Effect of Lateral Load on Moment Resisting Frame and Shear Wall in Multi-storey Regular Frame Structure

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Abstract - *Reinforced concrete (RC) structure has brought a revolutionary change to the construction industry by ensuring safe and cost-effective construction techniques. Frame Structure, Load Bearing Structure and Steel Structures are the three common types structures widely used in world. The analysis is carried out by simulating two experimental structures having same architectural plane layout, and namely are moment resisting frame without shear wall and moment resisting frame with shear wall. The important parameters of structural performance, such as, displacement, torsional Irregularity Check, & story drift are determined and results are also compared for both the structures. Additionally, a comparison of results obtained from analysis is also shown based on story height. The numerical simulation is performed using ETABS considering the ground acceleration and wind pressure for seismic zone-II.*

***Key Words*: Shear wall, Deflection, drift, Lateral load, Stiffness, Regular structure.**

1. INTRODUCTION

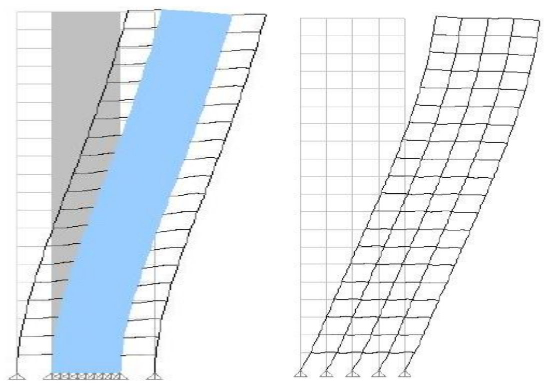
A Moment Connection is a joint that allows the transfer of bending moment forces between a column and beam (or any other two members). This is different to shear or pinned connections that prevent a moment-resisting frame to occur. Shear walls and frames in combination normally provide the required stiffness and strength to withstand lateral loads effectively in high rise buildings. In certain cases, the walls are much stiffer than the frames and thus take most of the lateral load. For this reason, the participation of the frame in resisting lateral load is often ignored. When the building is very tall, the shear wall flexural deformation become very pronounced and hence induces deformation in the frame which must be allowed for in the analysis. The composite action of the combined structure causes the frame to restrain the shear wall in upper storey and the shear wall to restrain the frame in the lower storey, hence the reducing the free deflection and improving the overall efficiency of the structural system.

1.1 MOMENT RESISTING FRAME (MRF)

Moment resisting frame is a jointing of beams and columns parallel perpendicularly to each other with resisting joints. To resistance the lateral loading it is provided by bending resistance of columns, girders and joints. Rigid frame have advantage of simplicity in design and free from bracing and structural walls. The horizontal stiffness of a rigid frame is governed mainly by the bending resistance of the girders, the column and their connection. Story drift of a frame member in tall building can be monitored by stiffness rather than strength.

1.2 Shear Wall (SW)

Reinforced concrete frame building with shear wall is most use for satisfying the growth population needs and for safety of the structure under any loading conditions. Shear wall in the Reinforced concrete building is generally provided to protect the structure under lateral loading conditions like Earthquake load, Wind load etc. Behavior of such type of Reinforced concrete building with provision of shear wall is different than the common R.C. structures. So, it is necessary to analyze the structure with provision of shear wall. The current work is focused on the comparative study of building without shear wall, building with shear wall and building with shear wall having different percentage of openings. Building without shear wall and building with shear wall having different conditions in framework so performance of the building differs on different loading circumstances. The shape and plan position of the shear wall influences the behavior of the structure considerably. Structurally, the best position for the shear walls is in the center of each half of the building. This is rarely practical, since it also utilizes the space a lot, so they are positioned at the ends. It is better to use walls with no openings in them. So, usually, the walls around lift shafts and stairwells are used. Also, walls on the sides of buildings that have no windows can be used.



a) Building with Shear Wall

b) Building with Moment Resistance Frame only

Fig-1: Deformation Profile

2. PARAMETRIC STUDY

In case of tall building it is very essential that the structural system should satisfy the strength and stiffness requirement. The response of the different structural system is depends upon its behavior and load transfer mechanism. In this paper the comparison of the Moment Resisting Frame and Shear-Wall Frame is presented. Analysis is carried out in ETABS.

Analysis results for 15 storey regular building with two different structural systems are compared.

