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Seismic Performance of Infilled Frames with and without Opening

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Abstract: *The usual practice in the analysis of reinforced concrete frame structures is to analyse the frames with skeleton members comprising of only slabs, beams and columns. However, in reality the structures also possess masonry infill within most of the frames, but they are ignored in the models so as to minimize the computational works. Researchers have indicated that the frames comprising of masonry panels behave significantly stiffer as compared to bare frames. Masonry infill walls are mainly used to increase initial stiffness and strength of reinforced concrete frame buildings. In the present study, it is attempt to highlights the performance of masonry infilled reinforced concrete frames with and without opening under seismic forces. The opening is expressed in terms of various percentages. Currently publications like FEMA-273 and ATC-40 contain provisions for the calculation of stiffness of infilled frames mainly by modelling infill as an 'Equivalent diagonal strut'. In this paper an intermediate frame of a simple building (G+3) is considered for modelling of infill frame with and without opening using the equivalent diagonal strut using the software ETABS. It is concluded that the effect of opening in the masonry decreases the lateral stiffness in the frame and reduction factor, λ can be used as a multiplication factor to calculate the reduced equivalent width of diagonal strut. Later deflection and drift do not increase considerably beyond 40-50% of opening.*

Keywords- *Equivalent Diagonal Strut, Masonry infilled frame, Opening percentage, Seismic*

1. INTRODUCTION

In the analysis of Reinforced concrete framed structures, there is a trend of ignoring the existence of brick infill mainly due to the reasons of complicated computations. Only the frame is considered in the analysis, which actually saves tedious calculation time and effort, but the real existence of bricks within the frames being ignored, actually underestimates the capacity of the structure. From the studies of Kodur et al, 1998 [1]and Asteris et al, 2012 [2] it has been found that the brick infills actually contribute in enhancing the strength of the structure by resisting the lateral deflection of frames applied to horizontal forces. Again, the contribution has been felt primarily during the earthquake events, where, most of the infilled framed structures remain less damaged as compared to the frames which are left bare. It is also necessary to examine whether the contribution of infilled frames remain equally good when some openings are provided within the panels. Studies from Asteris et al, 2012 [2] also have indicated that the infills which include opening tend to be less effective, although, better than with the bare frames.

An infill wall reduces the lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. Hence, accounting for the infills in the analysis and design leads to slender frame members, reducing the overall cost of the structural system. The total base shear experienced by a building during an earthquake is dependent on its time period. The seismic force distribution is dependent on the stiffness and mass of the building along the height. The structural contribution of infill wall results into stiffer structure thereby reducing the storey drifts (lateral displacement at floor level). This improved performance makes the structural design more realistic to consider infill walls as a structural element in the earthquake resistant design of structures.

Infill walls in the frame are frequently contained in door and window opening which reduces the stiffness and load carrying capacity depending upon the size of the opening. From the literature it is found that many works are carried out by providing diagonal strut to replace the effect of infill. However not much of work has been carried out to replace or modify the width of diagonal strut to consider the effect of opening in the infill.

2. METHODOLOGY

The different techniques used for the numerical simulations of infilled frames can be divided into two groups namely local or micro models and simplified macro models [3]. The first group involves models that divide a structure into numerous elements to take into account the local effect in detail. The second group consists of simplified models based on a physical understanding of the behavior of the infill panel. This paper uses the second group's approach and considers the infill panels as equivalent diagonal struts, which carry loads only in compression. It included the modeling of brick infill panel as equivalent struts and studying the behavior of a bare frame, infill frame and infill frame with opening. Also the performance of brick masonry infill panel for displacements, drifts, lateral force and maximum base shear are compared with the performance of bare frame.

3. MODELLING

3.1 Equivalent Diagonal Strut Method

The equivalent diagonal strut approach is used for the analysis and design of infilled frames subjected to in-plane forces [4]. Fig.1 shows the details of equivalent strut model. Currently, the single strut model suggested by Mainstone is used in the response spectrum analysis of infilled RC frames with and without opening [1][4]. The Federal Emergency Management Agency (FEMA306) also uses it for calculating the equivalent width of a diagonal strut which is given by expression[6]:

$$W = 0.175\,(\lambda\, H)^{-0.4}\, D \qquad \ldots\ldots. (1)$$

$$\lambda = \sqrt[4]{\frac{E_i t \sin(2\theta)}{4 E_f I_c h}} \qquad \ldots\ldots.. (2)$$

Where,
Ei = Modulus of elasticity of the infill material, N/mm^2
Ef = Modulus of elasticity of the frame material, N/mm^2
Ic= Moment of inertia of column, mm^4
t = Thickness of infill, mm
H= Centre line height of frames, mm
h = Height of infill, mm
L = Centre line width of frames, mm
l = Width of infill, mm
D = Diagonal length of infill panel, mm
θ = Slope of infill diagonal to the horizontal.

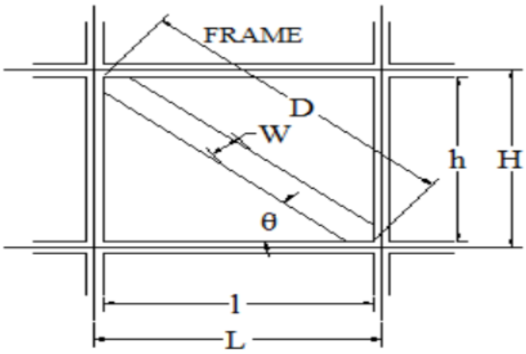

Fig.1: Brick infill panel as equivalent diagonal strut

3.2 Infill Frame with Opening

In order to consider the effect of openings in the masonry infill walls, a finite element technique called Method of Contact points proposed by Asteris is used[3]. Asteris et al presented the analytical results of the influence of opening size on the seismic response of masonry infilled frames [2]. Fig.2 shows the variation of the λ factor as a function of the opening percentage for the case of an opening on the compressed diagonal of the infill wall. The aspect ratio of opening is considered to be same as the aspect ratio of infill:

Opening percentage (α_w) = $\frac{Area\ of\ Opening}{Area\ of\ Infill}$ …….. (3)

Width of strut with opening = Stiffness Reduction factor as per Fig 2 x W without opening. ……. (4)

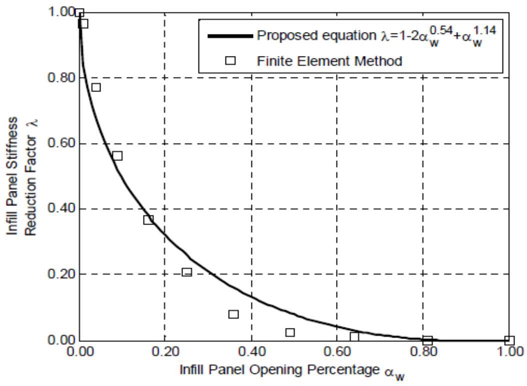

Fig.2: Stiffness reduction factor for infill with opening

Knowing the percentage of opening, stiffness reduction factor, λ can be obtained from the Fig.2 and the width of the diagonal strut is modified.

4. PROBLEM DEFINITION

In order to understand the behavior of bare frame and infill frame with and without opening, a 4 storey frame with typical bay width of 6 m is considered for the present study. Plan and Elevation view of the frame model considered for the study are shown in Fig.3 (a) and Fig.3 (b). The dead load transferred to beam for seismic calculation is obtained as follow.

