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Analysis of RCC Building with different Types of infill Wall, without infill Wall and Infill Wall with Diagonal Strut

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Abstract— Infill walls are integral parts of any building including residential, commercial & industrial as well. These infill walls mostly serve purpose of room separators. For residential buildings these infill walls are required to maintain privacy of different rooms. The safety against fire is also one of the prime requirements of infill walls. In addition to these the infill walls also beneficial for thermal comfort, sound insulations, weather resistance, and durability & water-proofing. The thermal comfort is a requirement that the enclosure walls must comply. The infill walls should be durable, sound resistant, weatherproofed and waterproofed considering surrounding environment.

There are large varieties of infills walls available in the market like brick infill walls, thin concrete infill walls, light weight AAC block infill walls. Timber infill walls, light weight still infill walls, glass infill walls (mostly used in commercial buildings) etc. However commonly used infill wall types are Brick, thin concrete and light weight AAC block infill walls.

However various past studies have shown that the infill walls contribute majorly to the stiffness of building. This study is intended to understand the effect of various types of infill walls on structural behavior of the same building. The structural effects compared for the study includes modal behavior, deflections, drift, base shear etc. These results are also compared with building model without infill walls. Earthquake analysis method considered for this study is static coefficient method & Response Spectrum (dynamic analysis) method.

IS 1893:2016 clause no. 7.9 gives provisions for RC framed Buildings with Unreinforced Masonry Infill walls, these provisions are also studied & applied in the dissertation. Results of actual infill models & without infill models are compared with infill walls modeled by using equivalent diagonal strut as per provisions of IS 1893:2016.

Key words: ETABS, Earthquake load, wind load, dumbbell shaped shear wall, response spectrum analysis.

I. INTRODUCTION

General Introduction

The presence of masonry infill walls in reinforced concrete (RC) buildings is very common; however, and even today, during the design process of new buildings and in the assessment of existing ones, infills are usually considered to be non-structural elements, and their influence on the structural response is ignored. Their influence is recognized in the global behavior of RC frames subjected to earthquake loadings.

Over the last years, many authors have studied the effects of the infill panels on the response of RC structures and the need of inclusion of these non-structural elements on the structural seismic assessment and design process is recognized. Observations made by technicians and experts to damaged buildings caused by seismic actions proved that the presence of masonry infill walls can have beneficial or negative effects to the structure. The presence of the infills is commonly associated with the significant increase in the overall structural stiffness implied by the infills, and then, a higher natural frequency of vibration, which depends on the relevant seismic spectrum, can lead to an increase in seismic forces.

When constructed in buildings with steel or RC moment frames, infill walls are traditionally not considered as a part of the lateral load resisting system. An argument for ignoring the effect of these infill walls is that such walls typically do not offer much displacement capacity and in an event of significant lateral demands, the infill wall would disintegrate and the original lateral load resisting system acts as intended in the design assumptions and processes. The problem, however, is that on one hand such simplified design approach does not predict the level at which the damage in the URM infill wall occurs -this can be significant in terms of nonstructural damages- and on the other hand it does not consider the global and local effects of having these stiff and brittle elements coupled with the primary lateral load resisting system, e.g. shift in natural frequency of the structure, overall change of structural behavior, and increases in shear demand on the columns, in diaphragm demands, and in collector element forces.

Reinforced concrete (RC) frames with unreinforced masonry (URM) infill walls constitute a significant portion of the building stock throughout the world. Infill walls in these buildings are generally considered as non-structural elements. Observations after several earthquakes revealed that infill walls may significantly alter the response of adjacent columns. Studies point out that infill walls increase lateral stiffness and strength of a frame subjected to seismic excitations under low to moderate seismic demands. Under strong seismic excitations, sudden failure of masonry infill walls may accelerate the damage in the structural elements.