Building Data:
Number of stories- 15
Height of building- 158 ft
Plan dimension- 60 ft x 60 ft
Size of beams- 12 inch x 12 inch
Size of column- 20 inch x 20 inch
Slab thickness- 6 inch
Thickness of Shear wall- 12 inch
Live load- 40 psf
Floor finish- 30 psf
Partition Wall- 25 psf
Zone factor- II
Importance factor- 1.0
Compressive Strength of Concrete- 4 ksi
Site Coefficient- 1.5
Compressive Strength of steel- 60 ksi
Modulus of elasticity- 29000 ksi
Response Modification Co-efficient- 8
Basic wind speed- 161 mph

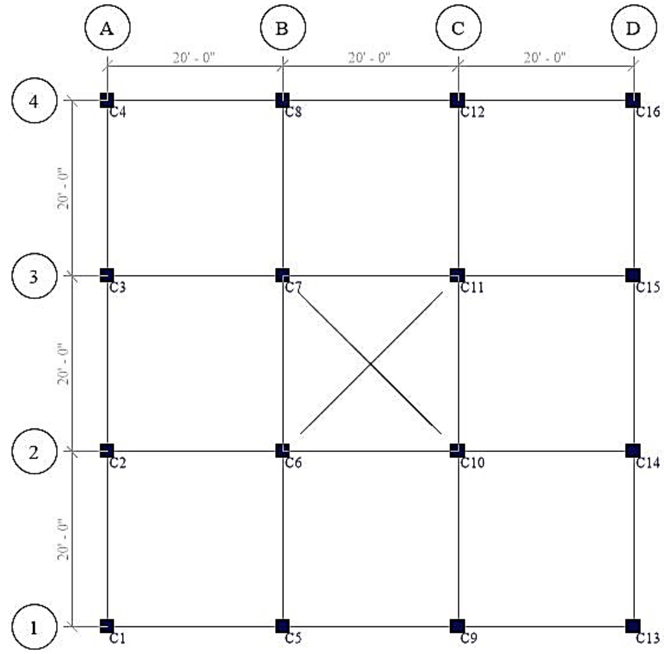


Fig-2: Plan of MR frame structure without shear wall

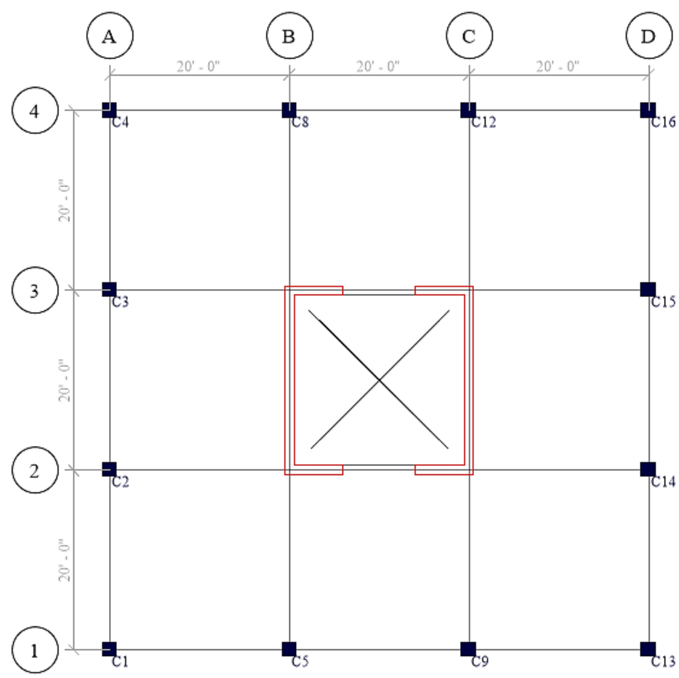


Fig-3: Column layout Plan of Moment Resisting Frame with Shear wall

3. MODELLING IN ETABS

After defining all the loads, load combinations are defined as per UBC-94. 3d model of structure is shown in figure 4 in below

