Dynamic Behaviour of Masonry Infill in 2D And 3D RC Frames by Macro Analysis

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Abstract - Reinforced concrete frames with unreinforced masonry infill walls represent a widely adopted building system. While during building construction, the frame structures are constructing first due to ease of construction and later the frames are infilled by masonry brick infill or concrete blocks or finished stones or concrete hallow blocks. The infill walls are giving protection from outside environment like external walls and also divide the inside structure like as partition walls. Predicting the behaviour of infill while during seismic action is difficult because it is brittle and ductility in nature. The IS code provisions do not provide any guidelines for the analysis and design of RC frames with infill wall, so during the analysis infilled frame is considered as bare frame and neglecting effect of infill on frame. In this study, we carried a effect of infills on bare frame and masonry infill as diagonal strut, in which using different methods of finding width of diagonal strut given by different researchers and compering the analytical results carried using SAP2000 v.20 software with the experimental (reference only) results carried out on different models of 2D RC frames by time history and response spectrum analysis to find frequency, and displacement. Also we carried effect of infills on bare frame, masonry infill and soft storey models. The vertical discontinuity of stiffness in the structure called as soft storey. The soft storey are considering in different floors for different models. All the models are analyzed by response spectrum analysis and infills are modelled by equivalent diagonal strut. Following parameters are determining like time period, displacement and axial forces in columns.

***Key Words*: Masonry infill, earthquake, time history, response spectrum method, SAP 2000 v20.**

1. INTRODUCTION

A large number of reinforced concrete (RC) buildings are constructed with masonry infill. Masonry infill (MI) are often used to fill the void between the vertical and horizontal elements of the building frames with the assumption that these MI will not take part in resisting any kind of load either axial or lateral; hence its significance in the analysis of RC frame is generally neglected. Moreover, non-availability of realistic and simple analytical models of MI becomes another hurdle for its consideration in analysis. In fact, an infill wall enhances considerably the strength and rigidity of the structure. It has been recognized that RC frames with MI have more strength and rigidity in comparison to the bared frames and the ignorance of MI has become the causes of failure of many of the multi-storeyed buildings

1.1 Infilled Frame

The low levels of in-plane lateral force, the frame and infill panel act in a fully composite fashion, as a structural wall with boundary elements. As lateral deformations increase, the behaviour becomes more complex as a result of the frame attempting to deform in flexural mode while the panel attempts to deform in a shear mode. The result is separation between frame and panel at the corners on the tension diagonal, and the development of a diagonal compression strut on the compression diagonal. This may be found by considering the structure as an equivalent diagonally braced frame, where the diagonal compression strut is connected by pins to the frames corners.

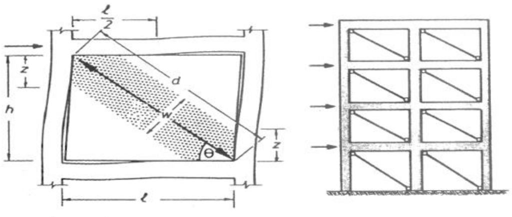


Fig 1: Equivalent bracing action of masonry infill

2. Objective

The main objectives of this research are:

i. A comparative study is carried out on 2D RC frames of one and two bays having one, two and three storeys and 3D RC frame with soft storey condition are taken to know the effects of infills on buildings in seismic regions.
ii. Using equivalent diagonal strut method and finding the width of the strut by 8 different formulas.
iii. The infills are modelled and response spectra and time history analysis are carried out as per IS 1893-2002.
iv. Following parameters are discussed by Time history analysis is carried out to get joint displacement, Modal analysis of MI 3D RC frame to get time period, mode shapes, displacement and axial force.