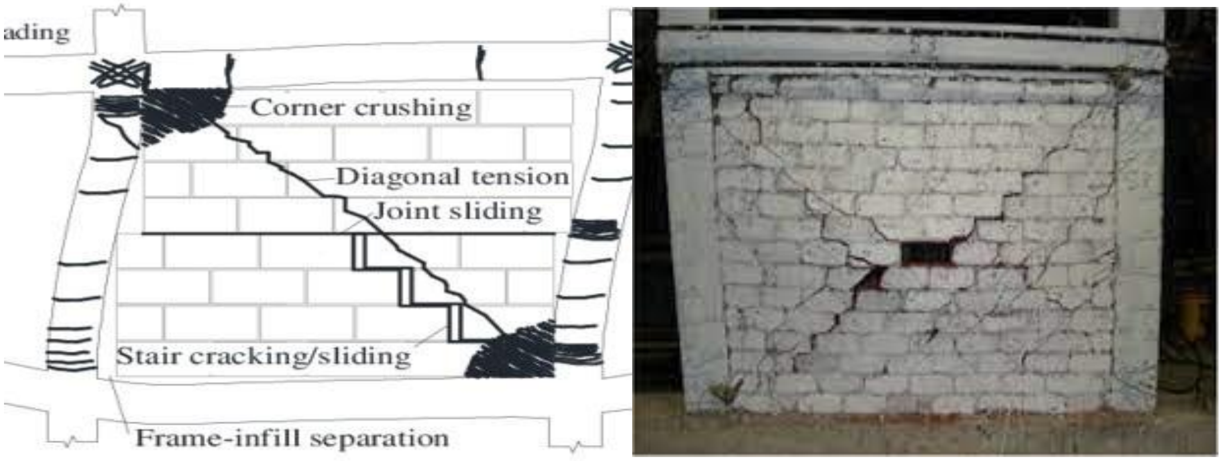


Fig. 1 Various Failure Patterns Of Infill Walls

The need for including infill panels in the analysis of RC frames has been recognized for a long time. The behavior of empty frames and infilled frames is very different. Researchers claims that the contribution of masonry infills to the global capacity of the structure constitutes the structural strength to the 80% and stiffness to the 85%. The main reason of their beneficial behavior is that the amount of increase in earthquake inertia force appears to be relatively small, comparatively with the increase in the strength of masonry infills. Although there is no general acceptance of the contribution of infill walls in the earthquake resistant design, many researches point out that negative effects are often associated with irregularities in the distribution of infills in plan and/or in the evaluation.

II. RESEARCH OBJECTIVE

The objectives of the dissertation are stated below.

1. To Perform Dynamic Analysis of RCC infill wall building with Diagonal struts using Response Spectrum Method in Medium soil conditions.
2. Analysis of G+20 Story building with IS456- Design of Concrete structure using ETABS 2016 software.
3. Design of G+20 Story building with IS 1893 – Criteria for earthquake resistant design of structures Part 1, by using software.
4. Comparing the results of different infill wall conditions i.e. Brick Infill wall, Brick without infill wall, Brick infill with Diagonal struts, Fly ash infill wall, Fly ash infill with Diagonal struts and concrete wall in Earthquake zones III.
5. Calculate earthquake displacement in X&Y directions, Base shear, Story drift in X& Y directions, Modal time Period, Modal Mass participations and also results compare to each other.

III. PROJECT STATEMENT

The study will give more knowledge which result into benefits for future implementation with the help of RCC building actual Analysis and design. To study the effect of infill wall and without infill wall building.

Response Spectrum Method

The total design lateral force or design seismic base shear, VB as per Clause 7.2.1, IS 1893(Part 1)-2016, along any principal direction shall be determined by,

$$V_B = A_h W$$

Where,

W is the seismic weight of the building & A_h is the horizontal seismic coefficient

Horizontal Seismic Coefficient, Ah

The horizontal seismic coefficient, Ah depends on several factors and can be written in different manner according to the seismic codes. In all cases the controlling parameters are the same.

As per Clause 6.4.2, IS 1893(Part 1)-2016,

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where,

Z - Zone factor

I - Importance factor

Sa/g - Average response acceleration coefficient

R- Response Reduction factor

Zone Factor (Z)

It is a factor to obtain the design spectrum depending upon the maximum seismic risk characterized by Maximum Considered Earthquake (MCE) in the zone in which the Structure is located. The basic zone factors included in Table 2, IS 1893(Part 1)-2016 are reasonable estimate of effective peak ground acceleration.

