Performance based seismic evaluation of G+2 RC building with varying central opening in infill walls.

Renu Dambal[1], Basavaraj Gudadappanavar[2]

[1] Mtech, CAD Structural-Civil Engineering Department, SDMCET Dharwad, Karnataka, India
[2] Asst. Professor –Civil Engineering Department, SDMCET Dharwad, Karnataka, India

---***---

Abstract - *In the multistory buildings the masonry infill walls will be advantageous for resisting the lateral forces during earthquake. The lateral force resistance of the building is reduced by providing the openings in the infill walls the openings may be in the form of windows, doors etc which are unavoidable. The present paper studies the performance based seismic weakness of the G+2 three dimensional reinforced multistorey building model, with different percentage of openings at center in unreinforced masonry infill walls ranging from 10 to 35%.The building models which are taken into account are bare frame, full closed frame and unreinforced masonry infill walls are modeled by providing equivalent diagonal strut with pin jointed. Seismic analysis for load combination 1.2(DL+LL+EL) for seismic zone III is carried out for three storeyed building. The present paper also present the performance based seismic evaluation using nonlinear static push over analysis. The results natural period, lateral displacement, storey drift, base shear, are obtained and compared for different six building models. The analysis is carried out using ETABS nonlinear version 9.1.1. The results obtained for different loading conditions for three storeyed building showed that the non-ductile RC multi storey building with central opening greater than 30%, in the unreinforced masonry infill walls are more weak, and when the central openings is more than 40% the lateral stiffness should not be taken into consideration.*

Key Words: Infill wall, Base shear, Performance point Drift, Displacement.

1. Introduction

Analysis of the building damage from strong earthquake reveals many instances in which the presence of masonry infill has advantageously affected the lateral resistance of reinforced concrete multistoried structure. Although the infill panel significantly improves both stiffness and strength of the structure, but the role of these infill panel is not considered into account because of deficient knowledge of combined behavior of frame and infill.

Even though the infill walls increases the lateral strength of the structure it is unavoidable to provide the openings in the infill walls which reduce the lateral strength of the structure. Further provision of openings in the walls of the soft storey building proves to be critical condition. Reduction of the lateral strength of the structure due to the presence of the openings in the infill walls depends upon the various factors such as percentage of opening, aspect ratio and the location of the opening in the masonry wall. Analysis and design of the structure without considering the reduction of the lateral strength due to the presence of openings in the infill wall, and considering the stiffness of the whole infill wall could lead to a crucial condition during the earthquakes.

The present work aims to evaluate the variation in the lateral strength of the building due to presence of central opening of aspect ratio one, in the unreinforced masonry infill walls. The various models with the varying percentage of central opening from 10 to 35 percent have been analyzed by seismic analysis methods prescribed by the Indian seismic code [1].

2. MODELING AND ANALYSIS

In the present paper lateral load analysis as per the seismic code IS 1893 –Part1 -2002 for the bare structure and in filled structure are carried out and an effort is made to study the effect of seismic loads on them and their capacity and demand is evaluated using nonlinear static pushover analysis. The ground storey height is 4.8 m and upper storey's height is 3.6 m. The building is commercial building used for official purpose. The building is assumed to be located in zone III, M-20 grade of concrete and Fe-415 grade of steel are considered. Density of RC is considered as 25Kn/m3, modulus of elasticity of brick masonry is 2100 x 103 KN/m2.

2.1 Member Properties

Table -1: Member properties

Beam size	0.30 x 0.45 m
Column size (mid & core)	0.30 x 0.60 m
(peripheral)	0.30 x 0.45m

2.2 Analytical Procedure For Modeling

In the present project, 3d models and analyses is carried out by utilizing the ETABS Nonlinear software. The software is able to perform the geometric nonlinear analysis of space frames under static loading, taking into account both geometric nonlinearity and material inelasticity, it also considers the P-Δ effect. The software accepts static loads (either forces or displacements) as well as dynamic (accelerations) actions and has the ability to perform eigenvalue analysis, nonlinear static pushover and linear dynamic analyses.
The analysis and design of the building is carried out using ETABS computer program. The following topics describe some of the important areas in the modeling.