2. 1 Scope of study

Since long masonry infill are being used to fill up the voids between the horizontal and vertical structural elements such as beams and columns. They are treated as non-structural elements and they are not considered during the analysis and design of the structure. But, when laterally loaded they tends to interact with the RC frame, changing the structural behaviour. However, infill walls contribute to lateral stiffness and seismic resistance to the building. In this study, an attempt is being made to incorporate the masonry infill in the form of Equivalent diagonal strut whose width is calculated using the various relations proposed by the researches. However, it is important to study the behaviour of masonry infill in RC structure during lateral forces.

3. METHOD OF ANALYSIS

Over the past few decades, several methods for the analysis of infilled frames have been proposed by various investigators.

3.1 Macro models

The basic characteristic of the macro models is that they aim at predicting the overall stiffness and failure loads of infilled frames, without considering all possible failure modes of local failure. This group of models can be subdivided to their origin into the following three categories, based on:

- the concept of the equivalent diagonal strut and
- the concept of the equivalent frame

3.1.1 Equivalent diagonal strut

The simplest (and most developed) method for the analysis of non-integral masonry infilled frames is based on the concept of the equivalent diagonal strut. This concept was initially proposed by Polyakov (1956) and later developed by other investigators. In this method, the infilled frame structure is modelled as an equivalent braced frame system with a compression diagonal replacing the masonry infill. Width

Table-1: Width of diagonal strut by different method

Sl No	Methods	Width (m)
1	Holmes	0.453
2	Smith and Carter	0.591
3	FEMA 273 and Main Stone	0.116
4	Liauw and kwan	0.287
5	Jamal et. Al	0.219
6	Pauley and Priestley	0.340
7	Eurocode 8	0.204
8	Chethan	0.332

3.2 TIME HISTORY AND RESPONSE SPECTRUM ANALYSIS

Modal Analysis is the study of the dynamic characteristics of structures. This analysis characterizes the dynamic properties of an elastic structure by identifying its mode of vibration. The response of the structure is different at each of the different natural frequencies. These deformation patterns are called mode shapes. Both the natural frequency (which depends on the mass and stiffness distributions in structure) and mode shapes are used to help the design of structural system mainly for vibration applications. An attempt has been made to find the natural frequencies and mode shapes of the structure.

4. MODELLING OF 2D AND 3D RC FRAMES

2D RC frames of one and two bays having one, two, and three storey and 3D RC frames with soft storey on different storey are modelled and analyzed using SAP 2000 v20. Software.

i. 2D MODELS

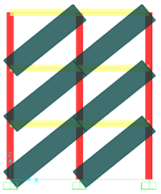
Table -2: 2D Modal Design Parameters

Sl. No.	Description of the Parameter	Value considered in the analysis
1.	Breadth of beam/ column, b	0.075m
2.	Depth of beam/column, d	0.1m
3.	Thickness of masonry infill, t	0.075m
4.	Height of masonry infill, h	0.8m
5.	Length of masonry infill, l	1.1m
6.	Diagonal length of masonry infill,d	1.36m
7.	Height of column, hc	0.9m
8.	Moment of Inertia of beam/column	6.25×10^{-6} m^4
9.	Modulus of elasticity of concrete	2.5×10^7 kN/m^2
10.	Modulus of elasticity of masonry infill	1.4×10^7 kN/m^2
11.	Seismic zone Importance factor Response reduction factor	Zone factors=0.10,0.16, 0.24,0.36 Zone I –Zone V I=1 R=5
12.	Soil type	Soft soil
13.	Damping	5%
14.	Unit weight of RC Unit weight of Brick Imposed load on slab	25 kN/m^3 19.2 kN/m^3 2 kN/m^2
15.	Load Combination	1.5(DL+IL) 1.2(DL+IL±EQ)1.5(DL±EQ) 0.9(DL±1.5EQ)

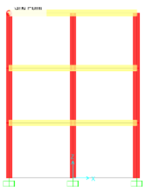
The dead load is considered as oer IS 875-1987 (Part I- Dead loads), "Code of practice for design loads for buildings and structures".

