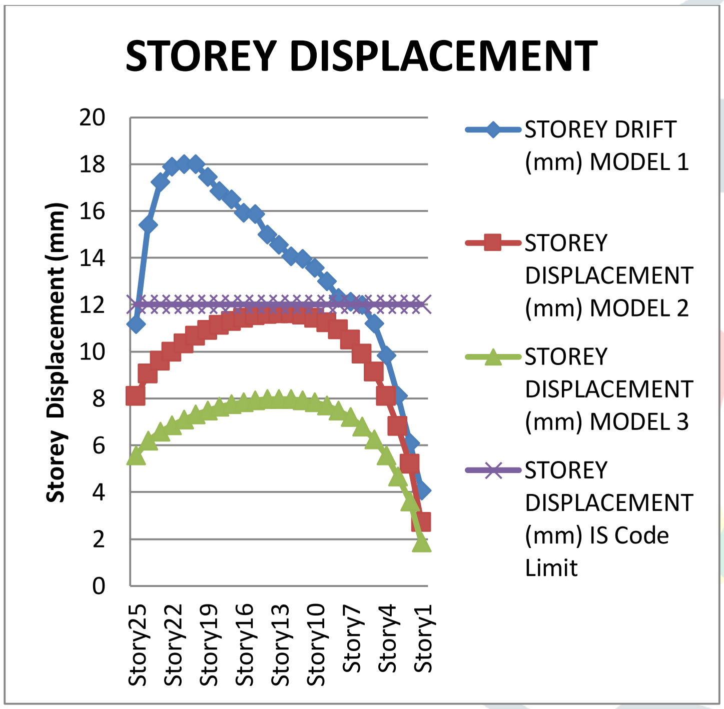

Fig 5.2.1 – Graph showing Storey displacement

5.2.2 STOREY DISPLACEMENT IN Y DIRECTION

STORY	STOREY DISPLACEMENT (mm)			
	MODEL 1	MODEL 2	MODEL 3	IS Code Limit
Story25	363.844	212.571	146.078	300
Story24	352.672	204.751	140.7	288
Story23	337.284	196.731	135.197	276
Story22	320.05	188.29	129.39	264
Story21	302.172	179.67	123.467	252
Story20	284.168	170.87	117.419	240
Story19	266.174	161.882	111.243	228
Story18	248.726	152.709	104.94	216
Story17	231.886	143.363	98.52	204
Story16	215.395	133.859	91.991	192
Story15	199.476	124.213	85.367	180
Story14	183.598	114.444	78.659	168
Story13	168.597	104.577	71.885	156
Story12	154.043	106.854	73.441	144
Story11	139.994	95.845	65.88	132
Story10	126.034	84.794	58.292	120
Story9	112.46	73.773	50.724	108
Story8	99.461	62.871	43.238	96
Story7	87.184	52.197	35.908	84
Story6	75.064	41.885	28.826	72
Story5	63.086	32.099	22.103	60
Story4	51.881	23.037	15.876	48
Story3	42.056	14.947	10.311	36
Story2	33.951	8.081	5.581	24
Story1	27.874	2.808	1.957	12

