Response Spectrum Analysis and Comparison of Seismic Parameters of Low-rise, High-rise and Asymmetrical RC Structure with and without Infill for Different Bay Dimensions

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Abstract - *Generally the effect of infill walls is not considered in the design process and is treated as non-structural components.This study provides the comparative study on performance of RC frame buildings considering infill, without considering infill. Here the masonry infill walls are entirely replaced by equivalent diagonal strut in-order to assess their contribution in seismic resistance of normal Reinforced concrete buildings. In this paper the Response Spectrum analysis has been performed using Response spectrum analysis on different types of RC framed structures i.e. G+3 frame without considering infill (bare frame), G+3 frame considering infill walls, with different dimensions and G+7 frame with same situations. Again the contribution of ground soft storey and introduction of shear wall in G+3 and G+7 RC frame and its effect on seismic parameters is also studied. One special case of a G+7 building frame irregular shape in plan is chose to focus on a resulting characteristics of realistic building frame.*

Key Words: RC Frame, Bare frame, Infill frame, Response Spectrum, Equivalent Diagonal Strut, Soft storey, shear wall.

1. INTRODUCTION

The present code of practice provides empirical formula for taking into concern the effect of infill. It can be expected that if the impact of infill is taken under consideration within the analysis of frame, the structure could also be significantly totally different.

The construction of high rise building is basically associated with infill frames. In tall structures, the vertical loads, do not pose problems in analysis and design as they are mostly deterministic but the lateral loads emerging due to wind and earthquake, are matter of concern. They require special consideration in design of tall building. These lateral forces produce critical stresses in structures and set up undesirable vibration or even cause excessive lateral sway of the structure.

There are two different approaches for designing masonry infill concrete frames depending on local construction site. In the first approach, masonry infill is taken as a part of structural system and they are assumed to brace the frame against horizontal loading. In the second approach, the frame is designed to carry the total vertical and horizontal loading. Moreover, masonry infill is uncoupled to avoid load being transferred to them. In earthquake prone regions like India, masonry infill walls are counted as non-structural elements. They are not taken into account at design stage. The later approach is more commonly used.

Besides, infill situated in total storeys offers a considerable involvement in the energy dissipation, decreasing the most displacements. The presence of infill increases the stiffness of the frame, which reduces the lateral deflection. Thus the deflections and internal forces for frames with infill are less than for frames without infill. Therefore the involvement of masonry infill in the analysis is of most importance.

1.1 Scope of the Work

The previous study shows the need in depth study for non-linear static analysis of masonry infill in multi-storey structure. In the present dissertation Response spectrum analysis of RC frame considering masonry infill and without considering infill and with also effect of soft storey and shear wall in RC building frame structure is studied and comparison made with bare frame.

1.2 Objectives

The objectives of present work are:

1. To assess the effect of infilled walls in low rise and high rise building frame.
2. To study the effectiveness of introduction of shear wall in building frame.
3. To study the effect of introduction of ground soft storey in building frame.
4. To study the effect of plan irregularity in building frame.

2. Equivalent Diagonal Strut Method

Under the action of in-plane lateral load, an infill frame behaves like a solid cantilever with an initial bond at the frame–wall interface. An infill wall which is not physically connected to the bounding members by shear keys or dowels is classified as non-integral. For such a wall, after the bond is broken, there is separation between the frame and the wall, at the diagonally opposite corners of the panel that are under tension. Compressive load is transferred to the wall near the other corners which are under compression, through certain lengths of contact with the bounding frame members. The wall then behaves like a strut under compression. This is the most accepted method for the analysis of infill frame structures in which the entire infill is replaced by a single equivalent strut. In this method, beams and columns are designed as frame members which are having 6 degrees of freedom at every node and the brick infill is replaced by a pin jointed diagonal strut. The thickness of the pin jointed diagonal strut is considered to be the same as infill and its length is equal to the length of the diagonal between the two compression corners. Relative stiffness of the frame and infill, contact length and the aspect ratio are general parameters that govern the effective width of the equivalent diagonal.

