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Seismic Behavior of Multistory Infilled R.C Frame with Or without Opening Including Stilted Storey by Using "Equivalent Diagonal Strut Method"

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ABSTRACT
In many cities of India, it is very common to leave the first storey of masonry infilled reinforcement concrete (RC) frame building open preliminary to generate parking space or any other purposes. Open first storey building is also known as "stilted buildings", "pilotis", or "soft storey". The presence of infill wall alters the behavior of the building. This type of building is showed vulnerability during past earthquakes. The failure pattern was observed in the open first buildings during the Jabalpur earthquake (1997), Bhuj earthquake. Generally, engineers analysis the building without considering the infill wall stiffness for conservative design. But this may not be always true, especially for vertically irregular buildings with discontinuous infill walls. Hence, the modelling of infill walls in the seismic analysis of framed buildings is imperative. Upper storeys are much stiffer than the open ground storey. Thus, the upper storeys move almost together as a single block, and most of the horizontal displacement of the building occurs in the soft storey itself. In this paper, symmetrical Special RC moment-resisting frame building situated in seismic zone V is considered with different height G+3, G+6, G+9. In the present study, it is attempt to access the effect of infill walls with support condition (fixed and hinged), opening at centre and corner (10%, 20%,30%) and infill wall panel at each corner of building frame on the seismic behaviour of OFS buildings.

Keywords
equivalent static and response spectra anlaysis; etabs;RC frame;equivalent diagnol strurt method, multistorey special moment resistant frame, openings at corner and centre, open first storey with adjacent side infill.

1. INTRODUCTION
Many urban multistorey buildings in India today have open first storey as an unavoidable feature. This leave the open first storey of masonry infilled reinforced concrete frame building primarily to generate parking in the first storey. It has been known for long time that masonry infill walls affect the strength & stiffness of infilled frame structures. There are plenty of researches done so far for infilled frames, however partially infill frames are still the topic of interest. Though it has been understood that the infill's play significant role in enhancing the lateral stiffness of complete structures. Infills have been generally considered as non-structural elements & their influence was neglected during the modeling phase of the structure. A soft storey building is a multi-storey building with one or more floors which are "soft" due to structural design. These floors can be especially dangerous in earthquakes. As a result, the soft storey may fail, causing what is known as a soft storey collapse. Soft storey buildings are characterized by having a storey which has a lot of open space. Parking garages, for example, are often soft stories, as are large retail spaces or floors with a lot of windows. While the unobstructed space of the soft storey might be aesthetically or commercially desirable, it also means that there are less opportunities to install shear walls, specialized walls which are designed to distribute lateral forces. If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft storey building. This soft storey creates a major weak point in an earthquake, and since soft stories are classically associated with reception lobbies retail spaces and parking garages, they are often on the lower stories of a building, which means that when they collapse, they can take the whole building down with them, causing serious structural damage which may render the structure totally unusable. As per Indian standard 1893 (part –I) 2002 code (BIS-2002) some design criteria are to be adopted after carrying out the earthquake analysis ,in which the columns and beams of the soft stories are the designed for 2.5 times the storey shears and moments calculated under seismic loads.

2. MODELLING OF INFILL WALL AS DIAGNOL STRUT

2.1 Width of the diagonal strut for infill without opening
Based on the study of available literature on various infill wall models conducted by Diana M. Samoila (2012), the study focuses on determining the width of compressed strut by means of different equations available in literature, but recommends the use of Paulay and Priestley (1992) relation. The infill influence on frame members is studied on several models, as the single strut model, the three-strut model and finite element models. By analyzing the resulting forces in the beam and columns both as values and distribution, it has been observed that the three-strut model can estimate local effects more precisely due to frame infill interaction.