TABLE 5.2.2 – Storey displacement in X Direction

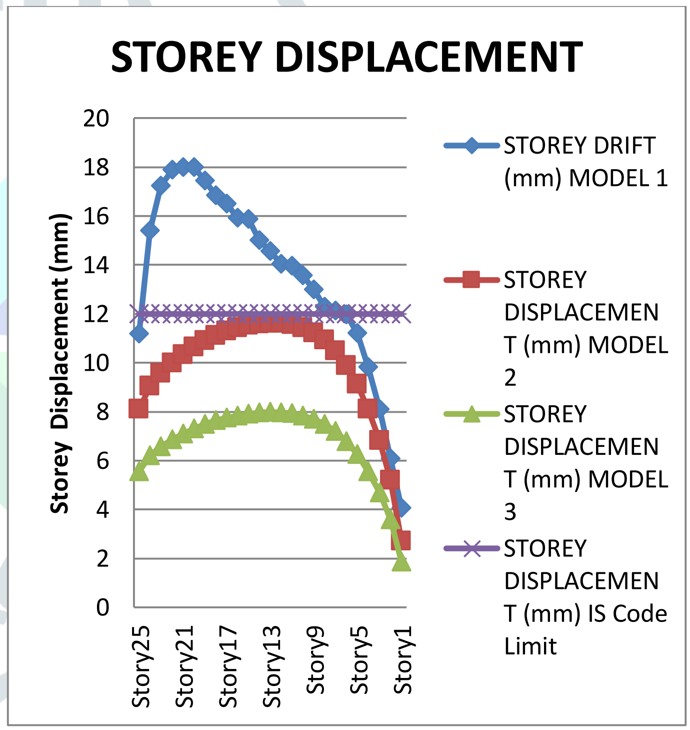

Fig 5.2.2 – Graph showing Storey displacement

Building without shear wall i.e. Model 1 shows larger displacement of 363.85 mm which exceeds the euro code limit and therefore the structure fails.

Building with RC shear wall is safe and values are within the permissible limit whereas building with Composite shear wall shows least displacement.

5.3 STOREY DRIFT

As per **IS 1893:2016** (clause 7.11.1) storey drift in any case shall not exceed 0.004 times of the storey height.

5.3.1 STOREY DRIFT IN X DIRECTION

STORY	STOREY DRIFT (mm)			
	MODEL 1	MODEL 2	MODEL 3	
Story25	11.172	8.084	5.562	12
Story24	15.388	9.027	6.208	12
Story23	17.234	9.571	6.583	12
Story22	17.878	9.968	6.855	12
Story21	18.004	10.323	7.099	12
Story20	17.994	10.634	7.312	12
Story19	17.448	10.894	7.49	12
Story18	16.84	11.107	7.636	12
Story17	16.491	11.278	7.752	12
Story16	15.919	11.411	7.843	12
Story15	15.878	11.512	7.911	12
Story14	15.001	11.579	7.957	12
Story13	14.554	11.61	7.977	12
Story12	14.049	11.599	7.968	12
Story11	13.96	11.538	7.925	12
Story10	13.574	11.416	7.84	12
Story9	12.999	11.213	7.7	12
Story8	12.277	10.908	7.492	12
Story7	12.12	10.476	7.194	12
Story6	11.978	9.886	6.792	12
Story5	11.205	9.106	6.26	12
Story4	9.825	8.091	5.562	12
Story3	8.105	6.799	4.678	12
Story2	6.077	5.196	3.591	12
Story1	4.063	2.691	1.854	12