2.3 Models Considered

In the present paper three-dimensional RC multi storey buildings of three storeys is considered. The plan and elevation are shown in Fig. 1 and Fig 2. The 3D view and elevations of different building models considered are shown in Figs.3. The building is deliberately kept symmetric in both the orthogonal directions in plan to avoid torsional response under pure lateral forces. The analytical models considered are as below,

1st model: Building is considered as bare frame structure i.e the buildings at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall is considered however the stiffness is not taken into consideration but masses are included.

2nd model: The building at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall is considered however the stiffness is also taken into consideration along with the masses.

3rd model : The building at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall with opening size of 10% of the total area at center is considered and even stiffness and masses are taken into consideration.

4th Model : The building at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall with opening size of 20% of the total area at center is considered and even stiffness and masses are taken into consideration.

5th Model : The building at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall with opening size of 30% of the total area at center is considered and even stiffness and masses are taken into consideration.

6th Model : The building at first storey has no walls but in the upper storey's the unreinforced brick masonry infill wall with opening size of 35% of the total area at center is considered and even stiffness and masses are taken into consideration.

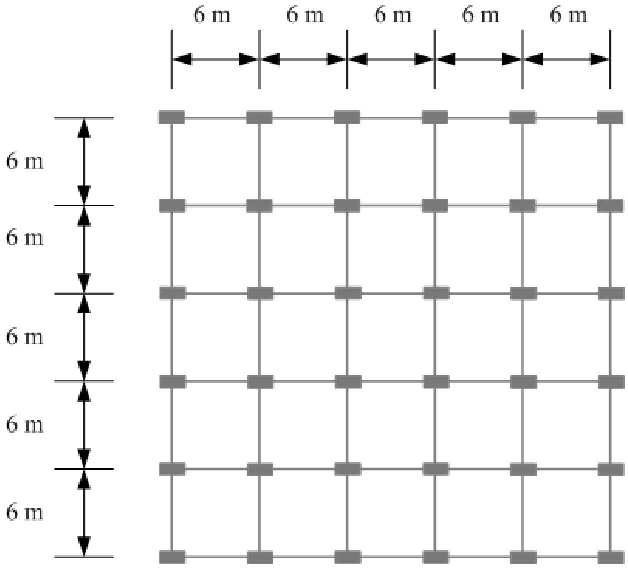

Fig -1: Plan of the building.

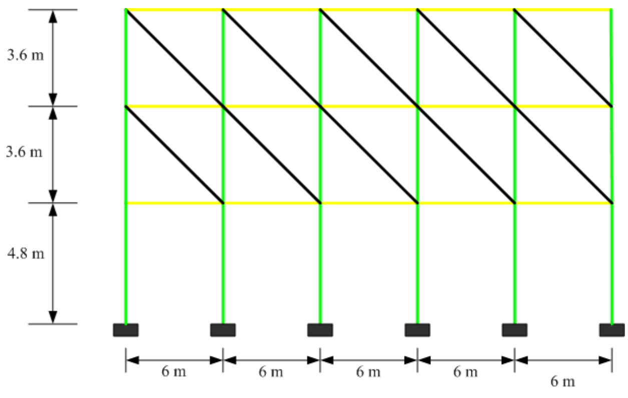

Fig -2: Elevation of three storeyed infill frame building models with openings (10% to 35%).

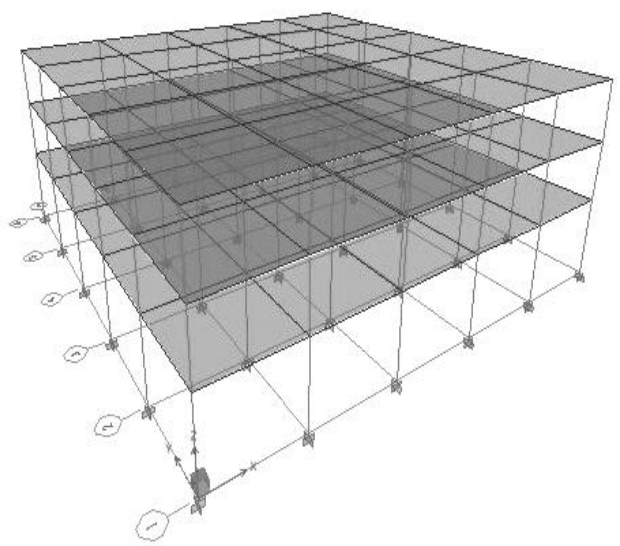

Fig -3: 3D view of three storeyed bare frame building

3. RESULTS AND DISCUSSION

3.1 Fundamental Natural Periods

The codal (IS 1893 (Part 1): 2002) and analytical (ETABS) fundamental natural periods of the various building models are tabulated in the table 2. The variations of the fundamental natural period of all the six models for 1.2(DL+LL+EL) load combinations are tabulated in below table.

