Effect of Infill Walls on Response of Multi Storey Reinforced Concrete Structure

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Abstract— The present research work investigates the seismic response of reinforced concrete (RC) frame building considering the effect of modeling masonry infill (MI) walls. The seismic behavior of a 10-storey RC frame building, considering and ignoring the effect of masonry, is numerically investigated using response spectrum (RS) analysis. The considered herein building is designed as a moment resisting frame (MRF) system following the IS 1893:2016 requirements. Two developed models in terms of bare frame and infill walls frame are used in the study. Equivalent diagonal strut methodology is used to represent the behavior of infill walls, whilst the well-known software package ETABS is used for implementing all frame models and performing the analysis. The results of the numerical simulations such as, displacements, and internal forces for the bare frame as well as the infill wall frame are presented in a comparative way. The results of the study indicate that the interaction between infill walls and frames significantly change the responses of buildings during earthquakes compared to the results of bare frame building model.

Keywords: seismic, Infill wall, ETAB-2015, IS 1893:2016

I. Introduction

REINFORCED CONCRETE (RC) frame buildings with MI walls are commonly built throughout the world. MI walls are widely used as partitions, and used either to divide the spaces to any required purposes or to protect inside of the structure from environment. Although the structural contribution of MI walls is rarely taken into consideration of such structures, it affects both the structural and non-structural performance of RC structures

Most of the previously conducted research works support that infill walls enhance the resisting capacity to dynamic lateral loads up to a certain level of structural response. The interaction between masonry infill’s and RC structures highly affects the dynamic characteristics of the structures such as stiffness and story displacement of the structure, which might be beneficial or in some cases detrimental depending on the frequency of the applied ground excitation. In addition, since the interaction between MI walls and the building’s frames affects the stiffness distribution of the structure, it tends to change the building’s overall strength. In spite of considering MI as non-structural elements which are used for architectural purposes and neglected in the frame design, there is a growing need for researchers to evaluate the performance of MI frame buildings in the major earthquake

The current research work investigates the interaction effect between the MI walls and RC on the dynamic response of RC framed structures with and without masonry infilled through conducting a comparative study between bare frame and infill frame structures. The interaction between MI walls and the analyzed RC structures are modeled with the finite element modeling technique. The infill masonry walls are idealized using the equivalent strut methodology to account for the specific behavior of MI walls. Response spectrum analysis is carried out to assess the behavior of MI-RC structures. The results for the considered RC framed structure considering and ignoring the MI walls action under dynamic response spectrum analysis are introduced in a comparative way in the form figures and tables of storey displacement, shear force, bending moment, axial force in corner column.

II. Methodology

A. *Equivalent Diagonal Strut Method:*

The most accepted method for the analysis of in-filled frame structure is Equivalent Diagonal Strut Method in which entire infill is replaced by a single equivalent strut. In this method beams and column are designed as frame members which are having six DOF at every node and brick infill is replaced by a pin jointed diagonal strut. The thickness of a pin jointed diagonal strut is considered to be same as infill and its length is equal to the length of the diagonal between the two compression corners. Width of a strut is calculated by IS 1893:2016.

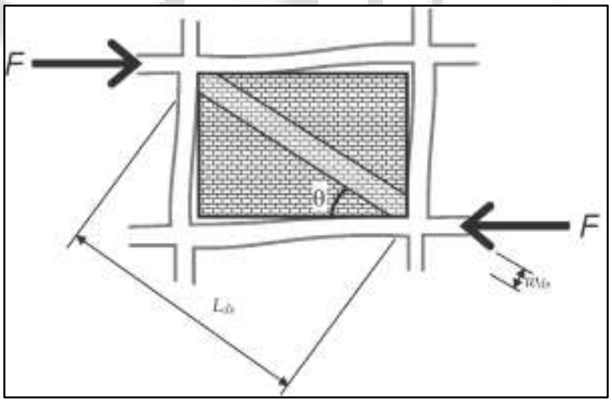


Fig. 1: Equivalent Diagonal Strut Model

AS PER IS1893:2016, Unreinforced Masonry Infill walls shall be modeled using equivalent diagonal struts as below

Em=550fm

fm =0.433fb^0.64fmo^0.36

Where,

Em= the modulus of elasticity (in MPa) of masonry infill wall.