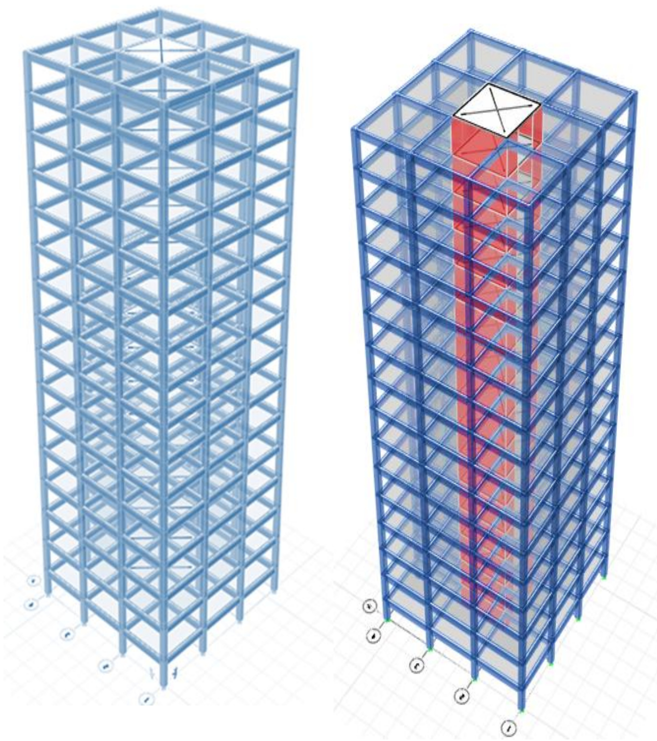


Fig-4: 3D model of structure in ETABS
a) MR frame without SW b) MR frame with SW

4. ANALYSIS RESULT

In this analysis results of two concrete frame structures of fifteen storied building will be presented and discussed. Different analysis is being conducted between moment resisting frame without shear wall and moment resisting frame with shear wall structures with necessary graphs and figures.

After analysis in ETABS software result shows that in shear wall with frame structure reduce the displacement and story drift for earthquake loading, wind loading.

Table-1: Analysis results of maximum displacement for Earthquake loading and Wind loading for frame with SW and without SW.

		Displacement (without SW) (inch)	Displacement (with SW) (inch)
Earthquake loading	X dir	3.657	2.425
	Y dir	3.657	1.019
Wind loading	X dir	7.582	5.315
	Y dir	7.582	1.782

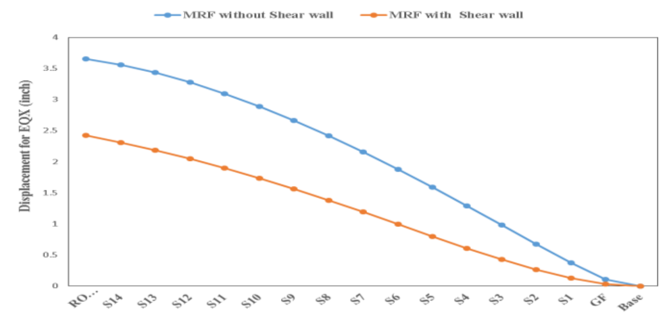


Fig-5: Maximum displacement for Earthquake loading (X-direction) for both structures

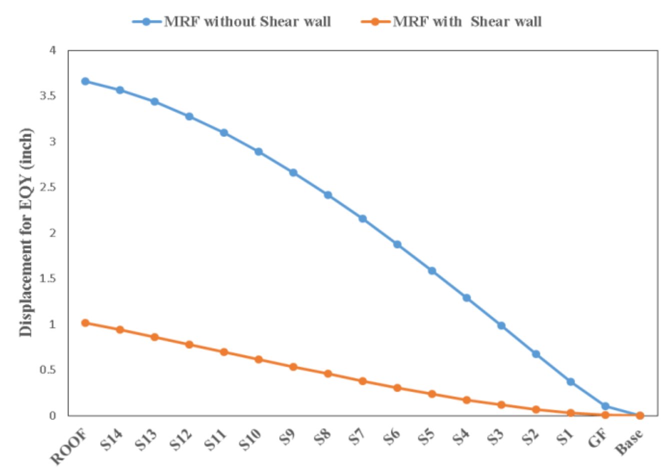


Fig-6: Maximum displacement for Earthquake loading (Y-direction) for both structures