3. Calculation Of The Effective Width Of Diagonal Strut Using Formula Given In Is 1893-2016

- IS 1893-2016 Clause No.7.9.2.2- URM infill walls shall be modeled by using equivalent diagonal strut as below:

a) Ends of diagonal struts shall be considered to be pin-jointed to RC frame;

b) For URM infill walls without any opening, width Wds of equivalent diagonal strut shall be taken as:

$$W_{ds}=0.175\alpha_h^{-0.4}L_{ds}$$

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4E_f I_c h}}\right)$$

Wds =Width of equivalent strut
Em =Modulus of elasticity of the infill material
Ef =Modulus of elasticity of the frame material
Ic =Moment of inertia of column
t =Thickness of infill
Lds = Length of the diagonal strut
h = Height of infill
θ = Slope of infill diagonal to the horizontal

4. Details Of The Models

For this study, a G+3 and G+7Storey building with 3 meters height for each Storey, regular in plan with bay 3x3 and 4x4 of 4m and 5m is considered. The building is designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures. The building is modeled using software ETABS. Models are studied for comparing Time period, Base shear, lateral displacement, and Storey drift.

Table -1: General details of Models

Specific weight of RCC	25 kN/m3
Specific weight of Infill	20 kN/m3
Materials	Concrete M20 Reinforcement Fe415
Infill Wall	250 mm
Dead Load	1.5 KN/m2
Imposed Load	2 KN/m2 1.5 KN/m2 (at top floor)
Size of Column	250 X 380(G+3) 380 X 450 (G+7)
Size of Beam	250 X 380
Depth of slab	150 mm
Type of soil	Rock (Hard)

Table -2: Equivalent Strut Widths for G+3 and G+7 models

Bay Dimension of frame	G+3	G+7
4m	0.424m	0.454m
5m	0.508m	0.545m

5. RESULTS

Table -3: Response Spectrum Analysis Results of G+3 frame for bare and infill case

Parameters			Time Period (Sec)	Base Shear(KN)	Max Displcement (mm)	Max Drift
G+3 (BAY 4M)	3X3	BARE	0.899	108.2578	0.063	0.000007
		INFILL	0.172	184.4005	0.046088	0.000005
	4X4	BARE	0.936	180.9993	0.047724	0.000005
		INFILL	0.171	318.3666	0.034138	0.000004
G+3 (BAY 5M)	3X3	BARE	1.137	125.362	0.052308	0.000006
		INFILL	0.184	293.693	0.038141	0.000004
	4X4	BARE	1.186	209.7257	0.039492	0.000004
		INFILL	0.184	513.4543	0.028241	0.000003

Table -4: Response Spectrum Analysis Results of G+3 frame for Ground soft storey and shear wall case

Parameters			Time Period (Sec)	Base Shear(KN)	Max Displcement (mm)	Max Drift
G+3 (BAY 4M)	3X3	BARE	0.579	169.0451	2.7663	0.00085
		INFILL	0.221	189.81	0.7761	0.000084
	4X4	BARE	0.605	279.5547	2.8743	0.000849
		INFILL	0.267	301.5478	1.1158	0.000119
G+3 (BAY 5M)	3X3	BARE	0.699	203.3527	3.3084	0.00103
		INFILL	0.208	269.4984	0.6823	0.000074
	4X4	BARE	0.733	336.3171	3.4518	0.00108
		INFILL	0.256	434.862	1.0108	0.000107

Table -5: Response Spectrum Analysis Results of G+7 frame for bare and infill case

Parameters			Time Period (Sec)	Base Shear (KN)	Max Displcement (mm)	Max Drift
G+3 (BAY 4M)	3X3	BARE	1.327	69.743	4.7	0.000281
		INFILL	0.357	204.92	1.06	0.000051
	4X4	BARE	1.36	117.13	4.78	0.000288
		INFILL	0.341	351.19	0.95	0.000048
G+3 (BAY 5M)	3X3	BARE	1.712	77.08	5.88	0.000355
		INFILL	0.374	290.54	1.13	0.000055
	4X4	BARE	1.762	129.64	6.001	0.000365
		INFILL	0.361	501.02	1.03	0.000055