Table -2: Fundamental natural period for 1.2(DL+LL+EL) seismic-designed buildings.

Model No	Analytical (sec)	Code (sec)
	3 Storey	3 Storey
1	1.505	0.330(78.07%)
2	1.209	0.197(83.71%)
3	1.245	0.197(84.18%)
4	1.306	0.197(84.92%)
5	1.371	0.197(85.63%)
6	1.421	0.197(86.14%)

From the above table it is very clear that, stiffness of the building is directly proportional to its natural frequency and hence inversely proportional to the natural period. That is, if the stiffness of building is increased the natural period goes on decreasing. The variation of the natural period from the model 1 to model 6 , illustrate that the presence of the opening in the infill wall reduces the stiffness of the building, thereby increasing the natural period, and the amount of reduction in the stiffness depends on the percentage of opening.

3.2 Base Shear

The base shear for the equivalent static method (VB) calculated through etabs modeling and manually calculated base shear as per ID 1893 (Part 1):2002, for the various building models are listed in the table below.

Table -3: Base shear for three storeyed building models

Model No	Longitudinal Direction		Transverse Direction	
	$\overline{V_B}$ (kN)	VB (kN)	$\overline{V_B}$ (kN)	VB (kN)
1.2(DL+LL+EL) Seismic-designed Building Models				
1	1639.07	2002.1	1639.07	2002.1
2	2553.25	2002.1	2553.25	2002.1
3	2333.42	1915.7	2333.42	1915.7
4	2216.51	1829.3	2216.51	1829.3
5	2079.46	1742.9	2079.46	1742.9
6	1957.22	1699.7	1957.22	1699.7

The base shear is a function of mass, stiffness, height, and the natural period of the building structure. From the previous results it is very clear that the fundamental natural periods obtained from the code, fall far short from that of the analytical natural periods.

From the above results it is observed that, the base shear in three storey building models as the stiffness and the mass of the infill wall reduces with the increase in percentage of opening the base shear goes on decreasing at an average rate of 6.4 % for model 2 to model 6 for equivalent static method along both the longitudinal and transverse directions.

3.3 Lateral Displacement

The lateral displacements obtained for equivalent static method for three storey building models, along both the longitudinal and transverse direction are listed in the table below.

Table -4: Lateral displacement (mm) of three storeyed models for 1.2(DL+LL+EL) seismic-designed buildings (Equivalent static method).

Storey No	Model No					
	1	2	3	4	5	6
Longitudinal Direction						
3	20.6	11.6	12.4	13.9	15.2	16.7
2	14.8	11.5	12.4	13.5	13.9	14.2
1	14.1	11.1	11.5	12.1	12.9	13.5
Transverse Direction						
3	25.4	17.5	18.2	19.9	20.5	22.5
2	21.7	17.5	17.9	19.6	19.9	20.5
1	21.1	17.4	17.7	19	19.9	20.1

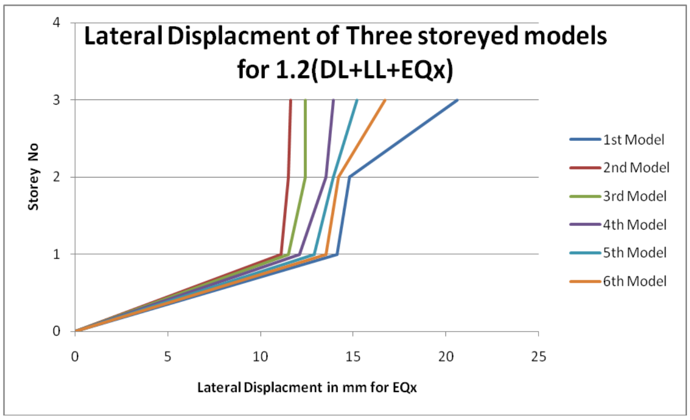

Fig -4: Lateral displacement of three storeyed models for 1.2(DL+LL+EL) seismic designed buildings.