The imposed load is considered as per IS-875-1987 (Part-II imposed loads), "Code of practice for design loads for buildings and structures".

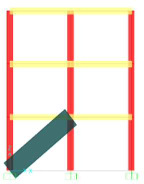
The earthquake load is considered as per the IS 1893-2002(Part-1).



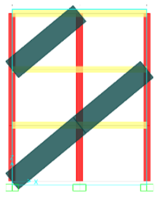
2B3SF



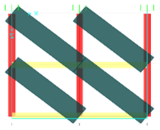
2B3S



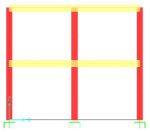
2B3S A



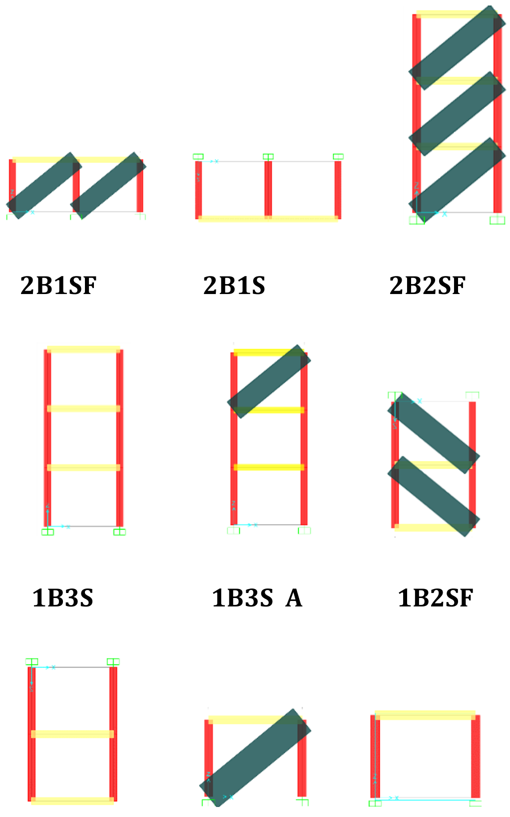
2B3S B



2B2SF



2B2S



2B1SF 2B1S 2B2SF

1B3S 1B3S A 1B2SF

1B2S 1B1SF 1B1S

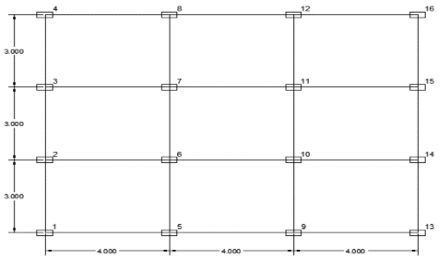
Fig 2: 2D Models Consider for analysis

ii. 3D MODELS

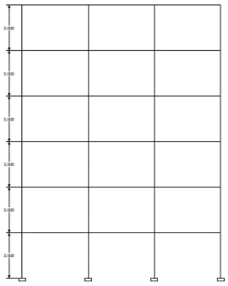
The plan layout of the RC frame building is with infill, without infill and soft storey located at different floors like ground floor, first floor, second floor and last floor are chosen for this study. The building is kept symmetric in plan to avoid torsional response under lateral forces.

Table -3: 3D Modal Design Parameters

Sl. No.	Description of the Parameter	Value considered in the analysis
1.	Plan Dimension	12mx19m
2.	Cross section of the RC column	230 mm x 500 mm
3.	Cross section of the RC beam	230 mm x 500 mm
4.	Storey height	3.0 m
5.	RCC slab thickness of the floor	150.0 mm
6.	Live load on the slabs (LL)	Floor slab=3.0 kN/mm2
7.	Masonry in-fill	230 mm
8.	Width of Diagonal strut as per smith and carter	Along 4m, W= 2.012mm Along 3m, W=1.5143
9.	Unit weight a. Concrete b .Masonry in-fill	25.0 kN/m3 19.2 kN/m3
10.	Seismic zone	Zone V Z=0.36 I=1 R=5
11.	Soil type	Medium soil
12.	Damping	5%
13.	Load Combination	1.5(DL+IL) 1.2(DL+IL±EQ)1.5(DL±EQ) 0.9(DL±1.5EQ)



