EVALUATION OF SEISMIC DESIGN MAGNIFICATION FACTOR FOR REGULAR AND L SHAPE OPEN GROUND STOREY BUILDINGS

Sukanya V Raj[1], Vivek Philip[2]

[1]PG Student, Department of Civil Engineering, SAINTGITS College of Engineering, Kottayam, Kerala
[2]Assistant Professor ,Department of Civil Engineering, SAINTGITS College of Engineering, Kottayam, Kerala, India

---

Abstract-. The multi storied structures that extant in urban areas have open ground storey (OGS) as an inevitable feature, essentially to accommodate parking or reception lobbies in the ground storey. These structures have greater affinity to collapse during earthquake because of the soft storey mechanism developed in ground storey, due to absence of infill. In conventional practice the effect of infill stiffness is neglected, however this is not factual in the case of OGS buildings for the reason that, when OGS buildings are analyzed as bare frames the member forces are under estimated. Therefore the bending moment and shear forces of ground storey columns and beams need to be magnified. The Indian seismic code IS 1893- 2002 recommends that the members of the open ground story to be designed for 2.5 times the member forces obtained without considering the effects of masonry infill in any story. This Magnification factor(MF) is specified for all the buildings with soft stories irrespective of the extent of irregularities and the method is quite empirical. This paper is an attempt towards the study of Magnification Factor for Regular and Plan irregular open ground storey buildings for different storey heights . The Magnification Factor is computed by comparison of Response spectrum Analysis of bare frame and infilled frame of different models using ETABS 2015.The results shows that there is no need for applying MF to soft storey beams, as increased demands due to stronger beams would further increase the seismic demands on the columns . Indian standards recommends a higher value of MF for low rise buildings and at the same it is inadequate for high rise buildings. It is also advisable to analyze OGS buildings as infilled fames considering infill stiffness rather than bare frames.

***Key Words*: Open Ground Storey, Infill stiffness, Plan irregularity, Magnification Factor, Equivalent strut method**

1. INTRODUCTION

Multi- storied buildings provide a large floor area in a relatively small area of land in urban centers. These multi-storied building, by virtue of its height, is affected by lateral forces to an extent that they play an important role in their structural design. Hence, these high rise buildings, if not designed properly for lateral forces, may lead to complete collapse and hence loss of life and property. Earthquake field investigations repeatedly confirm that irregular structures suffer more damage than their regular counterparts. This is recognized in seismic design codes, and restrictions on abrupt changes in mass and stiffness are imposed. Soft story are irregular building configurations that are a significant source of serious earthquake damage. These configurations that are essentially originated due to architectural decisions have long been recognized by earthquake engineering as seismically vulnerable.

1.1 Open Ground Storey

The majority of buildings that failed during the Bhuj earthquake (2001) and Gujarat earthquake were of the open ground storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behavior in the ground storey of this type of building. Many urban multi storey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storeys. The upper storeys have brick infilled wall panels. Reinforced concrete (RC) framed buildings with infill walls, are usually analyzed and designed as bare frame, without considering the strength and stiffness contributions of the infills. However during earthquakes, these infill walls contribute to the lateral load resistance and the behavior of infilled framed building is different from that predicted for bare frame structures. In the current practice OGS buildings are analysed as bare frames and are designed by multiplying MF of 2.5 to member forces of ground storey. The effect of stiffness contributed by infills present in upper storeys are being neglected.

1.2 Magnification Factor

The MF is applied to OGS buildings to compensate the stiffness irregularity in ground storey due to absence of infills. The Indian seismic code IS 1893- 2002 recommends that the members of the soft story to be designed for 2.5 times the seismic story shears and moments, obtained without considering the effects of masonry infill in any story. The factor of 2.5 is specified for all the buildings with soft stories irrespective of the extent of irregularities and the method is quite empirical and may be too conservative and thus have further scope for improvement.

$$MF=\frac{\textit{Member forces of infilled frame}}{\textit{Member forces of bare frame}}$$

2. PROBLEM STATEMENT

In the present scenario open ground stories (story stiffness less than 70% of that in the story above or less than 80% of the average lateral stiffness of the three stories above) to be designed for 2.5 times the seismic story shears and moments, obtained without considering the effects of masonry infill in any story. The factor of 2.5 is specified for all the buildings with soft stories irrespective of the extent of irregularities and the method is quite empirical and may be too conservative and thus there is a need for detailed study on Magnification Factor for OGS buildings considering the lateral stiffness contributed by infills present in upper storeys. Many buildings in the present scenario have irregular configurations, both in plan and elevation. The past experiences from earthquake showed that buildings with irregular configuration are more vulnerable to the danger of collapse than irregular buildings due to the non-uniform distribution of loads. This paper is an effort to study the effect of infill stiffness, storey height and plan irregularity in OGS buildings and inorder to predict a more realistic value of MF considering various Factor

3.1 Modeling of Infill as Equivalent Diagonal Struct

The effect of the masonry panels in infilled frames subjected to lateral loads could be equivalent to a diagonal strut.