Average Response Acceleration Coefficient (Sa/G)

The design ground motion is one of the important factors used to determine the required seismic resistance (strength) of structures and supported non-structural components. Average response acceleration coefficient depends on the type of rock or soil sites and also the natural period and damping of the structure. It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations. Average response acceleration coefficient for rock and soil sites can be determined from Figure 2 of IS 1893(Part 1)-2016.

Importance Factor (I)

The importance class or factor of a building depends on the occupancy category of the building. Hence, essential facilities such as hospitals, police stations, schools are designed for seismic forces greater than normal. The minimum value of importance factor are given in Table 8 of IS 1893(Part 1) - 2016.

Site Class (Ground Conditions)

To consider the site effect on the estimation of the equivalent lateral static force, the concept of Site Class is used to categorize common soil conditions into broad classes to which typical ground motion effects are assigned. Site Class is determined based on the average properties of the soil within a certain depth from the ground surface.

Response Reduction factor (R)

The behavior factor or the reduction factor R, which is determined by the type of lateral load resisting system used, is a measure of the system's ability to accommodate earthquake loads and absorb energy without collapse. The values of R, are prescribed in Table 9 of IS 1893(Part 1)-2016 for different types of building systems.

Fundamental Period (T)

The fundamental period, T of the structure is used to determine the design ground acceleration and in some codes to establish the distribution of the shear along the height of the structure. The fundamental time period for buildings are given in Clause 7.6.2 of IS 1893(Part 1)-2016.

Vertical Distribution of Base Shear to Different Floors

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B$$

where

Q_i = design lateral force at floor i;

W_i = seismic weight of floor i;

h_i = height of floor i measured from base; and

n = number of storeys in building, that is, number of levels at which masses are located.

After the total base shear is known, it is used to determine the forces on the various building elements. The sum of the loads at each level equals the total base shear. Since the greatest force is at the top, the shear increases from zero at the top to its maximum at the base of the building. Each floor shear is successively added to the sum from above. As per IS 1893(Part 1)-2002,

IV. PROBLEM FORMULATION

Multi-storied Reinforced concrete building, moment resisting space frame have been analyzed using professional software. Model of Multistoried building frame is analyzed by response spectrum Method. The plan dimensions of buildings are shown in table below.

Table 1. Detailed Features of Building

Sr. No.	Parameters	Values
1	Material used	Concrete- M30, M35, & M40
		Reinforcement Fe-415 & 500Mpa
3	Height of each Story	3.0m
4	Height of ground Story	2m
5	Density of concrete	25KN/m^3
6	Poisson ratio	0.2-concrete and 0.15-steel
7	Density of brick	20KN/m^3
9	Code of Practice adopted	IS456:2007, IS1893:2016
10	Seismic zone for IS1893:2002	III
12	Importance factor	1.2
13	Response reduction factor	5
14	Foundation soil	Medium
15	Slab thickness	150mm
16	Wall thickness	230mm
17	Floor Finish	1KN/m2
18	Live load	2.5 KN/m2
19	Earthquake load	As per IS 1893-2016
20	Wind load	As per IS 875- 2015
24	Model to be design	G+20
25	Ductility class	IS1893:2016 SMRF
27	Basic wind speed (Vb)	39 m/sec
28	Terrain category	2
29	Risk coefficient	1
30	Topography factor	1
31	Parapet wall ht.	0.9m

Load case and load combination

Unless otherwise specified, all loads listed, shall be considered in design for the Indian Code following load combinations shall be considered,

