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Effect of Position of Infill Wall for Seismic Analysis of Low Rise Open Ground Storey Building

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ABSTRACT
Presence of infill walls in the frames alters the behaviour of the building under lateral loads. However, it is common industry practice to ignore the stiffness of infill wall for analysis of framed building. Engineers believe that analysis without considering infill stiffness leads to a 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. Infill walls can be modelled in commercial software using two-dimensional area element with appropriate material properties for linear elastic analysis. But this type of modelling may not work for non-linear analysis since the non-linear material properties for a two-dimensional orthotropic element is not very well understood. Seismic evaluation of an existing reinforced concrete (RC) framed building would invariably require a non-linear analysis. Published literature in this area recommends a linear diagonal strut approach to model infill wall for both linear (Equivalent Static Analysis and Response Spectrum Analysis) and nonlinear analyses (Pushover Analysis and Time History Analysis).

Keywords: *infill walls, diagonal strut, open ground storey, equivalent static analysis, response spectrum analysis, pushover analysis, low rise building*

INTRODUCTION

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the building itself for parking. These types of buildings having no infill masonry walls in ground storey, but infilled in all upper storeys are called Open Ground Storey (OGS) buildings.

There is significant advantage of these category of buildings functionally but from a seismic performance point of view such buildings are considered to have increased vulnerability. From the past earthquakes it was evident that the major type of failure that occurred in OGS buildings included snapping of lateral ties, crushing of core concrete, buckling of longitudinal reinforcement bars etc. Due to the presence of infill walls in the entire upper storey except for the ground storey makes the upper storeys 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 ground storey itself. In other words, this type of buildings sway back and forth like inverted pendulum during earthquake shaking, and hence the columns in the ground storey columns and beams are heavily stressed. Therefore it is required that the ground storey columns must have sufficient strength and adequate ductility. The vulnerability of this type of building is attributed to the sudden lowering of lateral stiffness and strength in ground storey, compared to upper storeys with infill walls.

The OGS framed building behaves differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral load. A bare frame is much less stiff than a fully infilled frame. When this frame is fully infilled, truss action is introduced. A fully infilled frame shows less inter-storey drift, although it attracts higher base shear (due to increased stiffness). A fully infilled frame Inclusion of stiffness and strength of infill walls in the OGS building frame decreases the fundamental time period compared to a bare frame and consequently increases the base shear demand and the design forces in the ground storey beams and columns. This increased design forces in the ground storey beams and columns of the OGS buildings are not captured in the conventional bare frame analysis.

The study deals with the seismic analysis of the building its evaluation. The building will be assumed to be a low rise building which will be solved manually, on available software. The study would be carried out to understand, the behavior or performance evaluation of building and effect of all the basic parameter of height, stiffness, base shear, storey drift and deflection etc. will be incorporated.

Idealization of Structure

Modeling of Structure

A 5 bay x2 bay building frames with 3 storey's on isolated footing have been considered. The height of each storey is taken as 3.1 m. Thickness for roof and floor is taken as 120mm and their corresponding dead load is directly applied on the beam. The brick infill with thickness 230 mm.