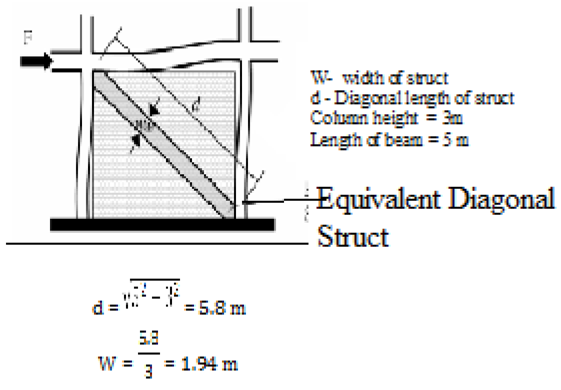


Fig-3: Equivalent Diagonal Stuct

4. OBJECTIVES OF PRESENT STUDY

- To study the effect of strength and stiffness of infill walls in regular and irregular OGS buildings.
- To study the effect of infill stiffness and various storey heights in evaluation of MF for regular and irregular OGS buildings.
- To check the applicability of Mf 2.5 recommended by code in regular and irregular OGS building by incorporating infill stiffness in analysis.
- To predict a more realistic MF for regular and irregular OGS building.

5. MODELLING OF THE BUILDING

The study is carried out on a (G+4), (G+9), (G+14)and (G+19) OGS building having rectangular and L shape plan with same plan area configurations. The building is considered to be located in Zone IV as per IS 1893:2002. The building is modeled using the software ETABS 2015. The dimensions of the beams, columns and slabs also the loads applied are summarized in the Table1.

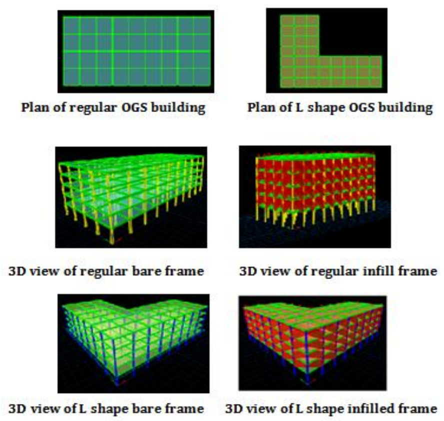


Fig-4: Plan and 3D view of models considered

Table 1: Details and dimensions of building models

Type of structure	Special moment resisting RC frame
Grade of concrete	M30
Grade of steel	Fe 415
Plan area	900 m^2
Typical Floor height	3 m
Ground floor height	4 m
Slab thickness	150 mm
Wall thickness	230 mm
Beam size	400mmx300mm
Column size	300mmx300mm 400mmx400mm 450mmx450mm 500mmx500mm 550mmx550mm 600mmx600mm 650mmx650mm
Live load on floor and roof	3kN/$m^2$and 1.5kN/m^2
Wall load	13.8 KN /m^2

6. RESPONSE SPECTRUM ANALYSIS

Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). Response spectrum can be interpreted as the locus of maximum response of a SDOF system for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-resistant design of structures

7. RESULTS AND DSCUSSIONS

After analyzing the models various results are obtained. These results are evaluated by preparing various graphs. The MF was computed for different models by taking ratio of member forces of infilled fame to bare fame.

7.1 Results of regular OGS building for different number of stories are tabulated below

7.1.1 Time Period

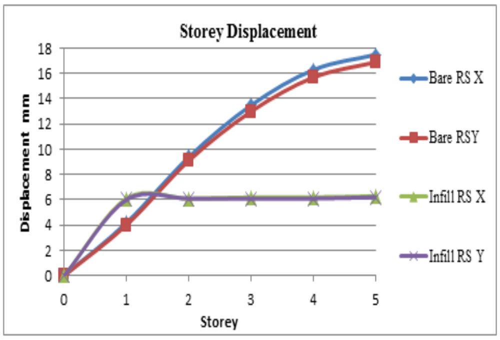
No of stories	Time Period	
	Bare	Infill
5	1.483 sec	0.761 sec
10	2.33 sec	0.749 sec
15	4.26 sec	0.867 sec
20	4.6 sec	0.979 sec