Fm= compressive strength of brick masonry prism (in MPa)

fb =compressive strength of brick, in MPa.

fmo= compressive strength of brick mortar, in MPa

For URM infill walls without opening, width Wds of equivalent diagonal strut shall be taken as:

$$Wds = 0.175\ (ah\ )^{-0.4}\ Ld$$

$$\alpha_h = h \sqrt[4]{\frac{Em\, t \sin 2\theta}{4EIh}}$$

Where,
Em = moduli of elasticity of the materials of the URM infill.
Ef = moduli of elasticity of the materials RC MRF.
t= the thickness of the infill wall, and
h= the height of the infill wall,
θ= angle of the diagonal strut with the horizontal.
From the above equation we can calculate the strut width of in-filled wall

B. *Response Spectrum Method*

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of Multi-Degree of freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single degree of freedom (SDOF) system, which are then combined to compute the total response. Modal analysis leads to the response history of the structure to a specified ground motion; however, the method is usually used in conjunction with a response spectrum.

In this method the load vectors are calculated corresponding to predefined number of modes. These load vectors are applied at the design center of mass to calculate the respective modal responses. These modal responses are then combined according to SRSS or CQC rule to get the total response. From the fundamentals of dynamics it is quite clear that modal response of the structure subjected to particular ground motion, is estimated by the combination of the result of static analysis of the structures subjected to corresponding modal load vector and dynamic analysis of the corresponding single degree of freedom system subjected to same ground motion. Static response of MDOF system is then multiplied with the spectral ordinate obtained from dynamic analysis of SDOF system to get that model response. Same procedure is carried out for other modes and the results are obtained through SRSS or CQC rule. In response spectrum analysis the spectral values are read from the design spectrum which are directly multiplied with the modal load vector and the static analysis is performed to determine the corresponding modal peak response. This method is known as the Classical Modal Analysis.

III. PROBLEM FORMULATION

For this study, a G+9 Storey building with 3 meters height for each Storey, regular in plan is considered. The building is designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures. The building is modeled using software ETABS 2015. Models are studied for comparing lateral displacement, axial force, and shear force in corner column.

Number of story	Ten
Floor height	3 m
LOADING	
Live load	4 Kn/m2 at typical floor
	1.5 Kn/m2 at terrace
Floor finish	1 Kn/m2
Water proofing	2 Kn/m2
Terrace finish	1 Kn/m2
Earthquake load	as per IS1893 PART I 2016
Response reduction factor	5
Location	Latur
Earthquake zone	III
Zone factor	0.16
Importance Factor	1.5
SECTION PROPERTY	
Size of column	600x600mm
Size of beam	300x600mm
Depth of slab	150mm
Infill wall thickness	230mm
MATERIAL PROPERTIES	
CONCRETE	
Grade of Concrete	M30
Weight per unit volume	25Kn/m3
Modulus of Elasticity E	27386.13 Mpa
MASONARY	
Unit weight of masonry	19Kn/m3
Modulus of Elasticity of masonry	2457mpa
Poisson's ratio	0.15
Compressive strength of masonry prism	4.46Mpa
Mortar Ratio	01:03
STEEL	
HYSD reinforcement of grade Fe415 confirming to IS:1786 is used throughout	