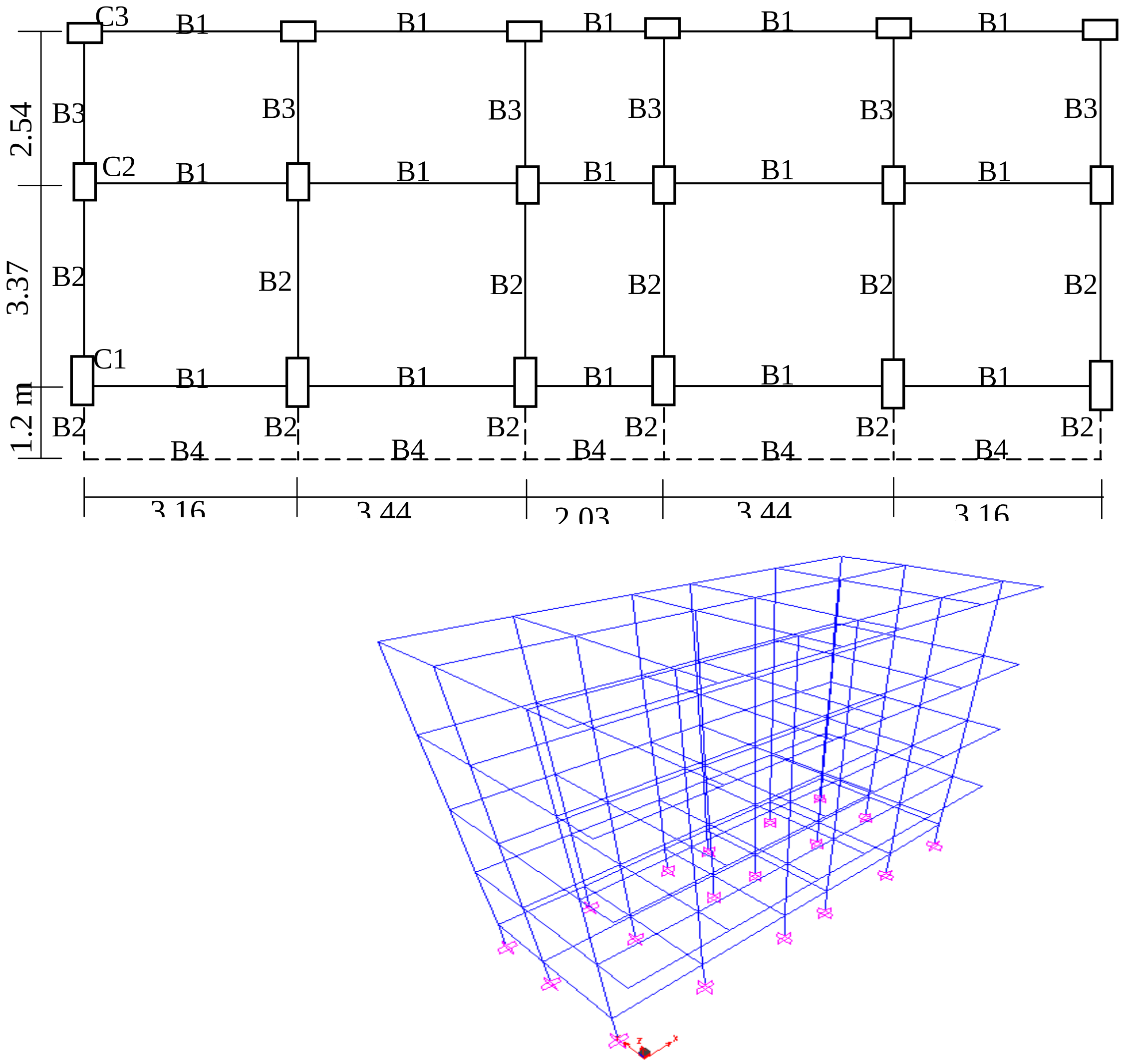
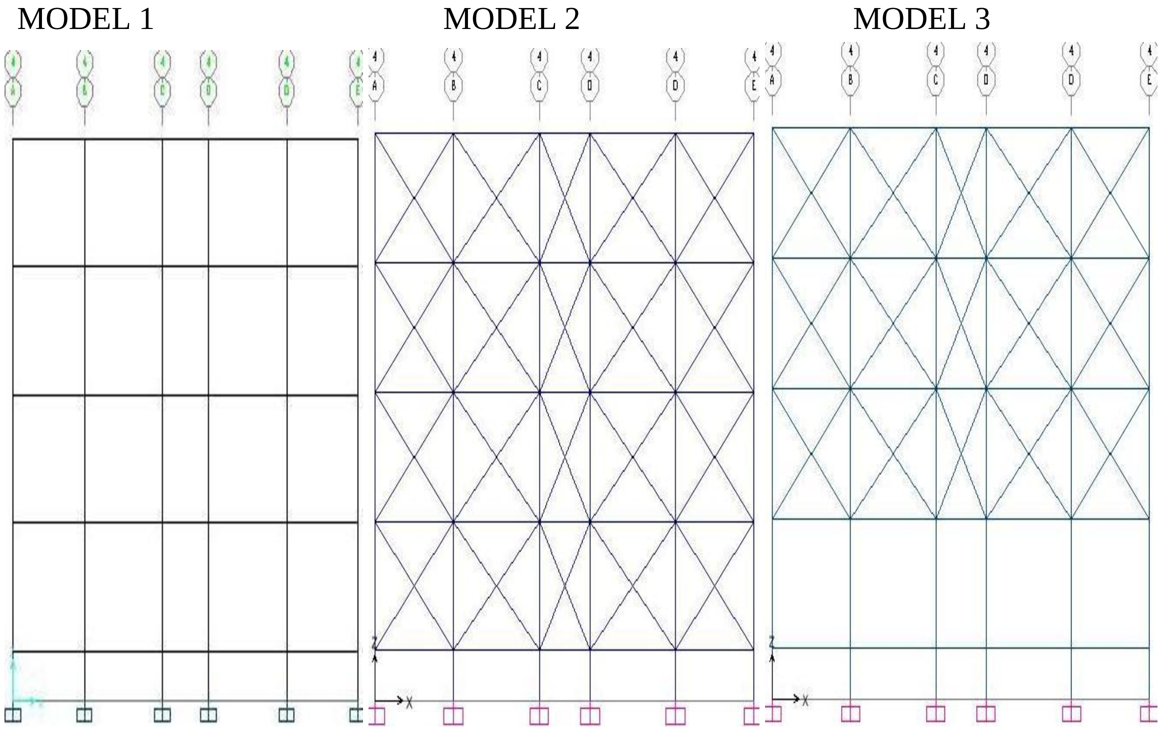


Fig. Plan and Elevation of building



MODEL 1 MODEL 2 MODEL 3

Fig 2: Plan elevation of various buildings

Analytical Methods for the Analysis of Infilled Frames

The most important step in the design process of the building is to create an appropriate mathematical model that will adequately represent its stiffness, mass distribution and energy dissipation so that its response to earthquake could be predicted with sufficient accuracy.