Load case

1.DL: Dead load

2.LL: Live load

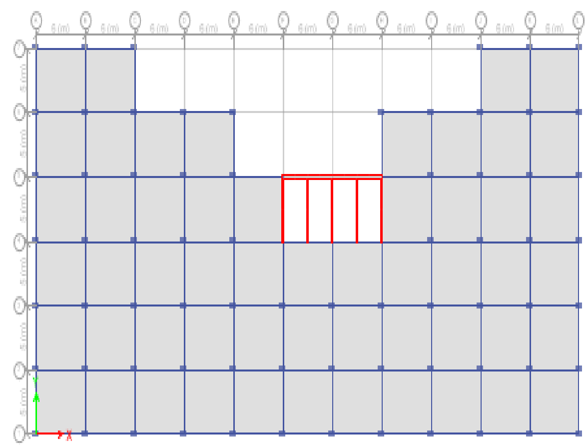
3.EQ: Earthquake load

4.W: Wind Load

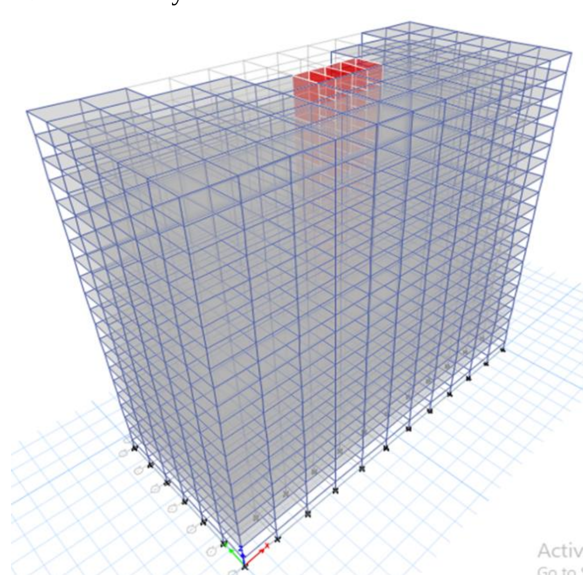
Load combination

1) 1.5DL+1.5LL
2) 1.2DL+1.2LL + 1.2EX
3) 1.2DL+1.2LL- 1.2EX
4) 1.2DL+1.2LL+ 1.2EY
5) 1.2DL+1.2LL - 1.2EY
6) 1.2DL+1.2LL+1.2WLX
7) 1.2DL+1.2LL-1.2WLX
8) 1.2DL+1.2LL+1.2WLY
9) 1.2DL+1.2LL-1.2WL

A. Building Plan



B. G+20 Story 3D Model



RESULTS

In the present study, Relative Analysis of RCC structure with different types of wall materials and conditions i.e. Brick without infill wall, brick infill wall, brick infill with diagonal strut, fly ash infill wall, fly ash infill wall with diagonal strut and concrete wall building with G+20 story building.

Table 2. Base shear Results in Different Types of Wall Material and Conditions

TABLE: Auto Seismic - IS 1893:2002								
Load Pattern	Z	Soil Type	Base Shear	Base Shear	Base Shear	Base Shear	Base Shear	Base Shear
			kN	kN	kN	kN	kN	kN
EQ+X	0.16	II	3622.106	4508.851	12713.51	4003.779	11365.71	4714.842
EQ-X	0.16	II	3622.106	4508.851	12713.51	4003.779	11365.71	4714.842
EQ+Y	0.16	II	2507.04	3125.613	10060.18	2772.431	8983.281	3266.51
EQ-Y	0.16	II	2507.04	3125.613	10060.18	2772.431	8983.281	3266.51