TABLE 5.3.1 – Storey drift in X direction

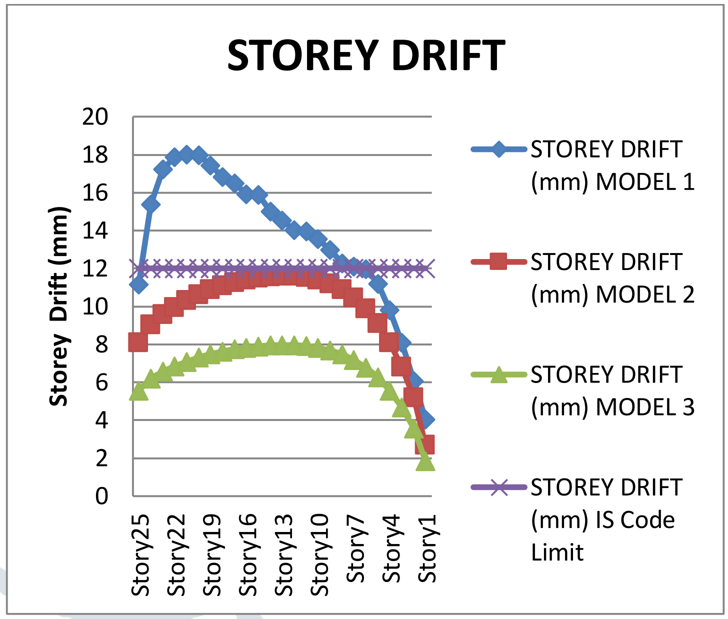

Fig 5.3.1 – Graph showing Storey drift

5.3.2 STOREY DRIFT IN Y DIRECTION

STORY	STOREY DRIFT (mm)			
	MODEL 1	MODEL 2	MODEL 3	
Story25	11.172	8.084	5.562	12
Story24	15.388	9.027	6.208	12
Story23	17.234	9.571	6.583	12
Story22	17.878	9.968	6.855	12
Story21	18.004	10.323	7.099	12
Story20	17.994	10.634	7.312	12
Story19	17.448	10.894	7.49	12
Story18	16.84	11.107	7.636	12
Story17	16.491	11.278	7.752	12
Story16	15.919	11.411	7.843	12
Story15	15.878	11.512	7.911	12
Story14	15.001	11.579	7.957	12
Story13	14.554	11.61	7.977	12
Story12	14.049	11.599	7.968	12
Story11	13.96	11.538	7.925	12
Story10	13.574	11.416	7.84	12
Story9	12.999	11.213	7.7	12
Story8	12.277	10.908	7.492	12
Story7	11.172	10.476	7.194	12
Story6	15.388	9.886	6.792	12
Story5	17.234	9.106	6.26	12
Story4	17.878	8.091	5.562	12

Story3	18.004	6.799	4.678	12
Story2	17.994	5.196	3.591	12
Story1	17.448	2.691	1.854	12

TABLE 5.3.2 – Storey drift in Y direction

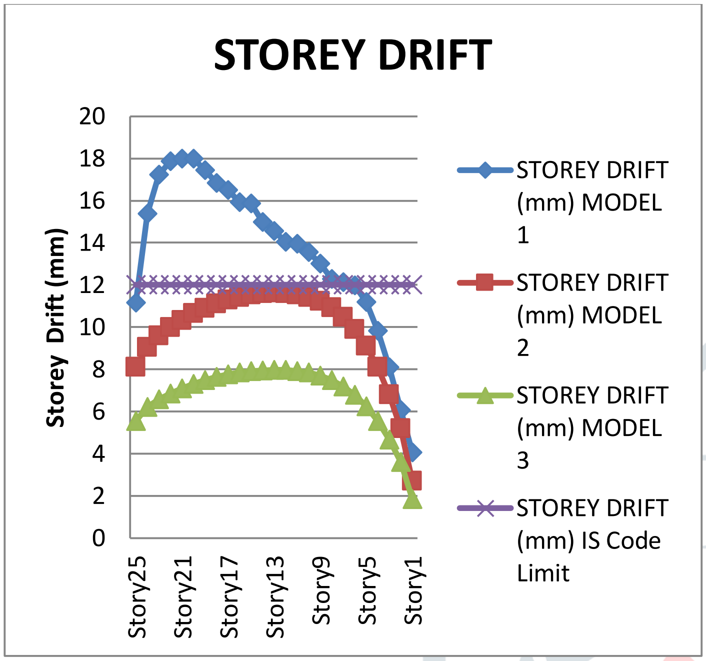

Fig5.3.2 – Graph showing Storey drift

Building without shear wall exceeds the permissible limit of storey drift i.e. the structure fails in storey drift.

Building with Composite shear wall shows least storey drift.

5.4 STOREY STIFFNESS

5.4.1 STOREY STIFFNESS IN X DIRECTION

STOREY	STOREY STIFFNESS (kN/m)		
	MODEL 1	MODEL 2	MODEL 3
Story25	1080323.098	846705.682	844728.608
Story24	1417390.413	1451630	1449853.748
Story23	1505332.038	1900548.852	1895526.594
Story22	1532860.052	2213933.907	2210858.804
Story21	1539757.057	2410962.06	2407900.557
Story20	1540258.425	2529538.296	2526686.826
Story19	1541214.452	2603221.708	2600509.251
Story18	1545374.53	2655358.072	2652781.703
Story17	1552181.444	2698891.029	2696490.087
Story16	1559582.096	2741082.162	2738959.708
Story15	1566074.214	2788948.625	2787173.249
Story14	1571597.669	2852317.031	2850868.509
Story13	1577111.903	2942850.303	2941620.27
Story12	1583528.089	3069696.705	3068555.111
Story11	1590874.681	3239259.677	3238106.572
Story10	1598325.009	3454402.604	3453172.633
Story9	1604965.096	3719897.6	3718488.624
Story8	1610621.191	4047847.909	4046018.716
Story7	1616198.736	4461401.199	4458671.11
Story6	1623462.616	4998105.543	4993595.289
Story5	1634991.964	5718630.976	5710723.64
Story4	1656961.625	6733765.875	6718897.462
Story3	1713850.827	8260921.353	8220210.696
Story2	1926350.012	10681064	10504873
Story1	3541171.614	19238562	18784859