The lateral displacement of a building is a function of the stiffness, the lateral displacement of the structure will decrease when the lateral stiffness increases; hence the displacement of the model 2 is less than the model 1. For three storeyed buildings the percentage reductions in the lateral displacement for equivalent static method, of model 2 when compared with model 1 are 43.6 % and 31.1 % for 1.2(DL+LL+EL) seismic-designed building models along both the longitudinal and transverse directions respectively.

As the stiffness of walls is not considered for model 1 (bare frame) the variation of the lateral storey displacement curve is linear in nature. And for the model 2 the ground floor don't have the infill walls and the stiffness of the upper storey walls is considered, as the stiffness of only upper storey walls is considered, all the upper storeys act as a single structure and moves almost together, and ground floor columns suffer the larger displacement as shown in the above figure.

As the stiffness decreases from model 2 to model 6 due to the increase in the percentage of central opening, the lateral displacement increases from model 2 to model 6.

3.4 Inter Storey Drift

Inter storey drifts calculated for all the building models along both the longitudinal and transverse directions for the Equivalent Static method are listed in the tables below.

Table -5: Inter storey drift (mm) of three storeyed models for 1.2(DL+LL+EL) seismic designed buildings (Equivalent static method)

Storey No	Model No					
	1	2	3	4	5	6
Longitudinal Direction						
3	1.624	0.029	0.072	0.136	0.444	0.923
2	2.084	0.107	0.186	0.369	0.958	1.509
1	3.891	2.317	2.422	2.527	2.654	2.764
Transverse Direction						
3	1.593	0.006	0.033	0.083	0.327	0.667
2	2.476	0.011	0.057	0.192	0.792	1.389
1	5.256	3.633	3.789	3.95	4.225	4.327

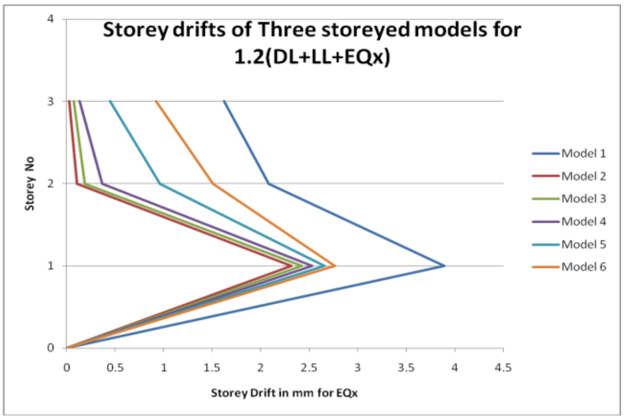

Fig -4: Storey drifts of three storeyed models for 1.2(DL+LL+EQx) seismic designed buildings.

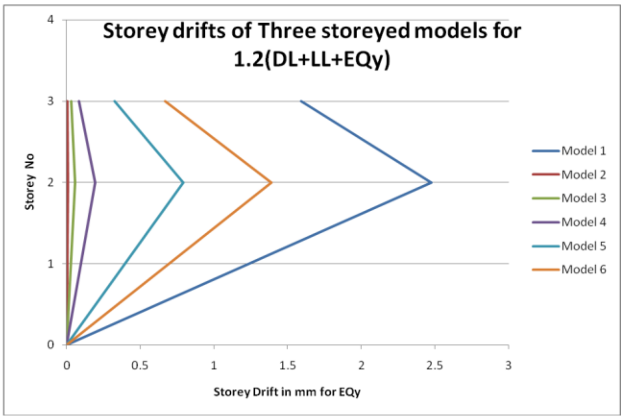

Fig -5: Storey drifts of three storeyed models for 1.2(DL+LL+EQy) seismic designed buildings.

3.5. Performance Evaluation Of Building Models

Performance based seismic evaluation of all the six models is carried out by nonlinear static pushover analysis, for all the seismic-designed building models along both longitudinal and transverse directions.

3.5.1 Location Of Hinges And Performance Point

The base force and the displacement at the performance point (PP), and the location of the hinges along both the longitudinal and transverse directions for all the building models are tabulated in table below.