$$w = \frac{d}{4}$$

Where, d = diagonal length of infill

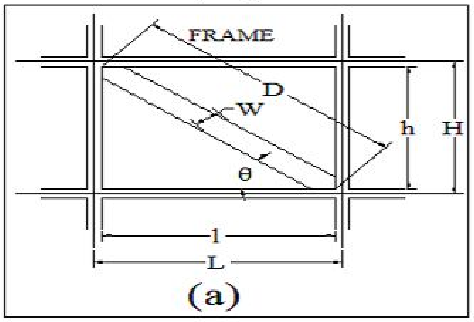
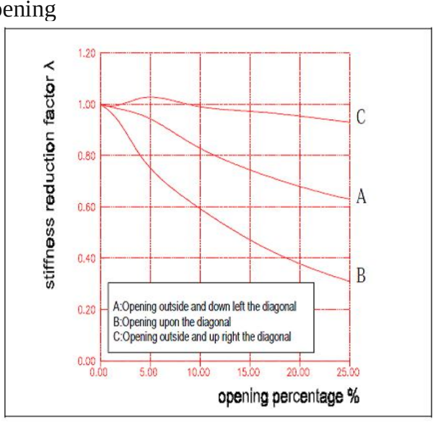


Figure 1. Equivalent diagonal strut model

2.2 Width of the diagonal strut with corner opening

Width of strut with opening = Stiffness Reduction factor X w without opening



$$\text{Opening-Area-Ratio } (\alpha_{co}) = \frac{\text{Area of Opening } (A_{op})}{\text{Area of Infill } (A_{infill})}$$

Fig 2: Stiffness Reduction Factor

2.3 Width of the diagonal strut with centre opening

Strut width reduction factor (Drf) = 3.58(Oar)^2-3.56(Oar)+1

Where,

Oar = percentage of centre opening.

3. ANALYSIS PROBLEM

In the present study, symmetrical special moment resisting four bay each 5m with different height G+3, G+6, G+9 with the typical storey height 3m and the thickness of infill class A table molded brick is 230mm. modulus of elasticity of infill is 5500 and according to difference in internal stiffness and vertical irregularities different typical models are considered with different support conditions (fixed and hinged):

1. bare frame
2. infill frame
3. open first storey
4. open first storey with adjacent side infill
5. opening centre 10%
6. opening centre 20%
7. opening centre 30%
8. opening corner 10%
9. opening corner 20%
10. opening corner 30%