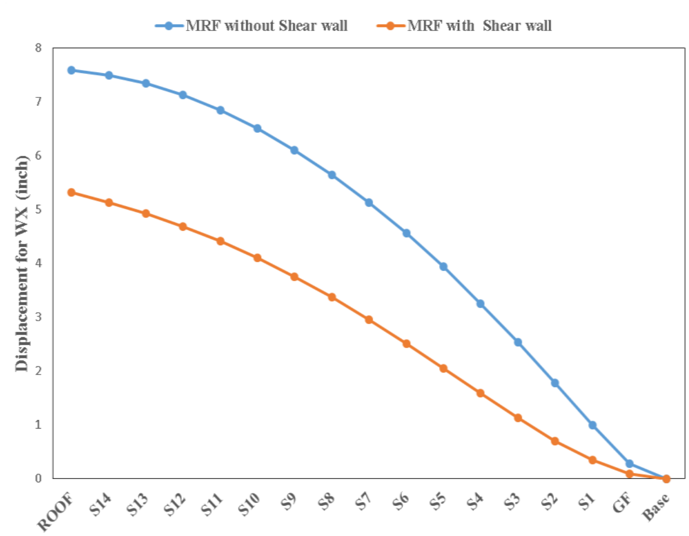


Fig-7: Maximum displacement for Wind loading (X-direction) for both structure

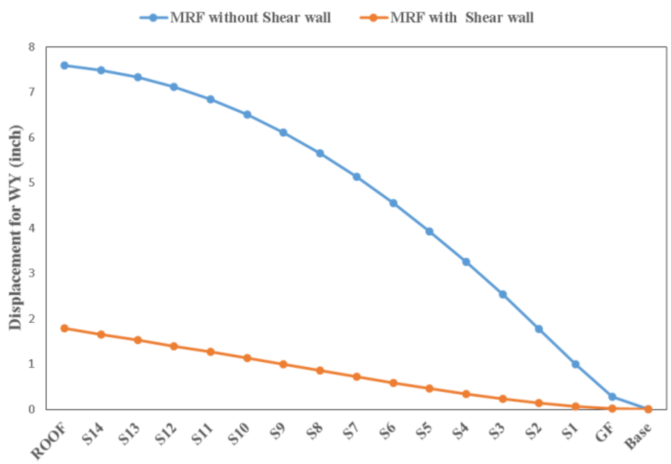


Fig-8: Maximum displacement for Wind loading (Y-direction) for both structures

Story drift is the displacement of one level relative to the level above or below due to design lateral force. Earthquake plays a vital role in the lateral deformation of structure. Storey drift influenced by Earthquake mainly as it is a permanent occurrence for building structure

Table-2: Analysis results of maximum Story drift for Earthquake loading and Wind loading MR frame and Wall-frame structure

		MRF without SW (inch)	MRF with SW (inch)
Earthquake loading	X dir	0.0028	0.0017
	Y dir	0.0028	0.0079
Wind loading	X dir	0.0065	0.0039
	Y dir	0.0065	0.0011