Table -6: Performance point and location of hinges for three storeyed 1.2(DL+LL+EL) seismic designed building models along longitudinal direction for EQX (Equivalent Static Method)

Model No	Performance Point		Location of Hinges								
	Base Force (kN)	Displacement (mm)	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
1	18792.4	61	536	16	4	16	0	4	0	0	576
2	18298.6	33	776	16	16	6	0	2	0	0	816
3	18542.2	27	780	12	12	10	0	2	0	0	816
4	18491.3	44	764	12	28	11	0	1	0	0	816
5	19050.6	44	744	28	20	21	0	3	0	0	816
6	19087.3	54	744	20	12	37	0	3	0	0	816

Table -7: Performance point and location of hinges for three storeyed 1.2(DL+LL+EL) seismic designed building models along longitudinal direction for EQY (Equivalent Static Method)

Model No	Performance Point		Location of Hinges								
	Base Force (kN)	Displace	A-B	B-IO	IO-	LS-CP	CP-	C-D	D-E	>E	TOTAL
1	17535.7	85	540	4	8	20	0	4	0	0	576
2	17896.6	54	783	9	16	7	0	1	0	0	816
3	18228.7	56	776	12	16	11	0	1	0	0	816
4	17112.5	66	788	16	4	6	0	2	0	0	816
5	17791.2	69	796	4	0	14	0	2	0	0	816
6	17354.6	75	780	12	8	14	0	2	0	0	816

Seismic evaluation of building models for three storeyed, is carried out using nonlinear static pushover analysis method, after analysis and design of the building models according to IS: 456-2000 using the design feature of ETABS. The base force of the building which is dependent on the lateral strength, as the stiffness of walls is considered in soft storeyed buildings, the base force is more than that of bare frame. And for all building models for three storeys the base force at performance point along longitudinal direction is more than that along transverse direction.

Due to increase in the opening percentage in the infill wall the stiffness goes on decreasing due to which the base force at the performance point also decreases from model 2 to model 6.

4. CONCLUSION

From the results discussed in this paper with respect to the building models considered leads to the following conclusions:

- Fundamental natural period of the building is a function of its lateral stiffness, therefore fundamental natural period increases with increase in the percentage of opening. The stiffness of masonry infill wall should not be considered if the percentage of central opening is more than 40%.
- Fundamental natural periods obtained from codal empirical formula (IS 1893: 2002 (Part 1)) are lesser than actual fundamental natural period (ETABS 9.1.1).
- Base shear of the building is directly proportional to the lateral stiffness and the mass of the building, as the stiffness of the building decreases with the increase in the percentage of central opening from model 2 to model 6, the base shear decreases at an average rate of 6.4%.
- Lateral displacement at the roof of building models, increases with the increase in central opening in the masonry infill walls, and it is found more for the

building models with the percentage of central opening more than the 30%.

- Due to the soft ground storey, the storey drift is found more in the ground storey.
- The base force at the performance point decreases with the increase in the percentage of central opening in the masonry infill wall.

REFERENCES

[1] IS: 1893(Part1)-2002, Criteria for earthquake resistant design of structure, General Provision and Building.
[2] IS:456-2000 "Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, India
[3] Amlan k.Sengupta and Himanshu Goyal (2008). "Indices for assessing seismic vulnerability of buildings based on linear and non-linear static analyses" Journal of Structural Engineering, Vol.35, No.1, April-May 2008 pp.9-15.
[4] M. M. Maniyar, R. K. Khare, S Ghosh and T. Chakrapani (2008). "Seismic collapse of non-seismic RC frames" Journal of Structural Engineering, Vol.35, No.1, April-May 2008 pp.1-8.
[5] B.P Annapurna and H.Sharada Bai "Effect of Size of Openings within the Infill on the Members of Multistoreyed Infill Frame", Structural Engineering Convention, an International meet, Dec 14-16, 2006, Department of Civil Engineering, IISc Bangalore.
[6] Kanitkar, R. and Kanitkar, V. (2004), "Seismic performance of conventional multi-storey buildings with open ground floors for vehicular parking", The Indian Concrete Journal February 2004, pp 99-104
[7] G Mondal and S K Jain "Lateral Stiffness of Unreinforced Brick Infilled RC Frames with Central Openings" Proceedings of the 8th U.S. National Conference on Earthquake Engineering, April 18-22, 2006, San Francisco, California, USA

BIOGRAPHIES

The author is final year Mtech CAD structural civil engineering department from SDMCET Dharwad affiliated to VTU Belgaum.

The author is currently Working as Assistant Professor in Civil Engg. Department of SDMCET Dharwad affiliated to VTU Belgaum.

.