Graph 1. Base shear vs. Different Types of Wall Materials

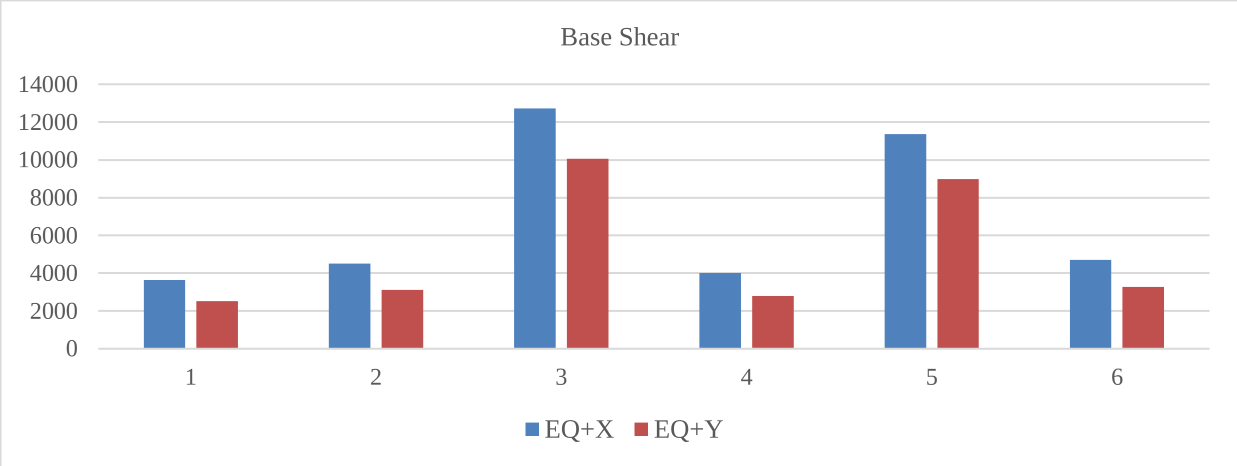


Table 3. Earthquake Displacement Results (Y- directions) In Different Types of Wall Material and Conditions

TABLE: Diaphragm Centre of Mass Displacements							
Story	Load Case/Combo	UY	UY	UY	UY	UY	UY
		mm	mm	mm	mm	mm	mm
20th slab	EQ+Y	33.993	41.734	14.025	37.303	12.609	43.495
19th slab	EQ+Y	32.364	39.787	13.43	35.535	12.067	41.465
18th slab	EQ+Y	30.659	37.732	12.791	33.68	11.486	39.329
17th slab	EQ+Y	28.897	35.602	12.112	31.761	10.871	37.114
16th slab	EQ+Y	27.069	33.385	11.396	29.767	10.224	34.809
15th slab	EQ+Y	25.176	31.083	10.649	27.7	9.55	32.412
14th slab	EQ+Y	23.219	28.693	9.876	25.557	8.853	29.924
13th slab	EQ+Y	21.238	26.268	9.085	23.387	8.142	27.398
12th slab	EQ+Y	19.212	23.781	8.281	21.164	7.419	24.807
11th slab	EQ+Y	17.163	21.261	7.472	18.914	6.692	22.18
10th slab	EQ+Y	15.107	18.728	6.663	16.653	5.966	19.538
9th slab	EQ+Y	13.061	16.202	5.864	14.403	5.249	16.905
8th slab	EQ+Y	11.059	13.727	5.079	12.198	4.545	14.323
7th slab	EQ+Y	9.115	11.321	4.314	10.057	3.859	11.812
6th slab	EQ+Y	7.26	9.022	3.575	8.012	3.198	9.413
5th slab	EQ+Y	5.525	6.871	2.869	6.099	2.566	7.169

4th slab	EQ+Y	3.946	4.91	2.204	4.357	1.971	5.123
3rd slab	EQ+Y	2.573	3.203	1.588	2.841	1.42	3.342
2nd slab	EQ+Y	1.441	1.796	1.029	1.592	0.92	1.873
1st slab	EQ+Y	0.609	0.759	0.552	0.673	0.493	0.792

Graph 2. Earthquake Displacement in Y- directions vs. Different Types of Wall Materials