Total number of modes = 60

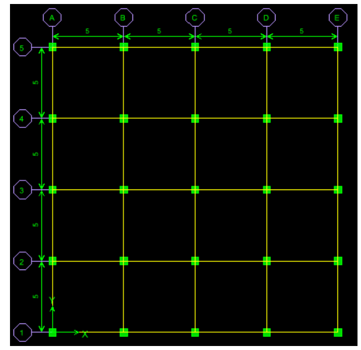


Figure 2. Typical Plan of building

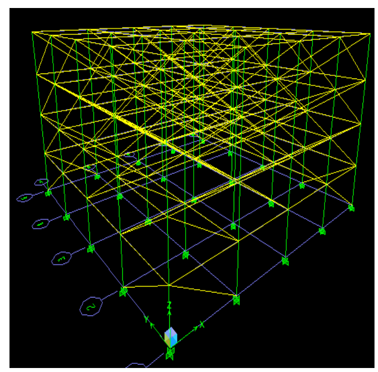


Figure 3. Diagonal Strut for adjacent side infill

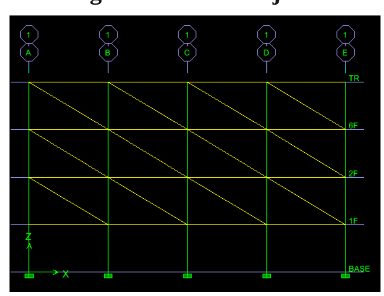


Figure 4. Diagonal strut for open first storey

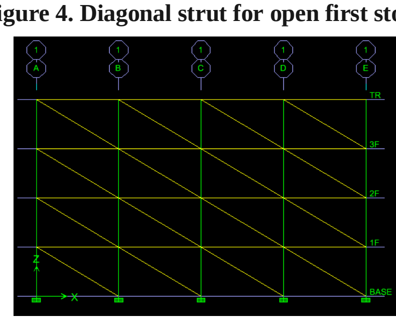


Figure 5. Diagonal strut for infill

3.1 Structural details

Table 1. Structural details

Type of Structure	Multistory rigid jointed plane frame (SMRF)
Seismic Zone	V
Number of stories	Four (G+3), Seven (G+6) And Ten (G+9)
Floors Height	3 m
Infill wall	230 mm
Type of soil	medium
Size of column	500x500, 650x650, 750x750 (mm)
Size of Beam	230x400 (mm)
Depth of Slab (RCC)	125 mm
Live load	2 kN/m^2
Terrace Water Proofing	2.5 kN/m^2
Floor Finishes	1.25 kN/m^2
Material Unit weights	a) Concrete = 25 kN/m^3 b) Masonry = 20 kN/m^3
Modulus of Elasticity of Masonry	5500 N/m^2
Damping in Structure	5%
importance factor	1.5

3.2 Width of diagonal strut

model	**Infill In(m)**	**Opening at centre in (m)**			**Opening at corner In (m)**		
		10%	**20%**	**30%**	**10%**	**20%**	**30%**
G+3	1.299	0.883	0.883	0.883	1.065	1.065	1.065
G+6	1.267	0.861	0.861	0.861	1.039	1.039	1.039
G+9	1.246	0.847	0.847	0.847	1.021	1.021	1.021

