RESEARCH ARTICLE OPEN ACCESS

Seismic Response of RC Framed Buildings with Open Ground Storey

Somani Kishangopal J*, Sangave Prakarsh A**
*Post Graduate Student (Department of Civil Engineering, Nagesh Karajagi Orchid College of Engg. and Tech., Solapur, Maharashtra, India)
** Associate Professor (Department of Civil Engineering, Nagesh Karajagi Orchid College of Engg. and Tech., Solapur, Maharashtra, India)

ABSTRACT
RC framed buildings are generally designed without considering the structural action of masonry infill walls. These masonry infill walls are widely used as partitions and considered as non-structural elements. But they affect both the structural and non-structural performance of RC buildings during earthquake. RC framed building with open ground storey is known as soft storey, which performs poorly during earthquake. In order to study this total 144 RC framed buildings having bare frame, full infill frame and open ground storey frame were analyzed by seismic coefficient method and response spectrum method for various seismic hazards. The present study deals with the comparison of base shear for medium rise RC framed buildings having P+5, P+7, P+9 and P+11 storeys for various seismic zones (III, IV & V) and for various soil conditions (Hard & Medium) as per IS 1893(part 1): 2002. This work helps in understanding the effect of earthquake with increase in height of RC framed buildings on base shear for various seismic zones and soil conditions. The result shows that the effect of infill stiffness on structural response is significant under lateral loads. It is found that the presence infill walls increases the base shear by 60-65% more than bare frame by both seismic coefficient method and response spectrum method.

***Keywords* -** bare, infill and open ground storey frames, equivalent diagonal strut, seismic coefficient method, response spectrum method.

1. INTRODUCTION

RC framed buildings have become common form of construction in urban and semi urban areas around the world which is having masonry infill. Numerous such buildings constructed in recent times have a special feature – the ground storey is left open, which means the columns in the ground storey do not have any partition walls between them. These types of buildings having no infill walls in ground storey, but having infill walls in all upper storeys are called as ‘Open Ground Storey’ (OGS) buildings. The open ground storey buildings are generally analysed as bare frame structures i.e. without considering structural contribution of masonry infill walls in the upper stories, this calls for assessment. Because the presence of infill walls in all upper stories except in the ground storey makes the upper stories much stiffer as compared to the open ground storey hence the upper stories move almost together as a single block and most of the horizontal displacement of the buildings occurs in the open ground storey itself. Thus the salient objective of the present study is to study the effect of earthquake with increase in height of medium rise RC framed buildings as well as the effect of infill strength and stiffness on the seismic analysis of open ground storey (OGS) buildings. In the case of horizontal loading due to seismic action, it is usual to assume that an equivalent compression strut can replace the action of the masonry infill panels.

2. DESCRIPTION OF MODEL

2.1 Geometry

For the present study, RC framed type of building with five bays in X and three bays in Y direction is considered as shown in fig. 01. A ground storey height of 4.2m and all other stories having 3.2m floor to floor height is considered for the analysis. The bay width along X as well as Y direction is 4m. The thickness of masonry wall is 150mm. The building is kept symmetric in both orthogonal directions in plan to avoid torsional response under lateral force. The column is kept square having size 450x450mm and size of the column is taken to be same throughout the height of the structure. The beams are of uniform size 230x450mm having 130mm thick slab for all the spans is considered.

2.2 Material Properties

M-25 grade of concrete and Fe 500 grade of reinforcing steel are used for all the frame models considered in this study. The unit weights of concrete and masonry is taken as 25kN/m^3 and 20 kN/m^3 respectively. The modulus of elasticity for concrete and brick masonry is taken as 25000MPa (as per IS: 456-2000) and 1255MPa respectively. The poison ratio of concrete is 0.2 and that of brick masonry is 0.15.

3. MODELS CONSIDERED FOR ANALYSIS

Following three main types of models having P+5, P+7, P+9 and P+11 numbers of storeys are considered and analysed for various seismic zones (III, IV & V) and soil types (Hard & Medium) with response reduction factor 5 and importance factor 1; using seismic coefficient method and response spectrum method.