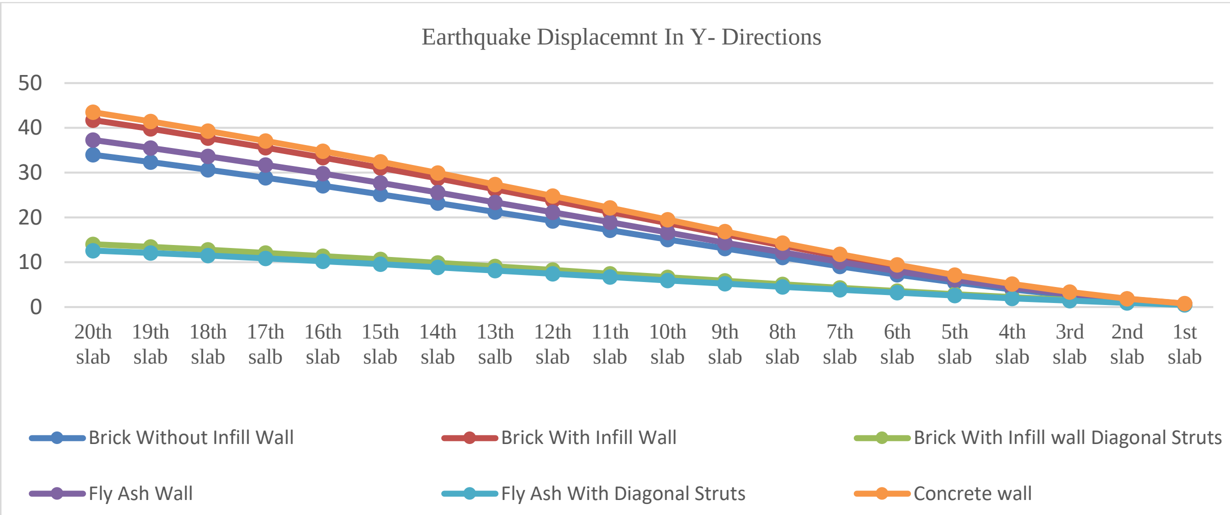


Table 4. Earthquake Displacement Results (Y- directions) In Different Types of Wall Material and Conditions

TABLE: Story Forces							
Story	Load Case/Combo						
20th slab	EQ+X	432.1976	389.175	1072.018	411.883	1122.11	381.1502
19th slab	EQ+X	878.8383	968.1768	2709.52	915.7714	2560.97	990.5919
18th slab	EQ+X	1280.535	1489.218	4183.295	1369.089	3855.68	1539.076
17th slab	EQ+X	1640.346	1955.93	5503.395	1775.138	5015.387	2030.369
16th slab	EQ+X	1960.576	2371.301	6678.28	2136.52	6047.522	2467.617
15th slab	EQ+X	2243.532	2738.323	7716.408	2455.838	6959.516	2853.97
14th slab	EQ+X	2494.489	3062.51	8632.533	2738.457	7765.578	3195.012
13th slab	EQ+X	2715.359	3346.519	9434.28	2986.613	8472.243	3493.57
12th slab	EQ+X	2905.09	3590.486	10122.99	3199.783	9079.276	3750.035
11th slab	EQ+X	3066.045	3797.453	10707.25	3380.623	9594.246	3967.604
10th slab	EQ+X	3200.591	3970.46	11195.64	3531.79	10024.72	4149.473
9th slab	EQ+X	3312.164	4113.46	11599.03	3656.94	10380.71	4299.721
8th slab	EQ+X	3402.842	4229.25	11925.38	3758.463	10669.12	4421.307
7th slab	EQ+X	3473.801	4319.86	12180.76	3837.908	10894.82	4516.453
6th slab	EQ+X	3527.457	4388.374	12373.87	3897.98	11065.48	4588.397
5th slab	EQ+X	3566.223	4437.876	12513.39	3941.383	11188.78	4640.377
4th slab	EQ+X	3592.889	4471.766	12608.8	3971.167	11273.26	4675.937
3rd slab	EQ+X	3609.618	4492.915	12668.27	3989.803	11326.02	4698.11
2nd slab	EQ+X	3618.467	4504.102	12699.73	3999.66	11353.93	4709.837
1st slab	EQ+X	3621.923	4508.471	12712.02	4003.51	11364.83	4714.418
P L	EQ+X	3622.106	4508.851	12713.51	4003.779	11365.71	4714.842

Graph 3. Earthquake Displacement in Y- directions vs. Different Types of Wall Materials