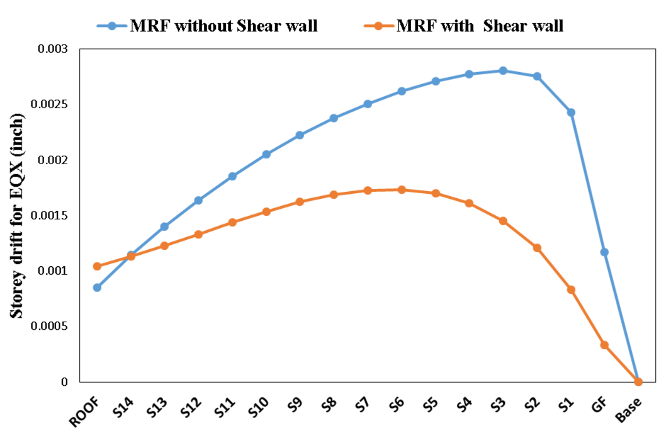


Fig-9: Story drift for EQ loading (X-direction) for both structures

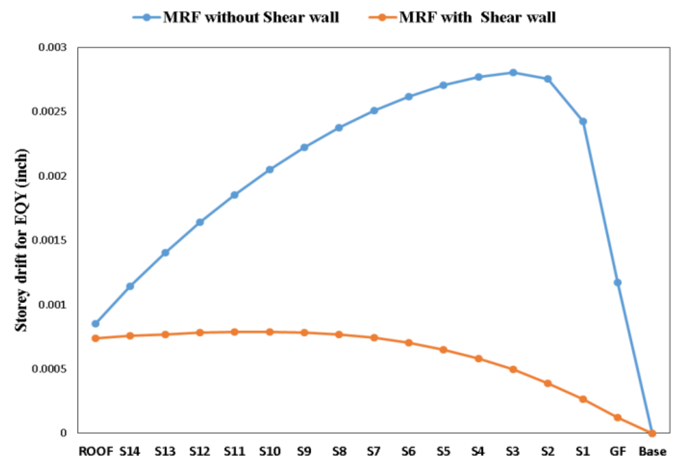


Fig-10: Story drift for EQ loading (Y-direction) for both structures

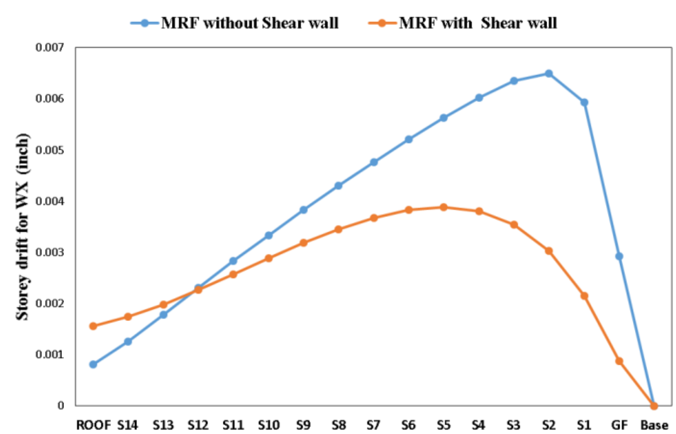


Fig-11: Story drift for WX loading (X-direction) for both structures

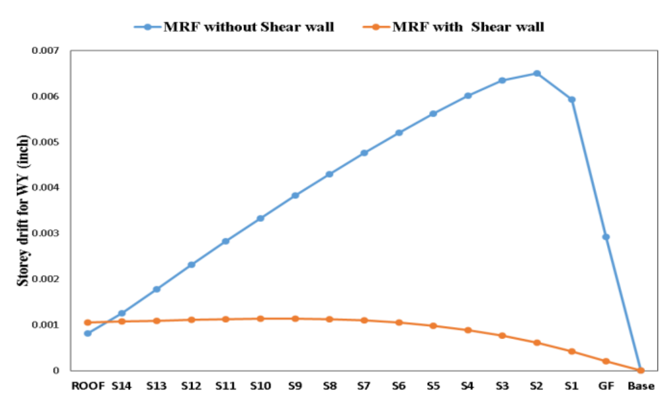


Fig-12: Story drift for WY loading (Y-direction) for both structures

4.1 TORSIONAL IRREGULARITY CHECK

Torsional irregularity shall be considered to exist when the maximum storey drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drifts of the two ends of the structure.

Table-3: Torsional Irregularities of Earthquake Loading for MRF without shear wall

Story Level	Max. Drift (X-dir)	Max. Drift (Y-dir)	Avg. Drift	Ratio	Torsion
ROOF	0.00085	0.00085	0.0008	1.068	Regular
S14	0.00114	0.00114	0.00107	1.074	Regular
S13	0.0014	0.0014	0.0013	1.078	Regular
S12	0.00164	0.00164	0.00152	1.08	Regular
S11	0.00186	0.00186	0.00172	1.082	Regular
S10	0.00205	0.00205	0.00189	1.083	Regular
S9	0.00222	0.00222	0.00205	1.084	Regular
S8	0.00238	0.00238	0.00219	1.085	Regular
S7	0.00251	0.00251	0.00231	1.086	Regular
S6	0.00262	0.00262	0.00241	1.087	Regular
S5	0.00271	0.00271	0.00249	1.087	Regular
S4	0.00277	0.00277	0.00255	1.088	Regular
S3	0.0028	0.0028	0.00257	1.089	Regular
S2	0.00276	0.00276	0.00253	1.09	Regular
S1	0.00243	0.00243	0.00223	1.09	Regular
GF	0.00117	0.00117	0.00108	1.091	Regular

Table-4: Torsional Irregularities of Wind Loading for MRF without shear wall

Story Level	Max Drift (X-dir)	Max Drift (Y-dir)	Avg. Drift	Ratio	Torsion
ROOF	0.00081	0.00081	0.00081	1	Regular
S14	0.00126	0.00126	0.00126	1	Regular
S13	0.00179	0.00179	0.00179	1	Regular
S12	0.00231	0.00231	0.00231	1	Regular
S11	0.00283	0.00283	0.00283	1	Regular
S10	0.00333	0.00333	0.00333	1	Regular
S9	0.00383	0.00383	0.00383	1	Regular
S8	0.0043	0.0043	0.0043	1	Regular
S7	0.00476	0.00476	0.00476	1	Regular
S6	0.0052	0.0052	0.0052	1	Regular
S5	0.00563	0.00563	0.00563	1	Regular
S4	0.00602	0.00602	0.00602	1	Regular
S3	0.00635	0.00635	0.00635	1	Regular
S2	0.0065	0.0065	0.0065	1	Regular
S1	0.00593	0.00593	0.00593	1	Regular
GF	0.00292	0.00292	0.00292	1	Regular