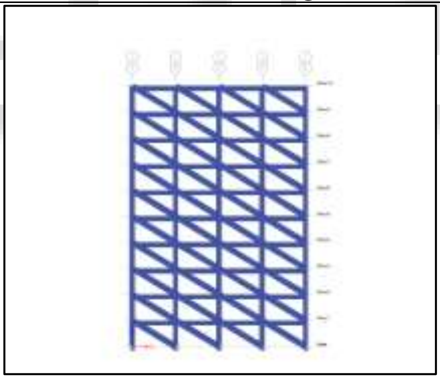


Fig. 1: Elevation of infill frame Model with Strut

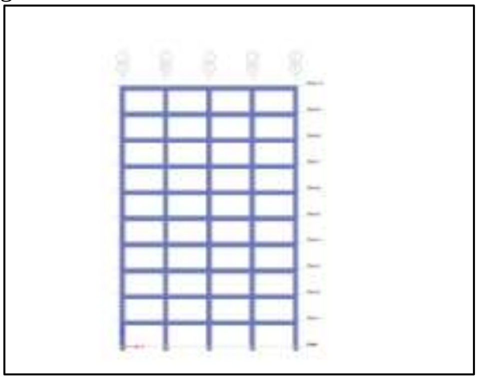


Fig. 2: Elevation of bare frame Model without Strut

IV. RESULT AND DISCUSSION

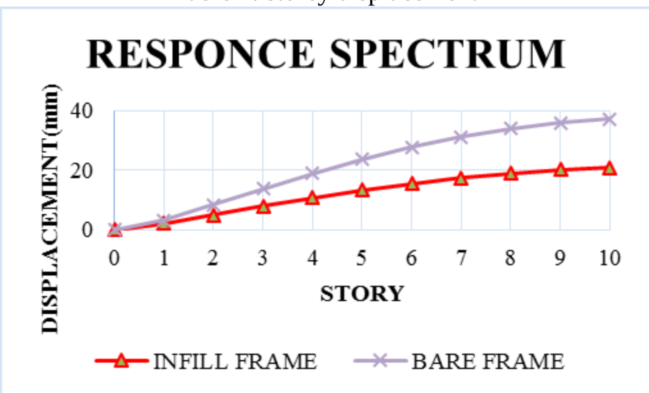
The seismic analysis of bare frame (without considering stiffness of infill wall), and In-filled frame (with considering stiffness of infill wall) has been done by using software ETABS and the results are shown below. The parameters which are to be studied are displacement, bending moment & shear force in corner column.

A. Displacement

The maximum story displacement was found to be more for bare frame model as Compared to the infill frame model. It is due to the fact that consideration of infill Enhances the strength and stiffness characteristic of the moment resisting Reinforced concrete structures

story	Displacement(mm)	
	Infill frame	Bare frame
1	2.2	3.1
2	5	8.3
3	7.9	13.7
4	10.7	18.9
5	13.3	23.5
6	15.5	27.6
7	17.4	31.1
8	18.9	33.9
9	20.1	35.8
10	20.8	37

Table 1: storey displacement



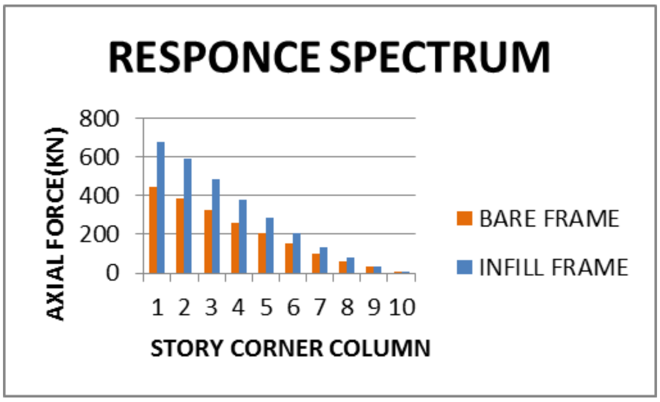
Graph 1: displacement vs. storey

B. Axial force

The corner columns were chosen for the bare, infill and it was found that the introduction of infill causes the increase in axial forces in Columns. The comparison of axial forces for the bare frame and infill frame are shown in the following table.