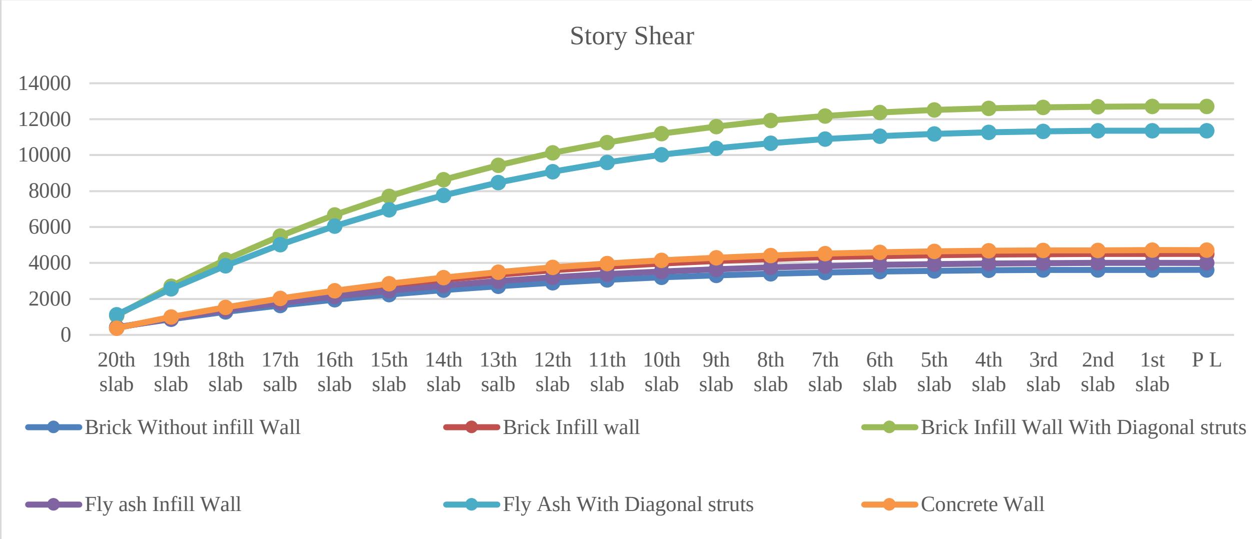
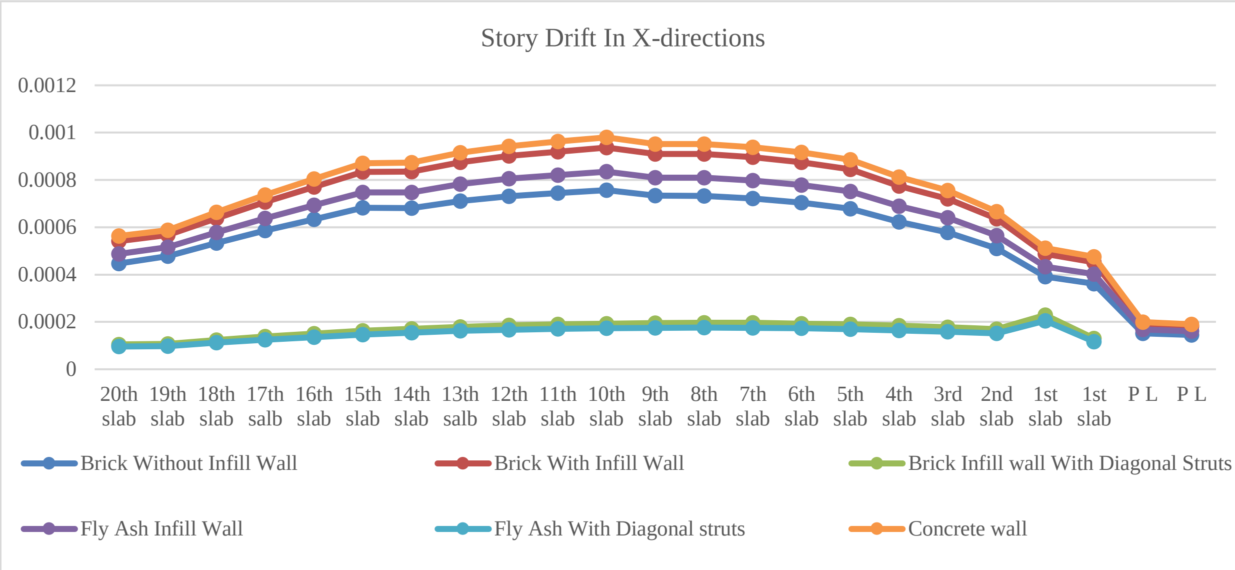


Table 4. Story drift Results (X- directions) In Different Types of Wall Material and Conditions