Table-5: Torsional Irregularities of Earthquake loading (X-dir.) for MRF with SW

Story Level	Max. Drift (X-dir)	Avg. Drift	Ratio	Torsion
ROOF	0.001043	0.000969	1.076	Regular
S14	0.001129	0.00105	1.075	Regular
S13	0.001226	0.001142	1.073	Regular
S12	0.001332	0.001244	1.071	Regular
S11	0.001438	0.001345	1.069	Regular
S10	0.001537	0.001439	1.068	Regular
S9	0.001621	0.00152	1.066	Regular
S8	0.001687	0.001584	1.065	Regular
S7	0.001726	0.001623	1.064	Regular
S6	0.001733	0.001631	1.063	Regular
S5	0.001699	0.001601	1.061	Regular
S4	0.001611	0.001519	1.06	Regular
S3	0.001454	0.001372	1.06	Regular
S2	0.001206	0.001138	1.06	Regular
S1	0.000834	0.000784	1.064	Regular
GF	0.000336	0.000312	1.079	Regular

Table-6: Torsional Irregularities of Earthquake loading (Y-dir.) for MRF with SW

Story Level	Max Drift (Y-dir)	Avg Drift	Ratio	Torsion
ROOF	0.00074	0.00065	1.132	Regular
S14	0.00076	0.00066	1.141	Regular
S13	0.00077	0.00067	1.148	Regular
S12	0.00078	0.00068	1.157	Regular
S11	0.00079	0.00068	1.166	Regular
S10	0.00079	0.00067	1.175	Regular
S9	0.00078	0.00066	1.185	Regular
S8	0.00077	0.00064	1.194	Regular
S7	0.00074	0.00062	1.205	Extreme
S6	0.0007	0.00058	1.215	Extreme
S5	0.00065	0.00053	1.227	Extreme
S4	0.00058	0.00047	1.239	Extreme
S3	0.0005	0.0004	1.254	Extreme
S2	0.00039	0.00031	1.272	Extreme
S1	0.00027	0.0002	1.301	Extreme
GF	0.00012	0.000159	1.326	Extreme

In the above graph, it has been seen that there is an extreme torsional irregularity from S-7 to GF levels due to Earthquake loading generating from Y-directions.

Table-7: Torsional Irregularities of Wind loading (X-dir.) for MRF with SW

Story Level	Max Drift	Avg. Drift	Ratio	Torsion
ROOF	0.00157	0.00157	1	Regular
S14	0.00175	0.00175	1	Regular
S13	0.00199	0.00199	1	Regular
S12	0.00227	0.00227	1	Regular
S11	0.00258	0.00258	1	Regular
S10	0.00289	0.00289	1	Regular
S9	0.00319	0.00319	1	Regular
S8	0.00345	0.00345	1	Regular
S7	0.00368	0.00368	1	Regular
S6	0.00383	0.00383	1	Regular
S5	0.00389	0.00389	1	Regular
S4	0.00381	0.00381	1	Regular
S3	0.00355	0.00355	1	Regular
S2	0.00303	0.00303	1	Regular
S1	0.00215	0.00215	1	Regular
GF	0.00088	0.00088	1	Regular

Table-8: Torsional Irregularities of Wind loading (Y-dir.) for MRF with SW

Story Level	Max Drift	Avg Drift	Ratio	Torsion
ROOF	0.00105	0.00105	1	Regular
S14	0.00108	0.00108	1	Regular
S13	0.00109	0.00109	1	Regular
S12	0.00111	0.00111	1	Regular
S11	0.00113	0.00113	1	Regular
S10	0.00114	0.00114	1	Regular
S9	0.00114	0.00114	1	Regular
S8	0.00113	0.00113	1	Regular
S7	0.0011	0.0011	1	Regular
S6	0.00105	0.00105	1	Regular
S5	0.00098	0.00098	1	Regular
S4	0.00089	0.00089	1	Regular
S3	0.00077	0.00077	1	Regular
S2	0.00061	0.00061	1	Regular
S1	0.00042	0.00042	1	Regular
GF	0.00021	0.00021	1	Regular

5. CONCLUSION

This comparative study contains displacement, story drift and torsional irregularity, to compare two structural systems Moment resisting frame and Shear wall with frame structure. Analysis is done in ETABS software. Results shows that for the Shear wall frame structure the displacement and story drift are less compare to moment resistant frame structure. Conclude that Shear wall frame structure is more beneficial than frame system so it can resist lateral loads effectively.

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