♣ ***M-1 Bare Frame Model*** (RCC frame taking infill masonry weight, neglecting effect of stiffness) (fig.02)

♣ ***M-2 Full Infill Model*** (Effect of stiffness is considered in addition to taking weight of infill) (fig.03)

♣ ***M-3 Open Ground Storey Model*** (Effect of stiffness is considered in addition to weight of infill excluding ground storey) (fig.04)

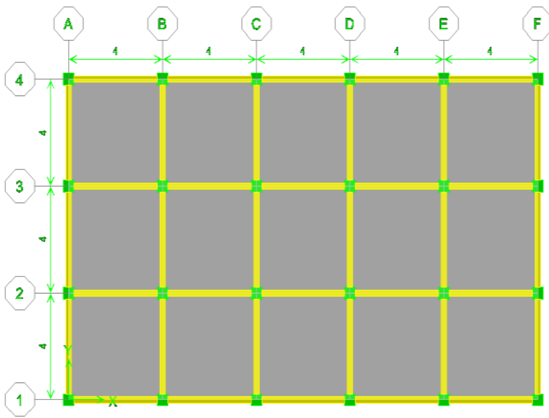

FIG. 01 BUILDING PLAN

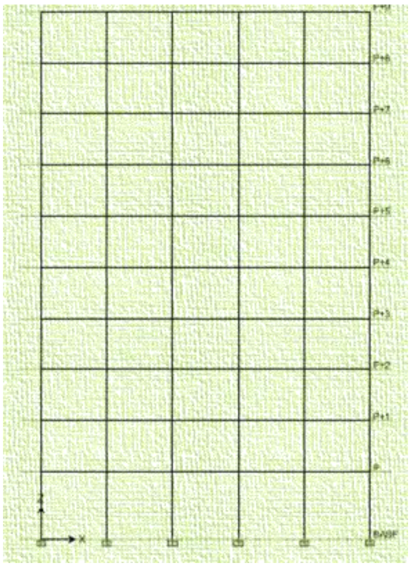

FIG. 02 BARE FRAME (M-1)

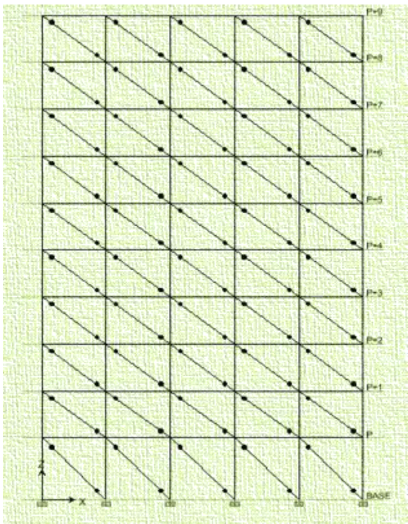

FIG. 03 FULL INFILL FRAME (M-2)

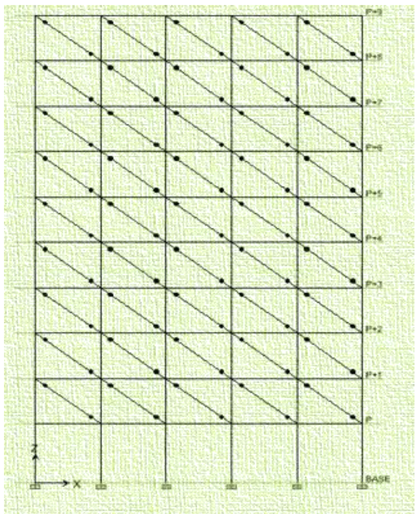

FIG. 04 OPEN GROUND STOREY FRAME (M-3)

4. MODELLING OF FRAME MEMBERS AND INFILL WALLS

The structural members are modeled with the aid of commercial software ETABS 9.7.4 in compliance with the codes IS 456: 2000 and IS 1893: 2002. The frame members are modeled with rigid end conditions. The floor slabs were assumed to act as diaphragms, which ensure integral action of all the lateral load-resisting elements. The floor finish on the floors is taken to be 1kN/m^2. The live load on floor is taken as 4kN/m^2. In seismic weight calculations 50% of the floor live load is considered in the analysis.