7.1.3 Base Shear

No of Stories	Base Shear			
	Bare		Infil	
	RS X	RS Y	RS X	RS Y
5	1301 KN	1254 KN	2388 KN	2363 KN
10	1812 KN	1777 KN	5374 KN	5204 KN
15	1939 KN	1853 KN	7569 KN	6779 KN
20	2311 KN	2352 KN	10975 KN	8203 KN

7.1.4.Storey Displacement

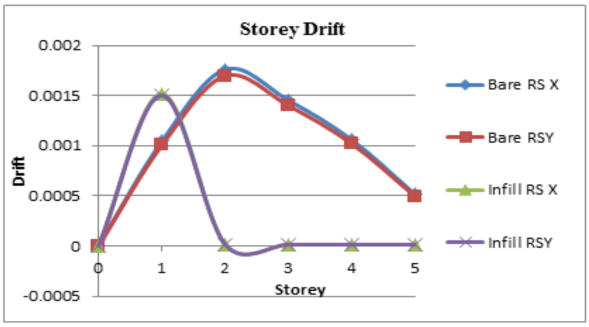
No of stories	Displacement			
	Bare		Infill	
	RS X	RS Y	RS X	RS Y
5	17.5mm	16.9 mm	6.3 mm	6.2 mm
10	25.2mm	26.7 mm	6.1 mm	7.2 mm
15	46.5mm	44.4 mm	11.2 mm	10 mm
20	66.5 mm	67.7 mm	15 mm	11.2 mm



7.1.5 Storey Drift

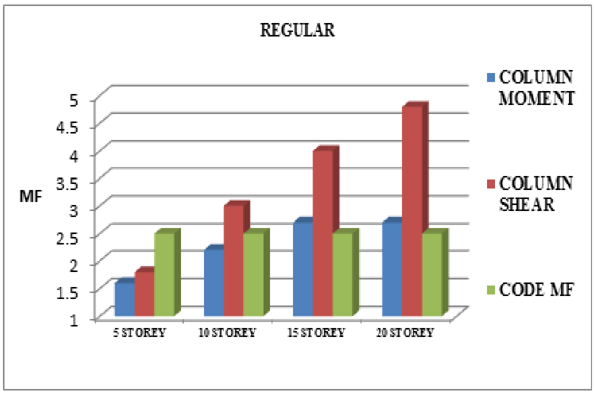
No of Stories	Storey No	Storey Drift			
		Bare		Infill	
		RS X	RS Y	RS X	RS Y
5	2	0.00176	0.001696	0.000017	0.000017
	1	0.001042	0.001004	0.001519	0.001503
10	2	0.001251	0.001227	0.000039	0.000038
	1	0.000854	0.000838	0.001464	0.001417
15	2	0.001242	0.001187	0.000026	0.000021
	1	0.000763	0.00073	0.001468	0.001313
20	2	0.001308	0.001331	0.000035	0.000026

	1	0.000701	0.000714	0.0012	0.000897



7.1.6Magnification Factor

No of Stories	Column Moment /Column Shear	Magnification Factor	% variation from code MF
5	CM	1.6	36% < 2.5
	CS	1.8	28% < 2.5
10	CM	2.2	10% <2.5
	CS	3	19 % > 2.5
15	CM	2.7	8 % >2.5
	CS	4	60 % >2.5
20	CM	2.7	8%>2.5
	CS	4.8	92%>2.5



7.2 Results of L shape OGS building for different number of stories are tabulated below

7.2.1Time period

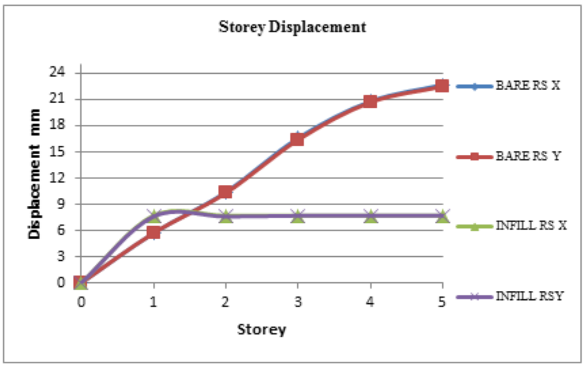
Storey No	Time Period Sec	
	Bare	Infill
5	1.798 sec	0.926 sec
10	3.029 sec	0.885 sec
15	4.372 sec	0.836 sec
20	4.519 sec	0.892 c