4. ANALYTICAL ASSESSMENT

4.1 Response Spectra analysis for fixed support

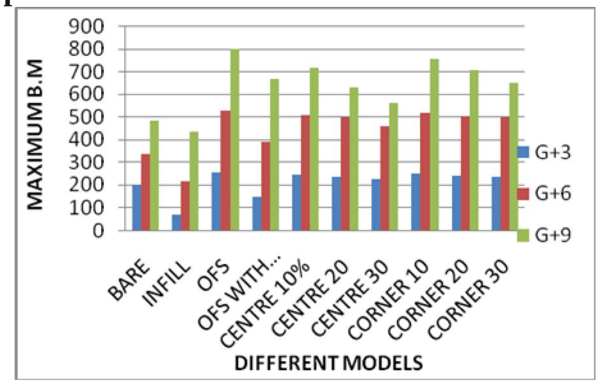


Figure 6. maximum B.M. for First Storey column

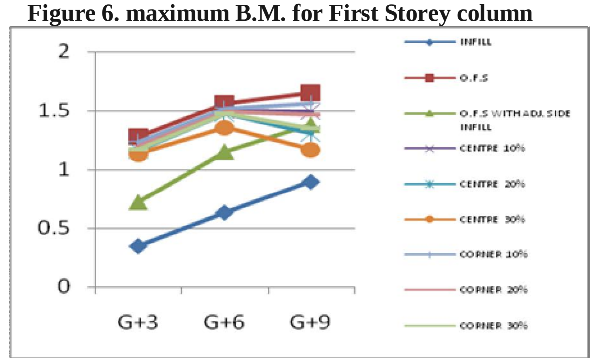


Figure 7. Typical magnification factor for different models

4.2 Response Spectra analysis for Hinged support

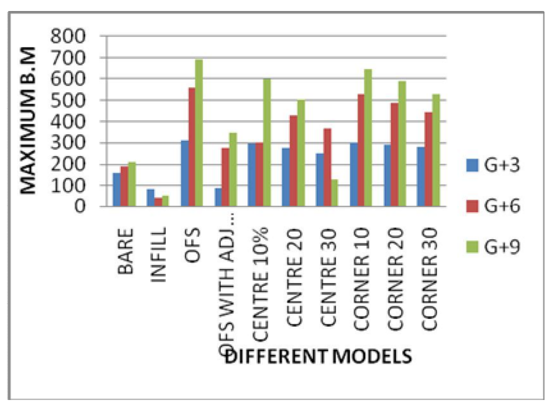


Figure 8. maximum B.M. for First Storey column

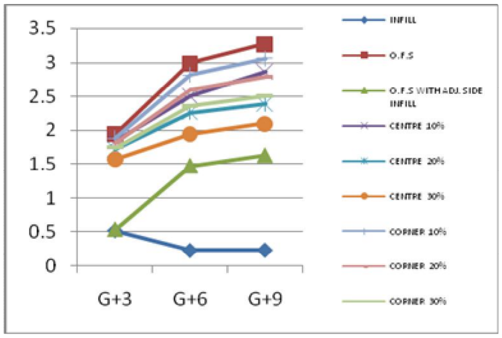


Figure 9. Typical magnification factor for different models

4.3 Equivalent static analysis for fixed support

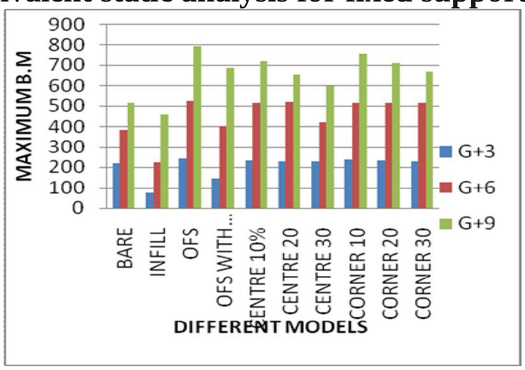


Figure 10. maximum B.M. for First Storey column

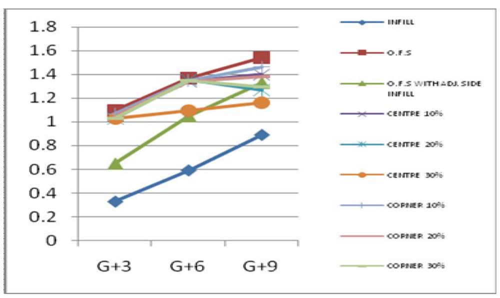


Figure 11. Typical magnification factor for different models

4.3 Equivalent static analysis for hinged support

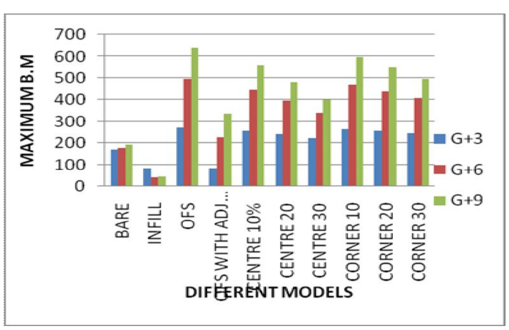


Figure 12. Typical magnification factor for different models

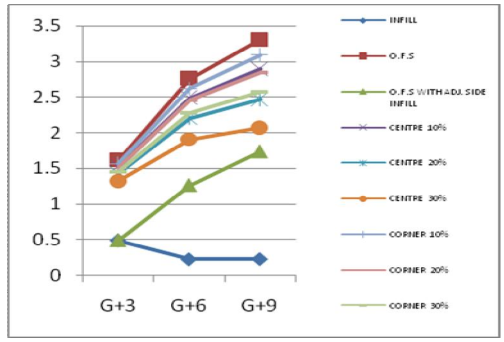


Figure 13. Typical magnification factor for different models

5. RESULTS AND DISCUSSIONS

In the present study, equivalent static analysis and response spectrum analysis was done with different support conditions, and different models on the basis of infill strength and stiffness to access the typical variation in the behavior of the structure. After analysis it clearly shows that

1. Magnification factor varies almost linearly with the height of the building
2. As per IS 1983 (Part 1):2002 magnification factor open soft story is 2.5
3. For fixed support magnification factor is 0.35 to 1.37 for G+3, 0.63 to 1.56 G+6, 0.9 to 1.65 G+9.
4. For hinged support magnification factor is 0.52 to 1.91 G+3, 0.22 to 2.98 G+6, 0.23 to 3.27 G+9
5. The least magnification factor shows in infill frame, due to presence of infill the stiffness of the structure increases.
6. And maximum magnification factor is observed in the open first storey, due to presence of soft storey.
7. Typical variation is observed due to presence of openings in centre or corner.

6. CONCLUSIONS

In the present study, equivalent static analysis and response spectrum analysis was done with different support conditions, and different models on the basis of infill strength and stiffness to access the typical variation in the behavior of the structure. After analysis it clearly shows that

1. Open first story is most vulnerability.
2. Hinges support shows maximum magnification
3. Magnification for fixed support as per IS code is 2.5 which is too high.

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