Plan

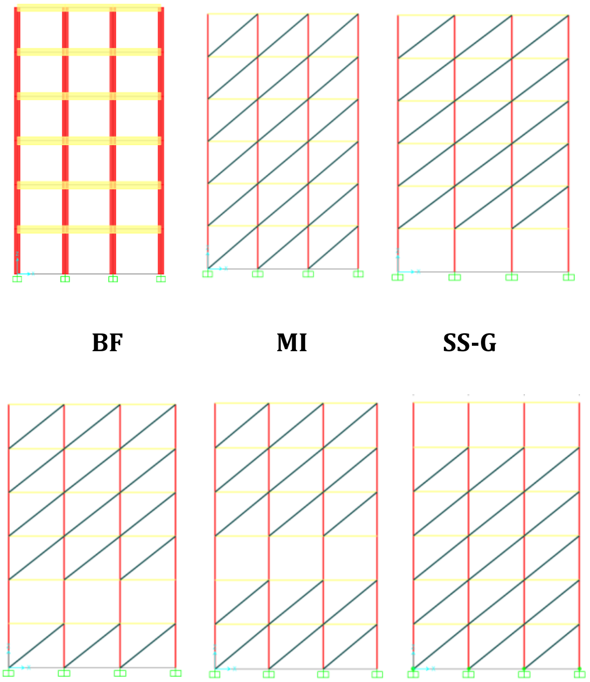


Elevation

Fig 3: Building Plan layout and location of points

Models		Description
Model-1	BF	Bare frame, however masses of infill walls are included in the model.
Model-2	MI	Masonry infill without soft storey having equivalent diagonal strut for modelling infills.
Model-3	SS-G	Masonry infill with soft storey at Ground Floor having equivalent diagonal strut for modelling infills.
Model-4	SS-F	Masonry infill without soft storey at First Floor having equivalent diagonal strut for modelling infills.
Model-5	SS-S	Masonry infill without soft storey at Second Floor having equivalent diagonal strut for modelling infills.
Model-6	SS-L	Masonry infill without soft storey at Last Floor having equivalent diagonal strut for modelling infills.

Table 4: **Model Description chart**



BF **MI** **SS-G**

SS-F **SS-S** **SS-L**

Fig 4: 3D RC Fame Model consider for analysis

5. RESULTS AND DISCUSSIONS

This research is carried out to find the influence of masonry infills on the dynamic characteristics of RC frames. In these work 15 numbers of 2D RC frames of one and two bays having one, two and three storeys and a 3 storey 3d Rc frame structure with and without diagonal strut are constructed and tested with various configurations of masonry infills to carryout Time history and response spectrum analysis.

5.1 RESULTS OF ANALYSIS OF 2D FRAMES

Table 5: Model frequencies of 2D RC frames

Model	Frequency by proposed strut model by SAP 2000(Chethan) in Hz	Frequency of shake Table test results of 2D RC frames (Reference only)
2B3SF	55.26	29.50
2B3S A	54.09	26.25
2B3S B	20.49	19.25

2B3S	14.73	14.00
2B2SF	90.51	42.00
2B2S	22.65	19.25
2B1SF	179.08	**
2B1S	44.01	**
1B3SF	45.06	29.00
1B3S A	12.80	
1B3S	14.88	14.00
1B2SF	78.89	42.75
1B2S	23.32	20.00
1B1SF	176.14	**
1B1S	46.75	41.25

Natural frequencies of RC frames with masonry infill modeled as equivalent diagonal strut using the proposed method are tabulated