7.2.3Storey Shear

No of stories	Base shear			
	Bare		Infill	
	RS X	RS Y	RS X	RS Y
5	1053 KN	1047 KN	1925 KN	1915 KN
10	1413 KN	1401 KN	4371 KN	4282 KN
15	1734 KN	1737 KN	7637 KN	7681KN
20	2347 KN	2368 KN	11474 KN	9162 KN

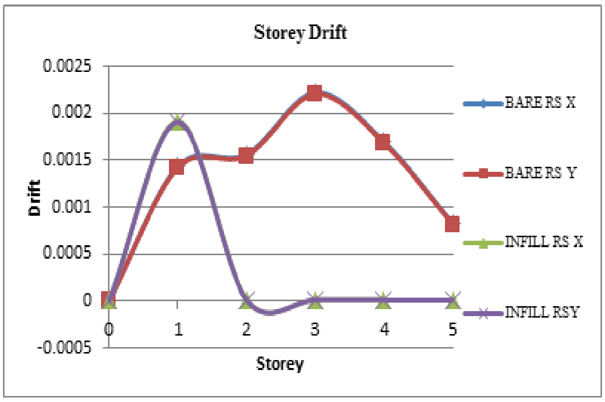
7.2.4 Storey Displacement

No of stories	Base shear			
	Bare		Infill	
	RS X	RS Y	RS X	RS Y
5	22.7mm	22.5mm	7.7mm	7.7mm
10	41.2mm	40.9mm	7.6mm	7.5mm
15	70.8mm	71mm	8.9mm	8.1mm
20	78.4mm	79.1mm	12.5mm	10mm



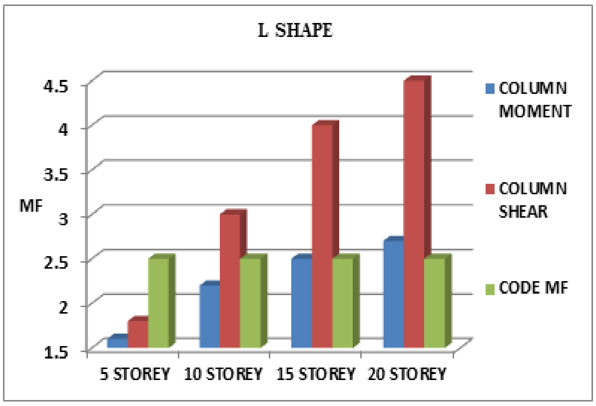
7.2.5 Storey Drift

No of Stories	Storey No	Storey Drift			
		Bare		Infill	
		RS X	RS Y	RS X	RS Y
5	2	0.00156	0.001548	0.000011	0.000011
	1	0.001432	0.001422	0.001914	0.001904
10	2	0.001817	0.001801	0.000026	0.000026
	1	0.001187	0.001176	0.001748	0.001712
15	2	0.00192	0.001923	0.000044	0.00004
	1	0.001047	0.001049	0.001431	0.001308
20	2	0.001497	0.00151	0.00006	0.000048
	1	0.000797	0.000804	0.001215	0.000969



7.2.6 Magnification factor

No of Stories	Column Moment /Column Shear	Magnification Factor	% variation from code MF
5	CM	1.6	36% < 2.5
	CS	1.8	28% < 2.5
10	CM	2.2	12 % < 2.5
	CS	3	20%> 2.5
15	CM	2.5	=2.5
	CS	4	60%> 2.5
20	CM	2.7	8%>2.5
	CS	4.5	80%>2.5



8. CONCLUSIONS

- The time period obtained for infilled frame was much less than bare frame.
- The base shear obtained for infilled frame was much greater than bare.
  The increase in base shear is due to stiffness of infill walls, which proves that when OGS building are analyzed as bare frame Base shear are under estimated.