4.1 Modelling of Infill Walls

For an infill wall located in a lateral load-resisting frame, the strength and stiffness contribution of the infill is to be considered. Non-integral infill walls subjected to lateral load behave like diagonal struts. Thus an infill wall can be modeled as an equivalent 'compression' strut in the building model. Rigid joints connect the beams and columns, but pin joints connect the equivalent struts to the beam-to-column junctions. The thickness of equivalent strut is equal to the thickness of infill wall and width of diagonal strut as indicated in Fig.05 is computed as

$$Wef = 0.175(\lambda hH)^{-0.4}(H^2+L^2)^{0.5} \quad \text{……….……….. (1)}$$

$$\lambda h = 4\sqrt{\frac{E_i t \sin 2\theta}{4E_c I_c H_i}} \quad \text{……………………..……… (2)}$$

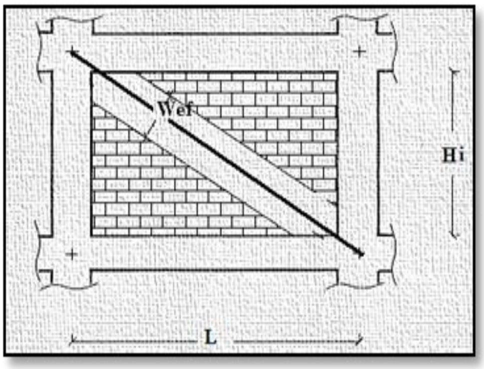

FIG. 05 EQUIVALENT DIAGONAL STRUT BY DEMIR AND SEVRIS APPROACH

Where,
Wef = width of diagonal strut
H, L =height and length of the frame,
Ec, Ei = Elastic moduli of the column and of the infill panel,
t = thickness of the infill panel,
θ = angle defining diagonal strut,
Ic = modulus of inertia of the column,
Hi = height of the infill panel.

5. RESULTS AND DISCUSSION

The seismic analysis for all the RC frame models that includes bare frame, infilled frame and open ground storey frame has been done by using software ETABS 9.7.4 and the results are tabulated below. The parameters which are to be studied are time period and increase of base shear by changing various seismic zones and soils.

Table 1: Time Period Variation by SCM & RSM

MODEL TYPE	SOIL TYPE	ZONE (Z)	Time Period (sec)						OBSERVATIONS (% Increase)					
			BARE (I)		FULL INFILL (II)		OGS (III)		I/II		I/III		III/II	
			Tx	Ty	Tx	Ty	Tx	Ty	Tx	Ty	Tx	Ty	Tx	Ty
P+5	I, II	III, IV, V	1.1512	1.1966	0.7745	0.8181	0.9001	0.9372	**48.64**	**46.27**	**27.90**	**27.68**	**16.22**	**14.56**
P+7			1.5173	1.5849	1.0186	1.085	1.1473	1.2056	**48.96**	**46.07**	**32.25**	**31.46**	**12.63**	**11.12**
P+9			1.887	1.981	1.2691	1.3645	1.3985	1.4845	**48.69**	**45.18**	**34.93**	**33.45**	**10.20**	**8.79**
P+11			2.2628	2.3873	1.527	1.6597	1.656	1.777	**48.19**	**43.84**	**36.64**	**34.34**	**8.45**	**7.07**