TABLE 5.4.1– Storey stiffness in X direction

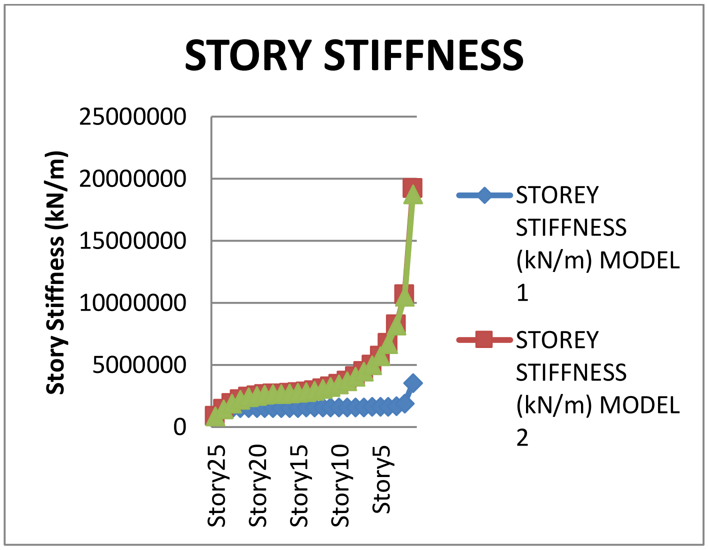

Fig5.4.1 – Graph showing storey stiffness

5.4.2 STOREY STIFFNESS IN Y DIRECTION

STOREY	STOREY STIFFNESS (kN/m)		
	MODEL 1	**MODEL 2**	**MODEL 3**
Story25	1080323.098	846705.682	844728.608
Story24	1417390.413	1451630	1449853.748
Story23	1505332.038	1900548.852	1895526.594
Story22	1532860.052	2213933.907	2210858.804
Story21	1539757.057	2410962.06	2407900.557
Story20	1540258.425	2529538.296	2526686.826
Story19	1541214.452	2603221.708	2600509.251
Story18	1545374.53	2655358.072	2652781.703
Story17	1552181.444	2698891.029	2696490.087
Story16	1559582.096	2741082.162	2738959.708
Story15	1566074.214	2788948.625	2787173.249
Story14	1571597.669	2852317.031	2850868.509
Story13	1577111.903	2942850.303	2941620.27
Story12	1583528.089	3069696.705	3068555.111
Story11	1590874.68	3239259.67	3238106.57
Story10	1598325.009	3454402.604	3453172.633
Story9	1604965.096	3719897.6	3718488.624
Story8	1610621.191	4047847.909	4046018.716
Story7	1616198.736	4461401.199	4458671.11
Story6	1623462.616	4998105.543	4993595.289
Story5	1634991.964	5718630.976	5710723.64
Story4	1656961.625	6733765.875	6718897.462
Story3	1713850.827	8260921.353	8220210.696
Story2	1926350.012	10681064	10504873
Story1	3541171.614	19238562	18784859