The designer can use static or dynamic analysis to design infilled frame subjected to seismic loading. Static or dynamic analysis can be classified into three broad categories; elastic, plastic and nonlinear analysis. For most application codes of practice recommend the elastic analysis. Four methods used for elastic analysis are,

1. Stress function method
2. Equivalent diagonal strut method
3. Equivalent frame method
4. Finite element method

Results from any of these four methods depend on the assumption made and idealization of the structure.

Equivalent frame method

In the equivalent frame method, frame infill composite system is replaced by an equivalent frame, and equivalent transformed properties are established. While transforming the frame infill members into equivalent section of frame using modular ratio of the frame and infill material, it is noted that calculation uses the corner part of the infill twice to calculate the moment of inertia of the beam and column of the frame. And hence it is expected to increase the stiffness of the frame, because corner of the infill stiffen both the beams and columns. Fig 2 shows the idealized rectangular infilled frame with an opening at the centre together with its dimensions. The cross section area of beam of an equivalent frame, Aeq is:

$A_{eq} = Bh_x + rt\,(b - b_o)$

Where $r = \left(\frac{Ei}{Ef}\right)$

The distance of centroid y, of the composite section from the outer fibre of the actual beam is:

$$\check{y} = \frac{1}{2}\left(\frac{Bh_x^2 + rt\,(b - b_o)(b - b_0 + 2h_x)}{Bh_x + rt(b - b_o)}\right)$$

Moment of inertia Ib with respect to the centroidal axis X for the beam member of the equivalent frame is:
$I_b = \Sigma (I_x + Ay^2) – A_{eq}\, y^{-2}$

In which the quantities on the left hand side refer to the actual frame member and the infill. Hence Ib is:

$$I_b = \frac{1}{12}\left[Bh_x^3 + rt(b-b_0)^3\right] + \frac{1}{4}\left[Bh_x^3 + rt(b-b_0)(b-b_0+2h_x)^2\right] - \frac{1}{4}\left[Bh_x^2 + \frac{rt(b-b_0)(b-b_0+2h_x)}{Bh_x + rt\,(b-b_0)}\right]^2$$

Calculation for the equivalent properties of the column member proceeds similarly

Displacement comparison for open ground storey

Displacement comparison for open ground storey in X direction

Zone	Floor Level	Without infill	Full infill	Open ground storey
II	GF	0.393	0.029	0.013
	1st Floor	4.234	0.049	2.372
	2nd Floor	8.191	0.073	2.404
	3rd Floor	11.273	0.096	2.433
	4th Floor	12.796	0.114	2.457
III	GF	0.629	0.046	0.021
	1st Floor	6.774	0.079	3.796
	2nd Floor	13.106	0.117	3.846
	3rd Floor	18.038	0.154	3.893
	4th Floor	20.474	0.183	3.932
IV	GF	0.943	0.07	0.032
	1st Floor	10.162	0.118	5.693
	2nd Floor	19.659	0.176	5.769
	3rd Floor	27.056	0.232	5.839
	4th Floor	30.711	0.275	5.898
V	GF	1.415	0.104	0.048
	1st Floor	15.242	0.177	8.54
	2nd Floor	29.488	0.264	8.654
	3rd Floor	40.585	0.347	8.758
	4th Floor	46.066	0.412	8.847

Displacement comparison for open ground storey in Y direction

Zone	Floor Level	Without infill	Full infill	Open ground storey
II	GF	0.222	0.02	0.048
	1st Floor	2.165	0.05	1.014
	2nd Floor	4.375	0.096	1.086
	3rd Floor	6.153	0.148	1.161
	4th Floor	7.164	0.199	1.235
III	GF	0.355	0.031	0.077
	1st Floor	3.464	0.08	1.622
	2nd Floor	7.001	0.153	1.738
	3rd Floor	9.845	0.237	1.857
	4th Floor	11.462	0.319	1.976
IV	GF	0.532	0.047	0.115
	1st Floor	5.196	0.12	2.433
	2nd Floor	10.501	0.23	2.606
	3rd Floor	14.768	0.356	2.786
	4th Floor	17.193	0.479	2.964
V	GF	0.799	0.071	0.172
	1st Floor	7.795	0.18	3.65
	2nd Floor	15.752	0.345	3.909
	3rd Floor	22.152	0.534	4.179
	4th Floor	25.79	0.718	4.446

CONCLUSIONS

The present study makes an effort to evaluate the effect of OGS building with respect to linear and non-linear dynamic analysis to regular building. The study as a whole identifies the influencing parameters, which can regulate the effect of open ground on displacement of building frames. A large number of curves exhibiting such variation for typical examples presented in this paper can help the designer to get a primary idea about effect of open ground storey in Low rise buildings.

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