Table -6: Response Spectrum Analysis Results of G+7 frame for Ground soft storey and shear wall case

Parameters			Time Period (Sec)	Base Shear (KN)	Max Displcement(mm)	Max Drift
G+3 (BAY 4M)	3X3	BARE	0.549	198.74	1.6806	0.000305
		INFILL	0.599	187.55	2.8877	0.000157
	4X4	BARE	0.555	337.34	1.6293	0.000327
		INFILL	0.707	252.83	3.28	0.000175
G+3 (BAY 5M)	3X3	BARE	0.63	245.86	1.81086	0.000375
		INFILL	0.588	266.03	2.829	0.000156
	4X4	BARE	0.645	414.48	1.7908	0.000399
		INFILL	0.718	351.14	3.319	0.000182

Table -7: Response Spectrum Analysis Results of G+7 frame Irregular in plan frame

Parameters		Time Period (Sec)	Base Shear (KN)	Max Displcement (mm)	Max Drift
BARE	X-DIR	1.328	181.14	9.81	0.000585
	Y- DIR	1.328	190.54	9.60	0.000573
INFILL	X-DIR	0.353	535.01	1.70	0.000083
	Y- DIR	0.353	534.66	1.69	0.000082
SOFT STOREY AT BASE	X-DIR	0.545	528.72	3.10	0.000607
	Y- DIR	0.545	528.67	2.71	0.000467
SHEAR WALL	X-DIR	0.37	636.55	2.69	0.000144
	Y- DIR	0.37	637.70	2.68	0.000143