TABLE: Story Drifts							
Story	Load Case/Combo	Drift	Drift	Drift	Drift	Drift	Drift
20th slab	EQ+X	0.000447	0.000542	0.000105	0.000488	0.000096	0.000564
19th slab	EQ+X	0.000478	0.000567	0.000107	0.000516	0.000098	0.000588
18th slab	EQ+X	0.000533	0.000638	0.000124	0.000578	0.000113	0.000663
17th slab	EQ+X	0.000586	0.000707	0.000138	0.000638	0.000125	0.000736
16th slab	EQ+X	0.000634	0.000771	0.000151	0.000693	0.000136	0.000804
15th slab	EQ+X	0.000682	0.000834	0.000162	0.000748	0.000146	0.00087
14th slab	EQ+X	0.000681	0.000836	0.000171	0.000748	0.000154	0.000873
13th slab	EQ+X	0.000711	0.000875	0.000179	0.000782	0.000162	0.000915
12th slab	EQ+X	0.000731	0.000902	0.000186	0.000805	0.000167	0.000943
11th slab	EQ+X	0.000745	0.00092	0.00019	0.000821	0.000171	0.000963
10th slab	EQ+X	0.000757	0.000937	0.000193	0.000835	0.000174	0.00098
9th slab	EQ+X	0.000734	0.00091	0.000195	0.00081	0.000175	0.000952
8th slab	EQ+X	0.000733	0.00091	0.000196	0.00081	0.000176	0.000952
7th slab	EQ+X	0.000722	0.000897	0.000196	0.000798	0.000175	0.000939
6th slab	EQ+X	0.000704	0.000875	0.000193	0.000778	0.000173	0.000917
5th slab	EQ+X	0.000679	0.000845	0.00019	0.000751	0.00017	0.000885
4th slab	EQ+X	0.000623	0.000775	0.000184	0.000689	0.000164	0.000812
3rd slab	EQ+X	0.000578	0.00072	0.000178	0.00064	0.000159	0.000755
2nd slab	EQ+X	0.00051	0.000636	0.00017	0.000565	0.000152	0.000666
1st slab	EQ+X	0.000392	0.000488	0.000229	0.000434	0.000205	0.000512
1st slab	EQ+X	0.000362	0.000453	0.00013	0.000402	0.000116	0.000476
P L	EQ+X	0.000152	0.00019		0.000168		0.000199
F L	EQ+X	0.000145	0.000181		0.000161		0.00019

Graph 4. Story Drift in X- Directions vs. Different Types of Wall Materials



CONCLUSION

In the present study, Relative Analysis of RCC structure with different wall types materials i.e. Infill Brick wall, without infill brick wall, infill brick wall with diagonal struts, Fly ash, without fly ash infill and concrete wall building with G+20 story building. The structures are analyses for earthquake zone III with medium soil and Results Compare. It has been made on different structural parameters viz. Mode shape, time period, Modal mass participations, Max. Displacement in X&Y directions, Earthquake Displacement Floor wise in X& Y- directions, base shear, Story Drift in X & Y-directions and Story shear in X&Y- directions etc. Grounded on the analysis results following conclusions are drawn.

1. Top Story displacement of different types of wall i.e. without Brick infill wall, with in fill brick wall, infill brick wall with diagonal struts and fly ash wall with percentage of displacement is 29.7%, 36.38%, 11.12%, 32.58% and 37.97% as compare to Fly ash with diagonal struts, Top Story displacement of brick wall diagonal struts and Fly Ash Brick infill with Diagonal struts model is good performance as compare to other models.
2. Top Story displacement of fly ash infill wall with diagonal struts model shows good performance in overall models.
3. Base shear of different type of wall materials i.e. without infill brick wall, with infill brick wall, infill brick wall with diagonal struts, fly ash infill wall, fly ash infill with diagonal struts and concrete wall base share is 1.25time, 3.5times 1.105times, 3.137times 1.3 times increased with compare to Brick without infill wall. Earthquake base shear of without infill wall and fly ash wall material is good performance in base shear results.
4. Story Drift of fly Ash infill with diagonal struts model shows good performance in drift, also model shows linear behavior, remaining all models shows non-linear behavior. Story shear results in different types of wall materials, story shear is increases in 11.33%, 10.2%, 28.125%, 10.80% & 29.44% as compare to Concrete wall materials. Concrete wall shows good performance in story shear.
5. The overall performance of Fly ash infill with Equivalent diagonal struts models shows good performance.

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