Column No	Axial force(KN)	
	Infill frame	Bare frame
1	675.82	443.83
2	594.06	388.49
3	484.64	324.23
4	381.22	261.77
5	288.1	203.55
6	205.9	150.35
7	135.4	102.92
8	77.96	62.54
9	35.46	31
10	10.33	10.89

Table 2: Axial force in corner column



Graph 2: column axial force vs. storey

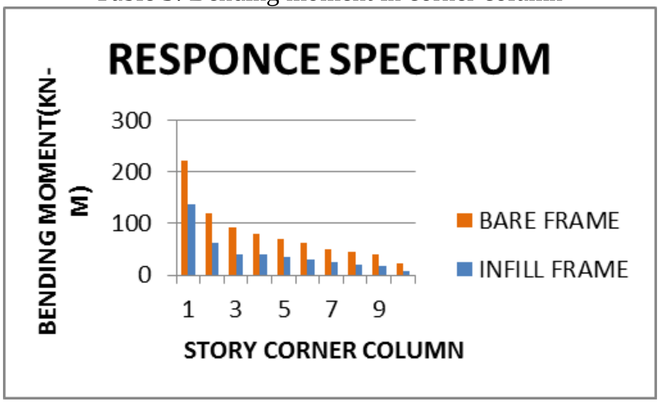
C. Bending moment in corner column (KN-m)

The corner columns were chosen for the bare, infill and it was found that the considering stiffness of infill causes the reduction in bending moment of column.

The comparison of bending moment in corner column for the bare frame (without considering stiffness of infill wall) and infill frame (with considering stiffness of infill wall) are shown in the following table.

Column	Bending Moment (KNm)	
	infill frame	Bare frame
1	136.82	221.72
2	63.77	119.96
3	41.08	92.45
4	39.76	80.17
5	34.17	70.83
6	29	61.71
7	23.98	50.92
8	21.35	44.49
9	18.89	39.51
10	8.42	21.52

Table 3: Bending moment in corner column



Graph 3: bending moment vs. storey corner column

D. Shear Forces in Corner Columns (KN)

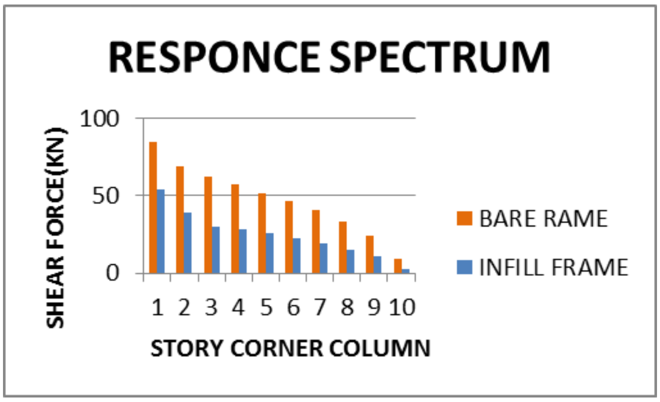
It was observed that the impact of infill reduces the shear forces on beam and columns.

The effect of stiffness of infill on shear force in corner column as shown in table.

Story column	Shear force(KN)	
	Bare frame	infill frame
1	85.14	54.017
2	69.36	39.22
3	62.77	29.59

4	57.32	28.53
5	51.92	25.45
6	46.41	22.47
7	40.43	19.09
8	33	15.07
9	24.42	10.78
10	8.81	2.51

Table 4: Shear Force in corner column



Graph 4: Shear force vs. storey corner column

V. CONCLUSION

Based on above study the following conclusions are drawn

- The seismic requirement of the structure in terms of storey drift and the maximum average roof displacement of the structure are markedly enhanced by the introduction of infill. As compared to bare frame the maximum roof displacement in infill frame is reduced up to 43.78%.
- The response of the structure in terms of bending moments and shear forces is greatly enhanced by considering stiffness of the infill. Both bending moment and shear force in beams and columns are reduced appreciably due to masonry infill.
- As compared to the bare frame, the bending moment in corner column of infill frame is reduced up to 60.07%.
- As compared to the bare frame, the shear force in corner column of infill frame is reduced up to 41.92%.
- Primary frame action of a moment resisting frame is converted to the primary truss action due to the introduction of the infill leading to the increased axial forces in column in infill frame model.
- As compared to the bare frame, the axial force in corner column of infill model is increased up to 47.7%.

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