Table 2: Base Shear Variation by Seismic Coefficient Method

MODEL TYPE	SOIL TYPE	ZONE (Z)	BASE SHEAR Variation (kN)						OBSERVATIONS (% Increase)					
			BARE (I)		FULL INFILL (II)		OGS (III)		II/I		III/I		II/III	
			Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy
P+5	I	III	289.34	278.34	474.79	449.47	404.47	388.47	64.09	61.48	39.79	39.56	17.38	15.70
		IV	434.01	417.51	712.18	674.21	606.71	582.7						
		V	651.02	626.27	1068.27	1011.32	910.06	874.05						
	II	III	393.5	378.55	645.71	611.28	550.08	528.31						
		IV	590.25	567.82	968.56	916.93	825.12	792.47						
		V	885.38	851.73	1452.85	1375.39	1237.69	1188.71						
P+7	I	III	293.17	280.65	482.89	453.41	425.53	404.95	64.71	61.56	45.15	44.29	13.48	11.97
		IV	439.75	420.98	724.34	680.12	638.08	607.42						
		V	659.63	631.47	1086.5	1020.17	957.45	911.13						
	II	III	398.71	381.69	656.73	616.64	578.72	550.73						
		IV	598.06	572.53	985.1	924.96	868.08	826.09						
		V	897.09	858.8	1477.65	1387.44	1302.13	1239.13						
P+9	I	III	294.86	280.91	485.36	451.45	437.85	412.49	64.61	60.71	48.49	46.84	10.85	9.44
		IV	442.28	421.37	728.04	677.17	656.77	618.74						
		V	663.43	632.05	1092.07	1015.76	985.16	928.11						
	II	III	401	382.04	660.09	613.97	595.47	560.99						
		IV	601.51	573.06	990.14	920.95	893.21	841.49						
		V	902.26	859.59	1485.21	1381.43	1339.82	1262.23						
P+11	I	III	295.34	279.93	484.58	445.93	444.7	414.32	64.08	59.30	50.57	48.01	8.97	7.63
		IV	443.01	419.9	726.87	668.89	667.05	621.48						
		V	664.51	629.85	1090.3	1003.34	1000.57	932.23						
	II	III	401.66	380.71	659.03	606.46	604.79	563.48						
		IV	602.49	571.06	988.54	909.7	907.19	845.22						
		V	903.73	856.59	1482.81	1364.54	1360.78	1267.83						

Table 3: Base Shear Variation by Response Spectrum Method

MODEL TYPE	SOIL TYPE	ZONE (Z)	BASE SHEAR Variation (kN)						OBSERVATIONS (% Increase)					
			BARE (I)		FULL INFILL (II)		OGS (III)		II/I		III/I		II/III	
			Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy	Vx	Vy
P+5	I	III	264.71	253.63	429.92	404.19	385.94	368.16						
		IV	397.07	380.44	644.88	606.29	578.92	552.25	62.41	59.36	45.80	45.16	11.39	9.79
		V	595.61	570.66	967.32	909.43	868.37	828.37						
	II	III	352.99	337.14	582.84	544.07	523	498.3						
		IV	529.48	505.71	874.26	816.11	784.5	747.44	65.12	61.38	48.16	47.80	11.44	9.19
		V	794.22	758.56	1311.39	1224.16	1176.75	1121.17						
P+7	I	III	269.89	257.71	435.31	411.84	401.08	378.69						
		IV	404.84	386.56	652.96	617.76	601.62	568.03	61.29	59.81	48.61	46.94	8.53	8.75
		V	607.26	579.84	979.44	926.64	902.44	852.05						
	II	III	360.36	344.77	581.11	547.18	540.22	508.11						
		IV	540.54	517.16	871.66	820.77	810.33	762.17	61.26	58.71	49.91	47.38	7.57	7.69
		V	810.81	775.74	1307.49	1231.16	1215.49	1143.25						
P+9	I	III	269.15	257.62	443.08	413.75	409.3	386.23						
		IV	403.73	386.43	664.62	620.62	613.95	579.35	64.62	60.60	52.07	49.92	8.25	7.13
		V	605.6	579.64	996.93	930.93	920.92	869.02						
	II	III	364.92	348.22	586.09	546.02	549.62	518.45						
		IV	547.38	522.32	879.14	819.04	824.43	777.67	60.61	56.80	50.61	48.89	6.64	5.32
		V	821.06	783.49	1318.71	1228.55	1236.65	1166.51						
P+11	I	III	273.51	258.67	443.23	409.49	414.82	384.68						
		IV	410.27	388	664.85	614.24	622.23	577.02	62.05	58.31	51.67	48.71	6.85	6.45
		V	615.4	582	997.27	921.35	933.35	865.54						
	II	III	368.6	348.12	591.18	550.02	561.59	522.66						
		IV	552.9	522.19	886.77	825.03	842.38	783.98	60.39	58.00	52.36	50.13	5.27	5.24
		V	829.35	783.28	1330.15	1237.54	1263.57	1175.97						