- In infilled frame upper stories moves as a monolithic structure and the bottom storey moves separately inducing large bending Moment and shear forces in ground columns
- The second storey has maximum drift in bare frames while first storey has maximum drift in infilled frames.
- It shows that infilled frames exhibit more realistic behavior of OGS buildings than bare frames.
- The MF obtained for 63 % of models studied was greater than 2.5 and for only 37% the MF was less than 2.5.
- MF 2.5 in case of low rise building, cannot be considered conservative as columns designed for such a high MF will be less ductile due to heavy reinforcement leading to uneconomical design consideration.
- MF 2.5 in case of high rise buildings , is also not conservative as columns designed for less MF 2.5 will be unsafe due to insufficient strength and total collapse of ground columns occurs.
- Beams between the stilt storey and the infilled storey are not to be designed for the increased demands because stronger beams would further increase the seismic demands on the columns
- MF 2.5 for beams is not valid.
- The MF increases with increase in storey height, but it is independent of plan irregularity
- There is also no effect of Seismic Zone on MF of OGS building.
- The magnification Factor obtained for response spectrum in x direction and y direction was same.
- There is no need for applying any Magnification Factor to beams of soft storey, when stiffness of infill is considered in Open ground storey building
- The real dynamic behavior of OGS buildings are only reflected when infill stiffness is considered.
- It would be ideal to model a OGS building considering infill stiffness .
- The use of MF is not that much relevant in case of plan irregular buildings and some other alternatives are needed to be investigated.
- Therefore it can be concluded that if infill stiffness is considered in OGS building, there is no need for high MF 2.5 in low rise building.

ACKNOWLEDGEMENT

I am thankful to my guide, Asst. Professor, Vivek Philip in Civil Engineering Department for his constant encouragement and able guidance. Also I thank my parents, friends and above all the god almighty for making this work complete.

REFERENCES

[1] Asokan A. (2006) Modelling of masonry infill walls for nonlinear static analysis of buildings under seismic loads. MS Thesis. Indian Institute of Technology Madras. Chennai.

[2]. Crisafulli, F.J. (1997). Seismic behavior of reinforced concrete structures with masonry infills. PhDThesis. University of Canterbury. New zealand

[3] Davis, R. (2008) Seismic resistant design of open ground storeyed building. PhD. Thesis, IIT Madras, Chennai

[4] Dharmesh Vijaywargiya, Dr. Abhay Sharma, and Dr. Vivek Garg" Seismic Response of a Mid Rise RCC Building with Soft Storey at Ground Floor" (2014)Dharmesh Vijaywargiya et volume 02 issue 06 july 2014 international journal

5].Fardis, M.N. and Panagiotakos, T.B. (1997). Seismic design and response of bare and masonry-infilled reinforced concrete buildings. Journal of Earthquake Engineering. 1:3, 475-503.

[6] IS1893-1 (2002): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings [CED 39: Earthquake Engineering

[7] Kanitkar, R., and Kanitkar, V. (2004) Seismic performance of conventional multi-storey buildings with open ground floors for vehicular parking. The Indian Concrete Journal. 78:2, 99-104.

[8] Kaushik, H. (2006). Strengthening schemes for open ground storey buildings. PhD. Thesis Indian Institute of Technology, Kanpur.

[9] Madan, A., Reinhorn, A.M., Mander, J.B. and Valles, R.E. (1997). Modelling of Masonry Infill Panels for Structural Analysis. ASCE Journal of Structural Engineering. 123, 1295-1301.

[10] Munde P. K.and Magarpatil H.R" Seismic Response of Rc Framed Masonry Infilled Buildings With Soft First Storey"(2012) MIT College of Engineering, Pune, Maharashtra, India.

[11] R. Davis1, D. Menon, A. M. Prasad "Evaluation of Magnification Factors for Open Ground Storey Buildings using Nonlinear Analyses"(2008) Department of Civil Engineering , Indian Institute of Technology, Madras. India , The 14thWorld Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[12] Ranjit V. Surve and D. S. Jagtap, Prof. Y. P. Pawar" Performance based Analysis of Multistoried Building with Soft Storey at Different Levels"(2015) International Journal of Engineering Research & Technology (IJERT)ISSN: 2278-0181IJERTV4IS040394 (This work is licensed under a Creative Commons Attribution 4.0 Interntional License.)Vol. 4 Issue 04, April-2015

[13] Saneinejad A and Hobbs B (1995), Inelastic design of infilled frames, ASCE Journal of Structural Engineering. 121, pp 634-650.

[14] S R Satish Kumar and J L Srinivasan," Performance Based Design of Reinforced Concrete Open Ground Storey Buildings"(2015) Department of Civil Engineering, Indian Institute of Technology Madras, Chennai 600 036, India.

[15] Subramanian N. (2004). Discussion on seismic performance of conventional multi-storey building with open ground floors for vehicular parking by Kanitkar and Kanitkar. The Indian Concrete Journal. 78:4, 11-13.

[16] Tuladhar P and Kusunoki K (2005), Seismic Design of the Masonry Infill RC Frame buildings with first soft storey, iisee.kenken.go.jp accessed april 2012.

[17] IS 456: 2000: Code of practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi.