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Effect of openings in RC Infilled Frame Structure under Seismic Loads

Karam Singh Yadav
Assistant Professor,
UIT Allahabad

Dr. Partap Singh
Professor,
NIT Jalandhar,

***Abstract* - Masonary infilled RC frames are the most common type of structures used for tall building constructions in the developing countries and also located in seismic regions. Window and door openings are important parts of infill walls for functional reasons. Currently, publications like FEMA-273 contain provisions for the calculation of stiffness of solid infilled frames mainly by modeling infill as a "diagonal strut." However, such provisions are not provided for infilled frames with openings. Present study is an attempt to analyze the performance of RCC frame with infills panels with and without openings. In this paper building (G+4) is considered by modeling of frame and masonry Infills by STAAD PrO. Software and modelling of infills is done as per actual size of openings with the help of plate tool in software. The various models such as bare frame, infill frame and infill frame with opening are analyze and concluded that infill panels increase stiffness of the structure the increase in the opening percentage leads to a decrease on the lateral stiffness of infilled frame**

Key words - — Masonary infill wall, equivalent diagonal strut, RC Frame

INTRODUCTION

The current design approach to tall-building design in most of the regions in the world requires the structural skeleton to resist vertical and lateral loads, under both the ultimate and serviceability loading conditions applied to the building. Non-structural components such as infill walls, facades and stairs are considered as non-load bearing components. These components are assumed to be detached from the primary structure in the design of high-rise buildings. However, because of different types of physical connections, interactions between the structural skeleton and the non-structural components do occur. Both structural and non-structural components participate in resisting structure movement.

In reality, the presence of infill wall changes the behavior of frame action into truss action, thus changing the lateral load transfer mechanism. The masonry can be of brick, concrete units or stones .Usually the RC frame is filled with bricks as non-structural wall for partition of rooms.

RC framed buildings are generally designed without considering the structural behavior of masonry infill walls present. These walls are widely used as partitions and considered as non-structural elements. But they affect both the structural and non-structural performance of the RC buildings under lateral loads

METHEDOLOGY

EQUIVALENT STRUT METHOD

In this method, the analysis is carried out by simulating the action of infills similar to that of diagonal struts bracing the frame. The infills are replaced by an equivalent strut of length *D* and width W_{ef}

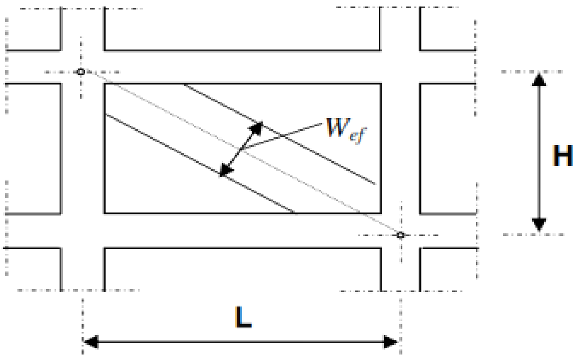

FIGURE 1
EQUIVALENT DIAGONAL STRUT MODEL

The width of the equivalent diagonal strut W_{ef} can be found by using number of expressions given by different investigators, are given below:

(i) Holmes (1961)gave a formula for determination of width of diagonal strut W_{ef} are given below:

$$W_{ef} = \frac{1}{3}D$$

(ii) Stafford Smith and Carter (1969) proposed a theoretical relation for the width of diagonal strut based on relative stiffness of infill and frame.

$$W_{ef} = 0.58\left(\frac{1}{H}\right)^{-0.445} (\lambda_h . H_{inf})^{0.335D\left(\frac{1}{H}\right)^{0.064}}$$

Where

$$\lambda_h = \sqrt[4]{\frac{E_{inf} t \sin 2\theta}{4E_c I_c H_{inf}}}$$

(iii) Mainstone (1974) proposed a relationship for computing the width of the equivalent diagonal strut, is given by.

$$W_{ef} = 0.175\, (\lambda_h H_{inf})^{-0.4} D$$

$$\lambda_h = \sqrt[4]{\frac{E_{inf} t \sin 2\theta}{4E_c I_c H_{inf}}}$$

Where
λ_h=Stiffness reduction factor
E_{inf}= Modulus of elasticity of the infill material, N/mm^2
E_c= Modulus of elasticity of the frame material, N/mm^2
I_c= Moment of inertia of column, mm^4
t = Thickness of infill, mm
H = Centre line height of frames
H_{inf} = Height of infill
L = Centre line width of frames
l = Width of infill
D = Diagonal length of infill panel.
θ = Angle between diagonal strut and beam

(iv) Pulay and Preistley (1992) suggested a conservative formula for design proposal , given by:

$$W = 0.25D$$

(v) FEMA (1998) provided a relationship for computing the width of the equivalent diagonal strut is given by:

$$W_{ef} = 0.175\ (\lambda\ H_{inf})^{-0.4}\ D$$

Where:$\lambda = \lambda_h$

ANALYSIS PROBLEM

A five storeyed building has been chosen for investigating the effect of openings in RC frame structure with masonry in-filled walls

TABLE - 1
STRUCTURAL DETAILS

Type of structure	(G+4) School Building
ZONE	IV
Foundation level to Ground level	0.9 m
FLOOR TO FLOOR HEIGHT	3.65 m
Thickness of masonry infill walls	230 mm
DEAD LOADS	Self-weight of structure & Dead load due to Mud Phuska at roof = 2.4 kN/m^2
LIVE LOAD	4 kN/m^2 on floor area
MATERIAL	M20 AND Fe415
SEISMIC ANALYSIS	EQUIVALENT STATIC METHOD (IS 1893-2002)
SIZE OF COLUMN	Column (No.1 to No. 9 and 15 to 23) = 350 mm × 750 mm Column (No.10 to No. 14) = 350 mm × 600 mm Column (No. 24 to No. 32) = 350 mm × 500 mm
SIZE OF BEAM	B_1= 230 mm × 550 mm B_2 = 230 mm × 450 mm B_3= 230 mm × 700 mm
DEPTH OF SLAB	140 mm
DESIGN PHILOSOPHY	LIMIT STATE METHOD CONFORMING (IS 456-2000)

Analytical Models

The present work has been divided into following four Cases.
Case - 1 RC framed structure without masonry infill walls.
Case – 2 RC framed structure with masonry infill walls.
Case -3 RC framed structure with masonry infill walls having 11.11 % openings.
Case - 4 RC framed structure with masonry infill walls having 20 % openings.

Openings in infill walls have been provided at periphery of building.

Column C-1 is exterior and C-2 in interior column respectively as shown in plan.

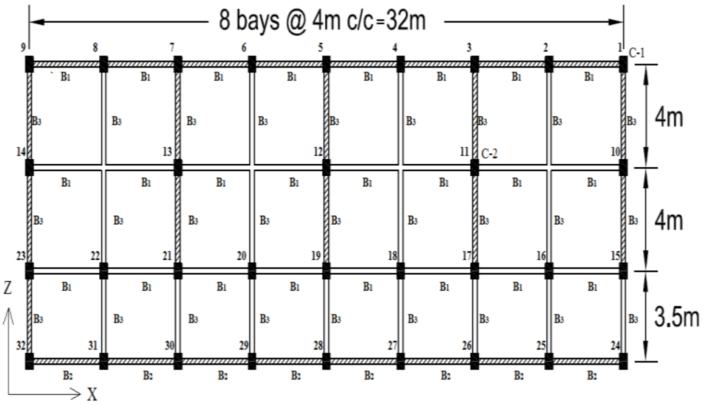

FIGURE 2
PLAN OF THE BUILDING WITH LOCATION OF INFILL

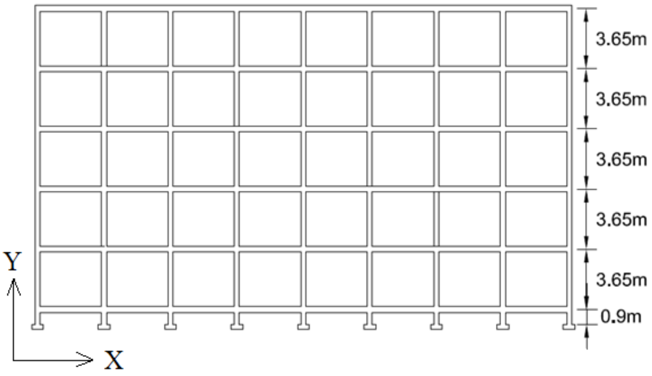

FIGURE 3
ELEVATION OF RC FRAME STRUCTURE

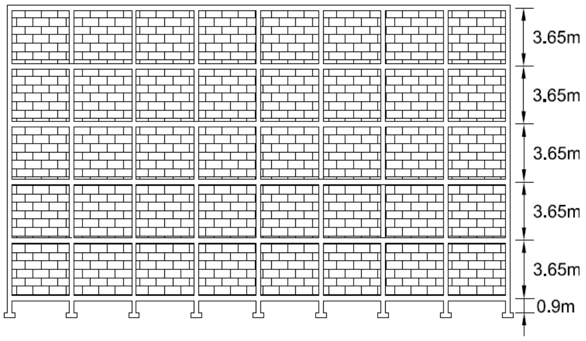

FIGURE 4

ELEVATION OF BUILDING WITH INFILL WALLS

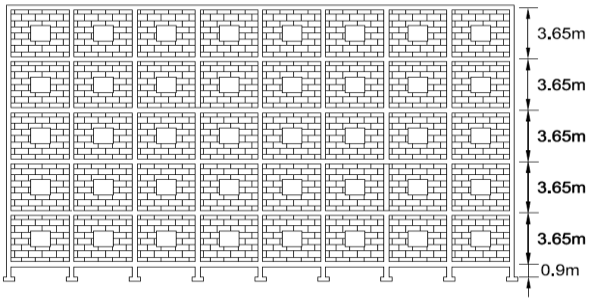

FIGURE 5

ELEVATION OF BUILDING WITH 11.11 % OPENING AT CENTRE

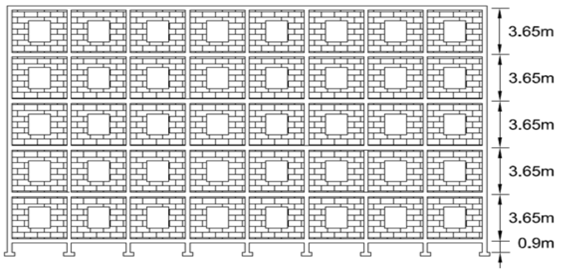

FIGURE 6

ELEVATION OF BUILDING WITH 20 % OPENING AT CENTRE

The above models have been analyzed with respect to

1. nodal displacements and
2. stress- resultants such as M_X, M_Z and F_Y in beams
3. stress resultants in column

RESULTS AND DISCUSSION

Comparison of all analytical models with the help of graph and discussion of result.

1. NODAL DISPLACEMENTS

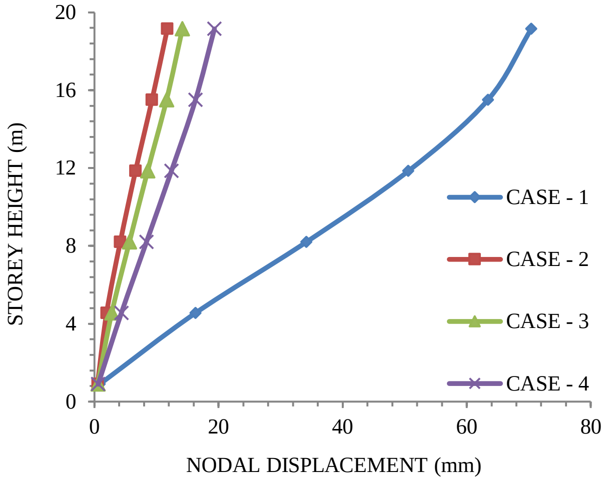

FIGURE 7
MAXIMUM NODAL DISPLACEMENT ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

Figure shows that, maximum nodal displacement decreases by 83.33 % in Case - 2 as compared to Case - 1.By providing 11.11 % and 20 % opening at centre, nodal displacement increases by 20.71 % and 64.87 % as compared to Case - 2 respectively. By increasing the opening from 11.11 % to 20 %, the nodal displacement increases by 36.58 % in Case - 4 as compared to Case – 3

2. STRESS- RESULTANTS

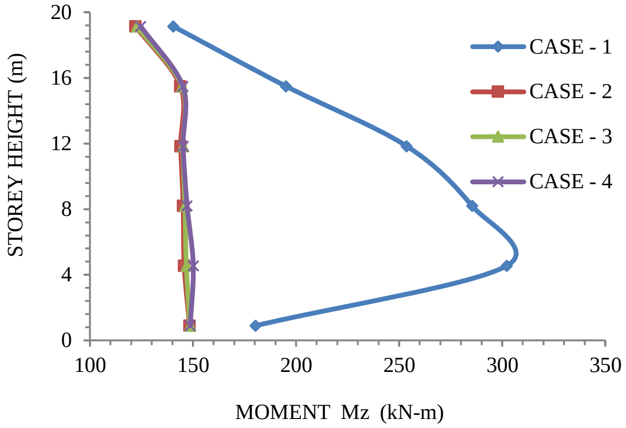

FIGURE 8
MAXIMUM MOMENTS M_Z IN BEAMS PARALLEL TO X - DIRECTION ALONG - WITH STOREY HEIGHT FOR CASESS-1, 2, 3 AND 4 .

In Case - 2, maximum moment decreases by 50.91 % as compared to Case - 1 because of presence of infill walls. By providing 11.11 % and 20 % opening at centre in infill walls in Case - 3 and 4, maximum moments are increases by 0.2 % and 1.2 % respectively as compared to Case - 2. By increasing the openings from 11.11 % to 20 %, moment increases by 1 % in Case - 4 as compared to Case - 3.

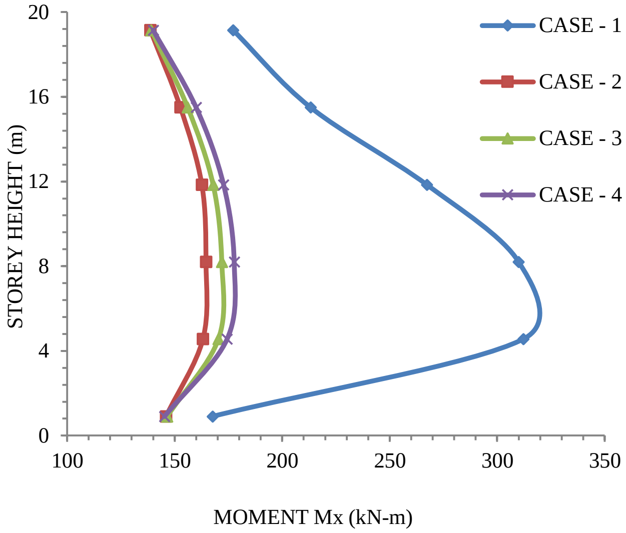

FIGURE 9
MAXIMUM MOMENTS M_X IN BEAMS PARALLEL TO Z - DIRECTION ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

In Case -2 maximum moment decreases by 47.26 % as compared to Case - 1 due to presence of infill walls. By providing central openings 11.11 % and 20 % in Case - 3 and 4, moment increases by 4.48 % and 7.97 % respectively as compared to Case - 2. By increasing the openings with 11.11 % to 20 %, moment increases by 1.4 % in Case - 4 as compared to Case - 3.

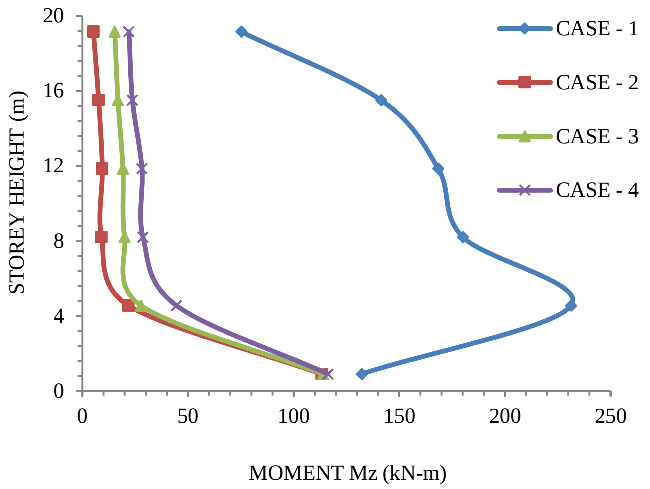

FIGURE 10
MAXIMUM MOMENT M_Z IN COLUMN C-1 ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

In Case - 2, maximum moment decreases by 90.52 % as compared to Case - 1 due to presence of infill walls. By providing 11.11 % and 20 % opening at centre in Cases - 3 and 4 moments are increases by 26.77 % and 103.14 % respectively as compared to Case -2. By increasing openings from 11.11 % to 20 %, maximum moment increases by 60.23 % in Case - 4 as compared to Case- 3.

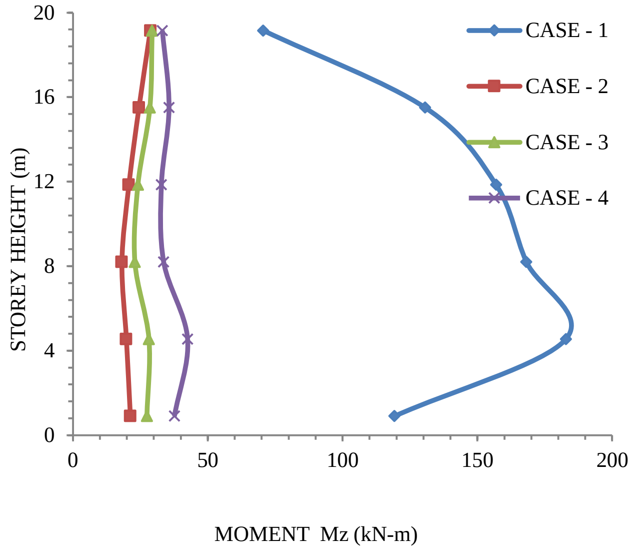

FIGURE 11
MAXIMUM MOMENT M_Z IN COLUMN C-2 ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

In Case - 2 maximum moment decreases by 84.6 % as compared to Case - 1 due to presence of infill walls. By providing opening 11.11% and 20% in Case - 3 and 4, moments are increases by 4 % and 49.1 % respectively as compared to Case - 2. By increasing the openings from 11.11% to 20%, maximum moment increases by 45 % in Case – 4 as compared to Case – 3.

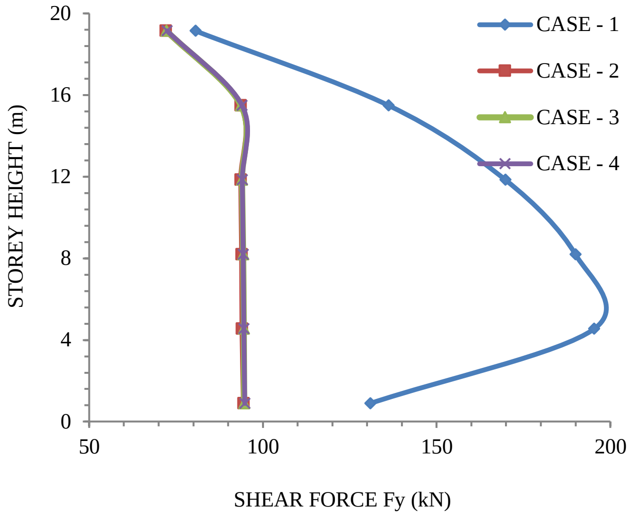

FIGURE 12
MAXIMUM SHEAR FORCE F_Y IN BEAM IN X - DIRECTION ALONG-WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

The maximum shear force decreases by 51.67 % in Case - 2 as compared to Case – 1. The maximum shear forces do not much differ in Cases - 3 and 4 as compared to Case - 2.

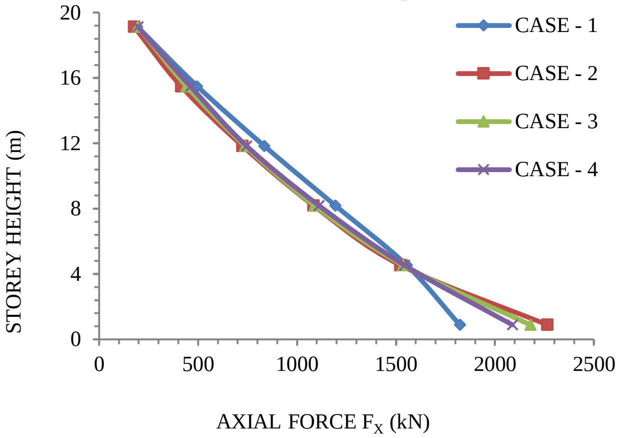

FIGURE 13
MAXIMUM AXIAL FORCE F_X IN COLUMN C-1 ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

Maximum axial force decreases by 2.01 % in Case - 2 due to presence of infill walls as compared to Case - 1. Maximum axial forces increase by 0.85 % and 1.38 % in Cases - 3 and 4respectively as compared to Case - 2, because of presence of 11.11 % and 20 % opening at centre in infill walls respectively.

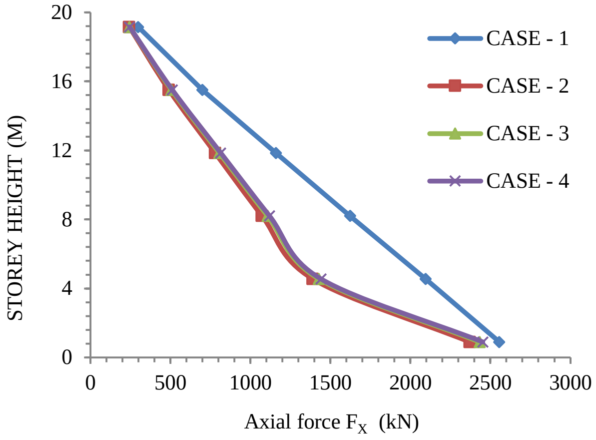

FIGURE 14
MAXIMUM AXIAL FORCE F_X IN COLUMN C-2 ALONG - WITH STOREY HEIGHT FOR CASES - 1, 2, 3 AND 4

The maximum axial force decreases by 7.27 % in Case - 2 due to presence of infill walls as compared to Case -1. Maximum axial force increases 2.62 % and 3.51 % in Cases - 3 and 4respectively as compared to Case - 2. By increasing openings from 11.11 % to 20 %, the maximum axial force increases by 0.83 %in Case - 4 as compared to Case - 3.

CONCLUSION

The results of the present study having following conclusions

1) By introducing infill walls, the maximum nodal displacement at roof level decreases about 80 %; Maximum moment and maximum shear force in beams decreases approximately 50 %; maximum moment M_Z in interior column decreases about 80 % respectively; Maximum axial force F_Y in interior column decreases nearly 7 % as compared to RC frame structure means in general, infill panels increase stiffness of the structure.

2) By providing openings of 11.11 % and 20 % , the maximum nodal displacement at roof level increases by about 20 % and 64 % respectively; maximum moments of beams M_Z parallel to X- direction increases about 0.5 % and 1.5 % respectively; maximum moment M_X in beams parallel to Z – direction increases approximately 5 % and 8 % respectively; the effects in maximum shear forces F_Y of beams are insignificant; maximum moment M_Z in interior column increases about 4 %and 50 % respectively; maximum axial forces F_Y in interior column increases nearly 3 % and 4 % as compared to RC frame structure with infill walls means the increase in the opening percentage leads to a decrease on the lateral stiffness of infilled frame.

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AUTHOR INFORMATION

Karam Singh Yadav, Assistant Professor, Department of Civil Engineering, UIT, Allahabad
Dr. Partap Singh, Professor, Department of Civil Engineering, NIT Jalandhar