TABLE 5.4.2 – Storey stiffness in Y direction

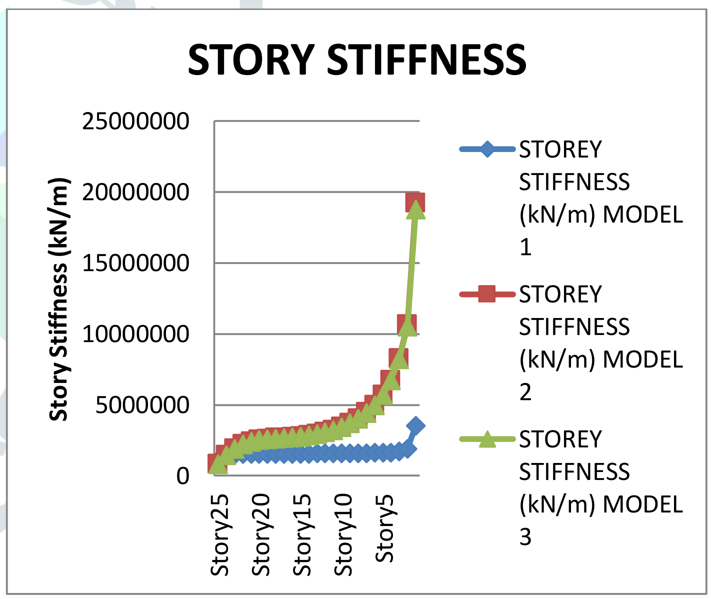

Fig5.4.2 – Graph showing storey stiffness

6. RESULTS AND DISCUSSION

1. The story displacement in Model 1 in X and Y direction is observed to be 363.84 mm which exceeds Euro code limit therefore the structure fails.
2. The story displacement in Model 3 in X and Y direction is observed to be least i.e. 146.07 mm compared to other models.

3. The story drift observed in Model 1 in X and Y direction is 18.004 mm which exceeds the IS code recommended value 12 mm (4% of storey height).
4. The story drift observed in Model 3 in X and Y direction is 7.97 mm which is within the IS code recommended value 12 mm (4% of storey height).
5. The time period of the building is found to be higher in Model 1. Model 2 and Model 3 have almost same time period.
6. The stiffness of building is found to be most in Model 2 & 3.

7. CONCLUSIONS

From the above results, it can be concluded that Composite shear wall provided at side centre is best for this structure.

Composite shear walls are cost effective and gives lesser displacement. Composite shear walls can be used with lesser thickness as compared to RC shear walls.

The strength and ductility of core walls is increased by providing Composite shear walls in the structure.

8. REFERENCES

[1] Qiuohong Zhao and Abolhassan "Seismic behaviour of composite shear wall system and application of smart structures technology" University of Tennessee, Knoxville, USA and University of California, Berkeley, USA ; 2007.

[2] A.Rahai and F.Hatami "Evaluation of composite shear wall behaviour under cyclic loadings" Civil Engg. Department, Amirkabir University of Technology, Tehran, Iran; 2009

[3]A.Arabzadeh, M.Soltani, A.Ayazi "Experimental investigation of composite shear walls under shear loading" Department of Civil and Environmental Engineering, TarbiatModares University, Tehran, Iran ; 2011

[4] AlirezaFarhidzadeh et.al "Structural Health Monitoring" Department of Civil Engineering, Texas Southern University, Texas ; 2012

[5] S.Rafiei et.al "Finite element modelling of double skin profiled composite shear wallsystem under in-plane loadings" Department of Civil Engineering, University of Toronto, Canada ; 2013

[6] Wanlin Cao et.al "Structural Performance of Composite Shear Walls under Compression" Beijing University of Technology, Beijing, China ; 2017

[7] Reslan N and Masri A "Composite Shear Walls an Efficient Seismic Resistant System for Multi-Storey Buildings" Department of Civil Engineering, Beirut Arab University, Lebanon ; 2018

[8]LanhuiGuoet.al "Experimental study of rectangular multi-partition steel-concrete composite shear walls" Harbin Institute of Technology, Harbin, China and Xijing University, Xian, China ; 2018

[9] Shao Teng Huang et.al "Experimental study on seismic behaviour of an innovative composite shear wall" South China University of Technology, China and Nanyang Technological University, Singapore ; 2018

[10] Yan Wang et.al "Experimental study on seismic behaviour of steel plate reinforced concrete composite shear wall" Tongji University, China ; 2018.