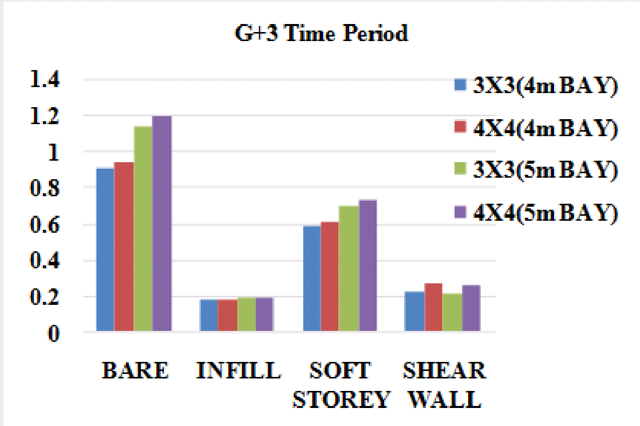

Chart -1: Comparison of Fundamental Time Period of G+3 building frame

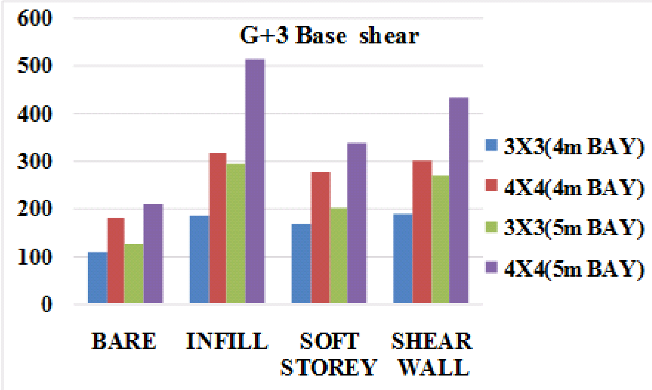

Chart -2: Comparison of Base Shear of G+3 building frame

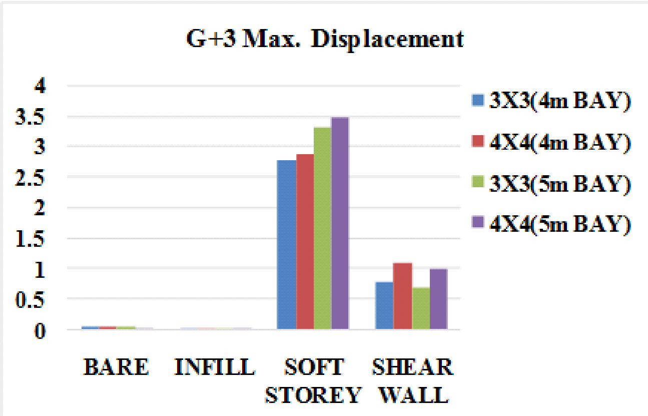

Chart -3: Comparison of Maximum Displacement of G+3 building frame

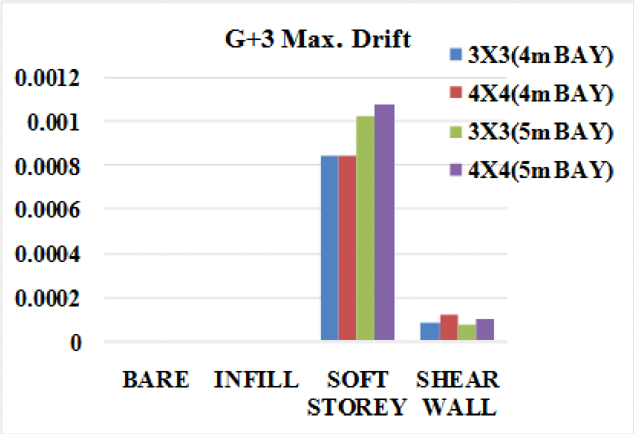

Chart -4: Comparison of Maximum Drift of G+3 building frame

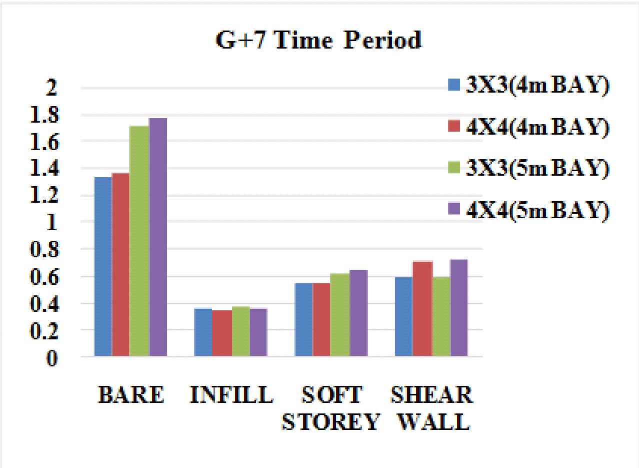

Chart -5: Comparison of Fundamental time Period of G+7 building frame

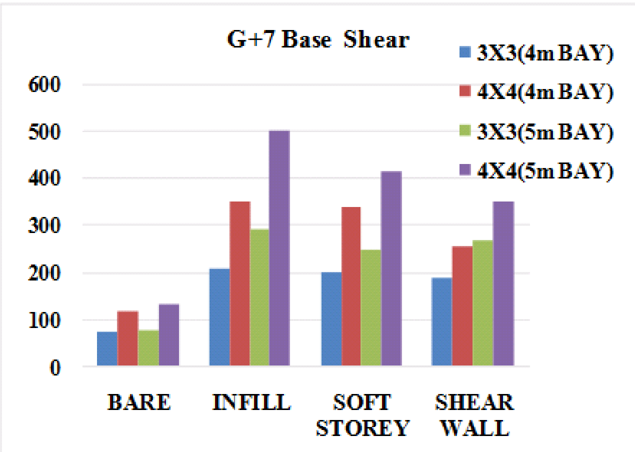

Chart -6: Comparison of Base Shear of G+7 building frame

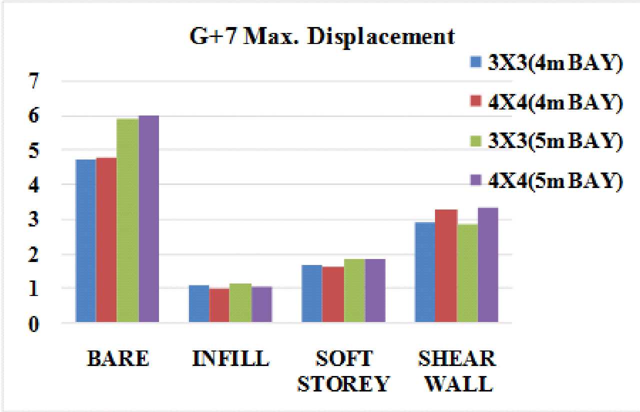

Chart -7: Comparison of Maximum Displacement of G+7 building frame

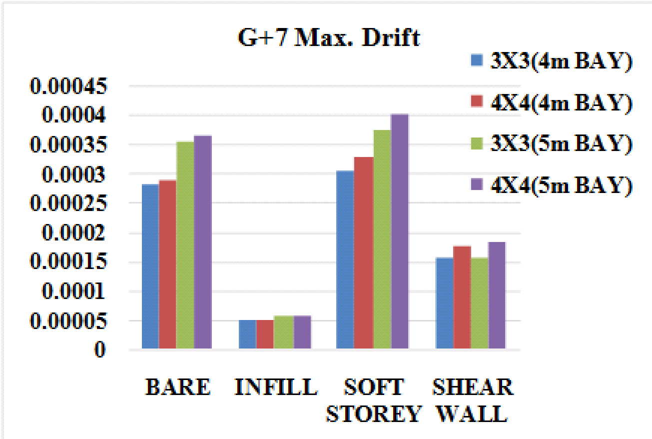

Chart -8: Comparison of Maximum Drift of G+7 building frame

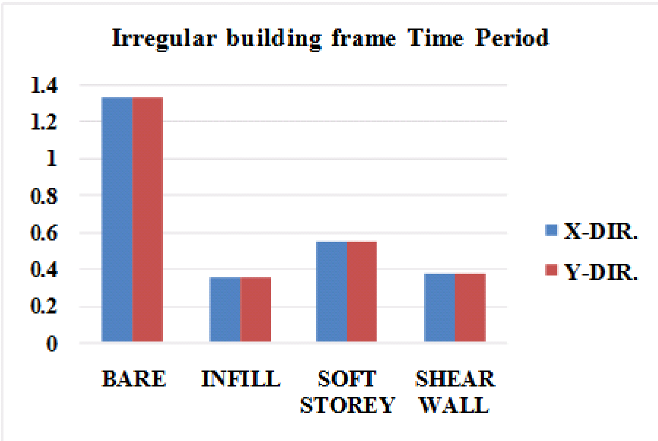

Chart -9: Comparison of Time Period of G+7 Irregular building frame

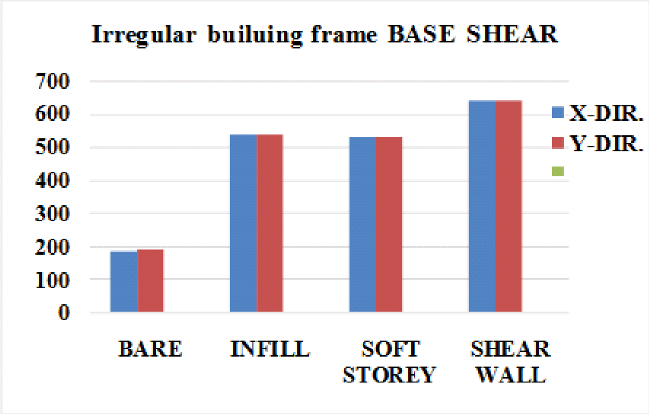

Chart -10: Comparison of Base Shear of G+7 Irregular building frame

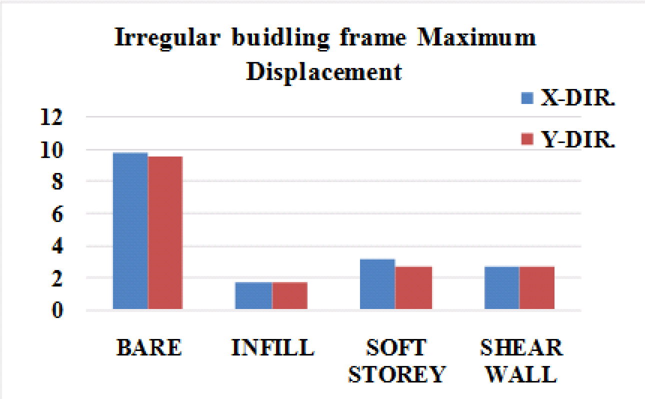

Chart -11: Comparison of Maximum Displacement of G+7 Irregular building frame

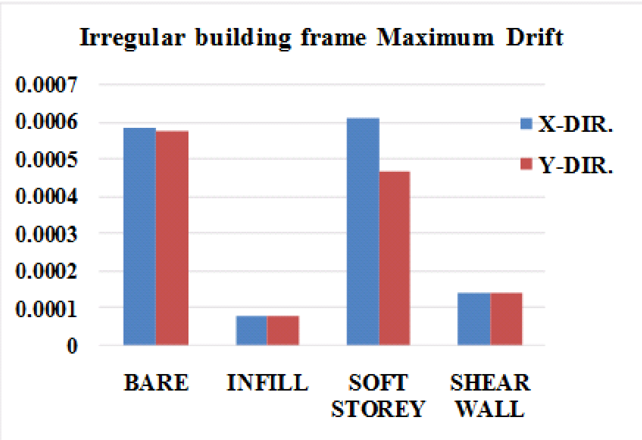

Chart -12: Comparison of Maximum Drift of G+7 Irregular building frame

6. CONCLUSIONS