Load from slab =15 kN/m,
Self-weight of beam =7.95 kN/m
Self-weight of column =2.95 kN/m

Self-weight of slab =15.3 kN/m
Total dead load =41.2 kN/m

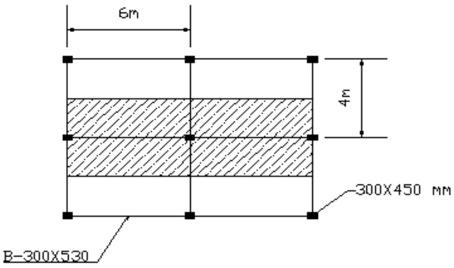

Fig.3(a): Plan

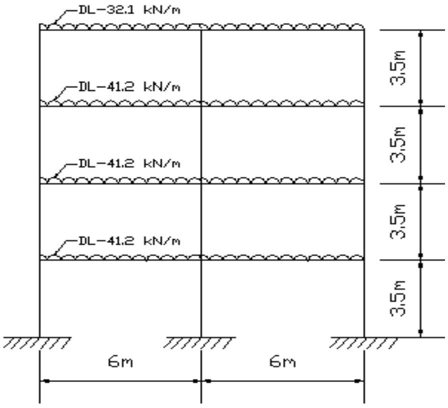

Fig.3(b): Elevation

Table.1: Structural Details

Grade of concrete	M25
Grade of steel	Fe 415
Density of Infill	19 kN/m^3
Young's modulus of concrete	2.5x10^7 kN/m^2
Young's modulus of Infill	0.8x10^6 kN/m^2
Column size	300x450 mm
Beam size	300x530 mm
Slab thickness	150 mm
Wall thickness	230 mm
Storey height	3.5 m
Live load	3 kN/m^2
Zone	II

5. RESULTS AND DISCUSSIONS

The frame is analysed using response spectrum method as per IS 1893-2002. The time periods are obtained from Eigen value analysis using ETABS. When infill stiffness was considered, the fundamental period of the structure reduced and the structure attracted maximum base shear. Table. 2 shows the fundamental natural time period using both IS 1893-2002 and using ETABS software analysis. The time period of frame with infill is decreased by 22% when compared to bare frame. The comparison of time periods indicates that the IS 1893-2002 gives a lower time period and thus imposes a large base shear on the building.

Table.2: Time period (sec) for bare frame and infilled frame

	ETABS							
Property	**Bare frame**			**Infilled frame**			**Code:IS1893-2002**	
Modes	1	2	3	1	2	3	Bare	Infilled
Period, sec	0.5974	0.2088	0.1372	0.4656	0.1626	0.1063	0.542	0.363

Table.3: Lateral force, (kN) at each storey level from RSM

Storey	**Bare frame**	**Infilled frame**
4	9.55	10.04

3	16.82	17.84
2	22.94	24.41
1	20.11	21.38
Base shear	69.42	73.67

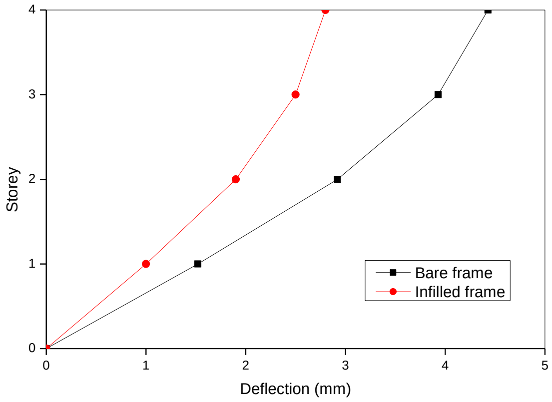

Fig.4:Variation of deflection from RSM

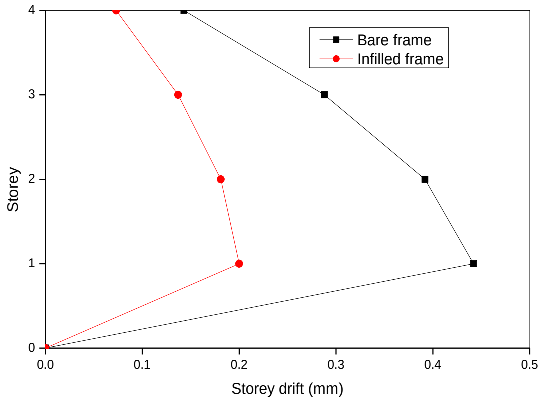

Fig.5:Storey drift from RSM

Fig.4 and Fig.5 shows the variation of deflection and storey drift respectively. The displacement variation along the building height is a typical way of illustrating the behavior of a building in each storey. A better representation of the above is the use of the storey drift and it is one of the commonly used damage parameter. The lateral displacement substantially reduces when the infill is considered. The drift in the first storey is more compared to other stories as the seismic forces are distributed more at the bottom of the structure.

Stiffness reduction factor (λ) for different percentages of opening is obtained from the Fig.2 and width of strut is calculated from equation (3) and is tabulated in the Table 4.

Table.4: Stiffness Reduction Factor and Width of Strut for different % of opening

Percentage of opening	**Stiffness reduction factor , λ**	**Width of strut, m**
0	-	0.77
5	0.636	0.45
10	0.495	0.38
20	0.32	0.25
30	0.21	0.16
40	0.13	0.10
50	0.078	0.06
60	0.04	0.031
70	0.016	0.012
80	0.00243	0.0018

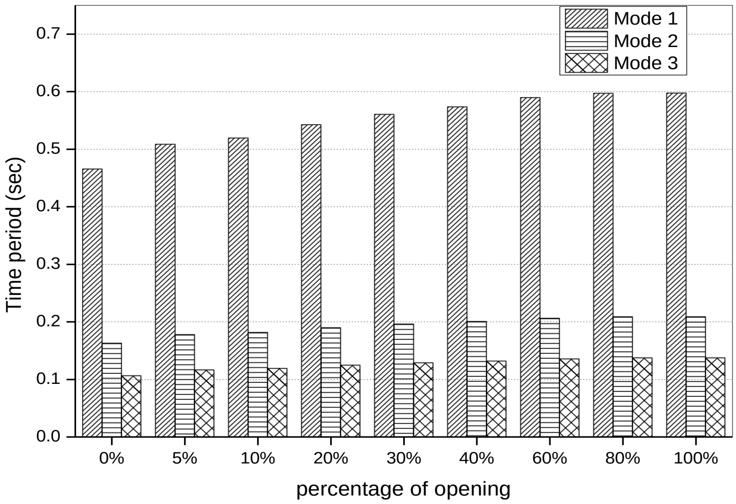

Fig.6:Variation of time period

Fig.6 shows the variation of time period for different percentages of opening. It is shown that the period of vibration of the structures is largely affected by the presence of openings, which in turn has an effect on the earthquake load that such structures will be subjected during an earthquake. The time period increases as the opening size increases due to reduction in stiffness of the structure. Such variation of time periods cannot be considered using the formula proposed by design code [5]. There is no clear relationship between the opening size and the fundamental period, but it is certain that the opening size influence on the fundamental period of the structure.

Fig.7 and Fig.8 show the variation of displacement and storey drift for infill frames with different percentages of opening. Deflection increased gradually as the percentage of opening increased due to the reduction in lateral stiffness. The storey drift of the first floor is more pronounced when larger openings in the infill panels are present. The fully infilled frame has the lowest storey drift value and the highest base shear value, which is expected.

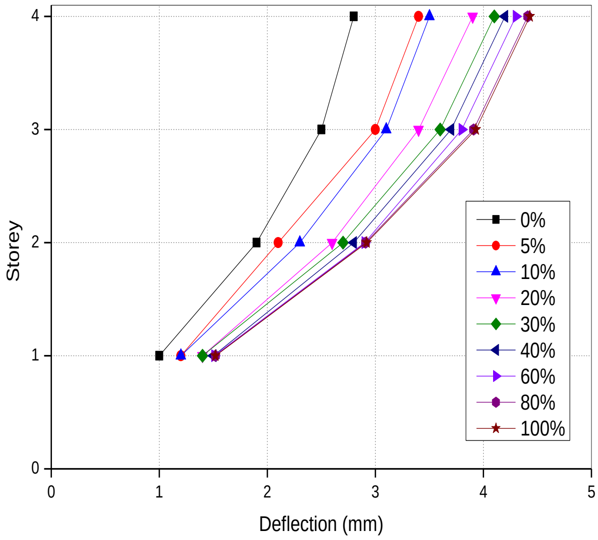

Fig.7: Variation of deflection from RSM

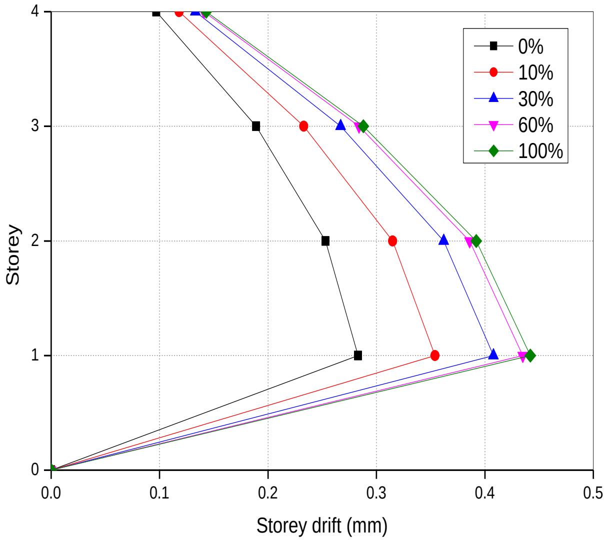

Fig.8:Variation of storey drift from RSM

6. CONCLUSIONS

The performance of infilled frame with and without opening is studied and compared with the bare frame model. From the results of response spectrum analysis for the model considered following conclusions can be made:

- Introduction of infill panels in the RC frame reduces the time period of bare frames and also enhances the stiffness of the structure.
- The fully infilled frame has the lowest storey drift value and the highest base shear value.
- The reduction factor □, can be used as a multiplication factor on well-known equations to calculate the reduced equivalent width of compression struts, so as to be able to model infill walls with openings.
- The increase in the opening percentage leads to decrease on the lateral stiffness of infilled frame.
- Deflection is very large in case of bare frame as compare to that of infill frame with opening and deflection will increase as the percentages of opening increases.
- The increase in the lateral drift and deflection are not considerable beyond 40-50% of opening in the masonry infill.

REFERENCES

[1] V.K.R. Kodur, M.A. Erki, and J.H.P. Quenneville, Seismic Analysis of Infilled frames, *Journal of Structural Engineering, Vol.25, No.2, 1996, 95-102.*

[2] Panagiotis G. Asteris, Ioannis P Giannopoulos, and Christis Z. Chrysostomou, Modelling of Infilled Frames With Openings ,*The Open Construction and Building Technology Journal, Volume 6,(Suppl 1-M6), 2012, 81-91.*

[3] P.G. Asteris, Finite Element Micro-Modelling of Infilled frames, *Electronic Journal of Structural Engineering, (8) 2008, 1-11.*

[4] P.G. Asteris, S.T. Antoniou, D.S. Sophianopoulos, and C.Z. Chrysostomou, Mathematical Modelling of Infilled Frames: State of the Art, *Journal of Structural Engineering, December 2011,1508-1517.*

[5] IS: 1893 (Part 1), (2002), Indian Standard Criteria for Earthquake Resistant Design of Structures, *General provisions and Buildings, Bureau of Indian Standards,* New Delhi, India.

[6] ETABS (2008), "*Analysis Reference Manual*", A Software for Building Structures, Computers and Structures, Inc., Berkeley, California, USA