Comparison between Bare frame and Infilled frame:

- There is a considerable difference is observed in the time period of bare frame and infilled frame.
- The time period of bare frame model in x and y direction is 49% and 46% more than the full infill frame for all the models considered in the study by both SCM & RSM.
- The base shear of infilled frame is more than bare frame and hence there will be a considerably difference in the lateral force along the height of the building.
- The base shear of full infill frame model in x and y direction is 64% and 61.5% more than the bare frame for all the models considered in the study by SCM.
- The base shear of full infill frame model in x and y direction is approximately 60% more than the bare frame for all the models considered in the study by RSM.

Comparison between Bare frame and Open Ground Storey frame:

- The time period of bare frame model in x and y direction is 27-36% more than the open ground storey frame for all the models considered in the study by both SCM & RSM.
- The base shear of open ground storey frame model in x and y direction is 40-50% more than the bare frame for all the models considered in the study by SCM.
- The base shear of open ground storey frame model in x and y direction is 45-52% more than the bare frame for all the models considered in the study by SCM.

Comparison between infilled frame and open ground storey frame:

- The time period of infilled frame model in x and y direction is 16-7% more than the open ground storey frame for all the models considered in the study by both SCM & RSM.
- The base shear of open ground storey frame model in x and y direction is 17-7% more than the infilled frame for all the models considered in the study by SCM.
- The base shear of open ground storey frame model in x and y direction is 11-5% more than the infilled frame for all the models considered in the study by SCM.

6. CONCLUSIONS

In this paper seismic analysis of RC frame models has been studied that includes bare frame, infilled frame and open ground storey frame. From the seismic analysis of RC frames following conclusions are drawn.

1. The seismic analysis of RC frames should be performed by considering the infill walls in the analysis. For modelling the infill wall equivalent diagonal strut method can be used effectively.
2. The presence of infill wall can affect the seismic behavior of frame structure to large extent and the infill wall increases the strength and stiffness of the structure.
3. The seismic analysis of bare frame structure leads to under estimation of base shear. Thus other response quantities such as time period, natural frequency and base shear are not significant.
4. The under estimation of base shear may lead to collapse of structure during earthquake shaking therefore it is important to consider the effect of infill walls in the seismic analysis of structure.
5. The time period of infilled frame is less than open ground storey frame and bare frame because of increased stiffness of the structure.
6. The base shear of infilled frame is more than open ground storey frame and bare frame because of increased mass of structure.
7. The time period and base shear for open ground storey frame is intermediate of bare and unfilled frame.

Present study will help the civil engineers to give an idea of increase in base shear value with increase in height and the behavior of multi storied RC framed building with change in zone and soil types.

REFERENCES

1. Venkatsai R. N. et. al, (2013). "*Seismic Behavior of Multistoried Buildings*", IJERA, Vol. 3 (4), pp 2076-2079.
2. Khandave A. V., (2012). "*Seismic Response of RC Frame Buildings with Soft Storeys*", IJERA, Vol. 2 (3), pp 2100-2108.
3. Kasnale A. S. and Dr. Jamkar S. S., (2013). "*Study of Seismic Performance for Soft Basement of RC Framed*", IJESRT, pp 9-14.
4. Arlekar J. N. et. al, (1997). "*Seismic Response of RC Frame Buildings with Soft First Storeys*", Proceedings of the CBRI *Golden Jubilee Conference on Natural Hazards in Urban Habitat*, 1997, New Delhi.

5. Vinod Housur, "*Earthquake Resistant Design of Building structures*", First Edition, WILEY Publication.
6. IS 1893(Part1): 2002, "*Criteria for Earthquake Resistant Design of Structures*", Fifth Revision, Bureau of Indian Standards, New Delhi