The response spectrum analysis was carried out on 36 kinds of frames with different storeys, different bay widths, frames with infill, with shear wall, with ground soft storey and with different plan shape to study the variation of seismic parameters such as fundamental time period, Base shear, Maximum Displacement and Maximum drift for different kind of models prepared on ETABS.

Following are the conclusions drawn from the above study:

1. General Conclusions:

- The time period is highest for Bare frame as compared to frame with infill, frame with shear and frame with ground soft storey.
- As bay dimension increases time period increases.
- As height of frame increases time period increases.
- The base shear is lowest for bare frame.
- The base shear is highest for infill frame.
- As bay dimension increases Base shear increases.
- Time period, Base shear, Maximum Displacement and Maximum drift increases when number of bays increase.
- As the height of frame increases the Maximum Displacement increases.
- For the frame with irregular plan time period and base shear in X and Y direction remains same but Maximum displacement and Maximum drift changes.

2. Conclusion for G+3

- For G+3 frame, infill frame shows better performance with lowest time period, highest base shear, lowest Maximum displacement and Maximum drift.
- When Bay dimension increases, time period increases around 4% to 26%, base shear increases around 15% to 60%, Maximum Displacement increases around 10% to 20% and Maximum Drift increases around 10% to 25%.
- Maximum displacements and Maximum drifts are highest for frame with ground soft storey.

3. Conclusion for G+7

- For G+7 frame, infill frame shows better performance with lowest time period, highest base shear, lowest Maximum displacement and Maximum drift.
- When Bay dimension increases, time period increases around 1% to 30%, base shear increases around 10% to 41%, Maximum Displacement increases around 2% to 25% and Maximum Drift increases around 0% to 28%.
- Maximum displacement is highest for Bare frame and Maximum drift is highest for frame with ground soft storey.

4. While analyzing frame the effect of infill wall should be considered. Considering effect of infill wall in analysis results onto increase in base shear for which the building frame is designed and which is less vulnerable to earthquake as compared to bare frame.
5. Bare frame and frame with ground soft storey are more vulnerable to earthquake with higher Displacements and drifts during earthquake.
6. Proper placement of shear wall will also reduce the vulnerability of frame to earthquake.

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