Models	Zone II displacement (mm)	Zone III displacement (mm)	Zone IV displacement (mm)	Zone v displacement (mm)
2B3SF	0.085	0.121	0.189	0.275
2B2SF	0.044	0.054	0.065	0.100
2B1SF	0.003	0.008	0.013	0.0850

Table 6: Displacement of two bay fully infilled RC frame models in different storeys in all seismic zones

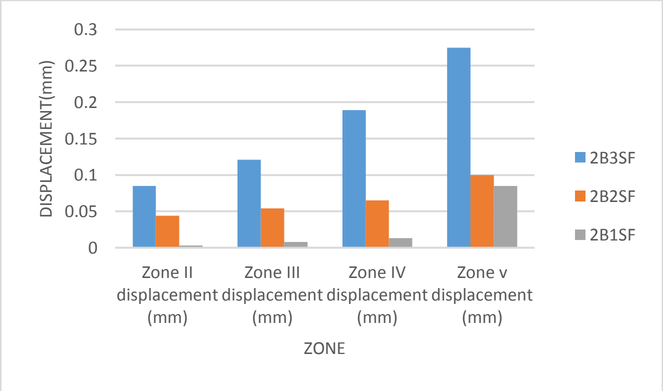


Fig 5: Displacement v/s seismic zones of MI RC diagonal strut frame models

Fig 5. Shows the displacement versus seismic zone graph of two bay fully infilled RC frame, it indicates that the displacement in zone V is more than displacement in zone II and the displacement goes on increases.

Table 7: Displacement of two bay bare frame models in different storeys in all seismic zones

Models	Zone II displacement (mm)	Zone III displacement (mm)	Zone IV displacement (mm)	Zone V displacement (mm)
2B3S	1.530	1.935	2.831	4.04
2B2S	0.670	0.890	1.166	3.331
2B1S	0.124	0.190	0.257	0.367

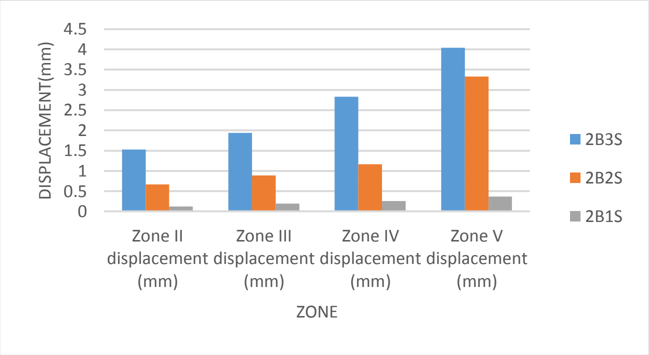


Fig 6: Displacement v/s seismic zones of bare RC frame models

Fig 6 shows the displacement versus storey number graph of two bay bare RC frames, it indicates that the displacement in zone V is more than displacement in zone II and the displacement goes on increases. But compared to two bay fully infilled RC frame models, two bay bare RC frame models displacement s much high because the MI in the infilled models contribute to the stiffness of the structure hence reduces the displacement of the structure.

5.2 RESULTS OF ANALYSIS OF 3D FRAMES

Results of time history, maximum displacement, and axial force, bending moment and shear force for considered 3d models.

i. TIME PERIOD

MODE	BF	MI	SS-G	SS-F	SS-S	SS-L
1	1.033	0.313	0.718	0.669	0.609	0.339
2	0.651	0.246	0.449	0.419	0.376	0.245
3	0.539	0.152	0.383	0.371	0.347	0.177
4	0.349	0.089	0.167	0.141	0.117	0.174
5	0.219	0.073	0.125	0.109	0.096	0.114

Table 8: Tabulation of time period of all models

Introduction of infill wall in the RC frames reduces the time period of BF and enhances stiffness to the structure. The time period is more in BF than MI and SS models. In SS models, time period is depending on location of soft storey providing. In the SS model, period is maximum in SS-G and SS-F and it depends on providing soft storey at respective floors.

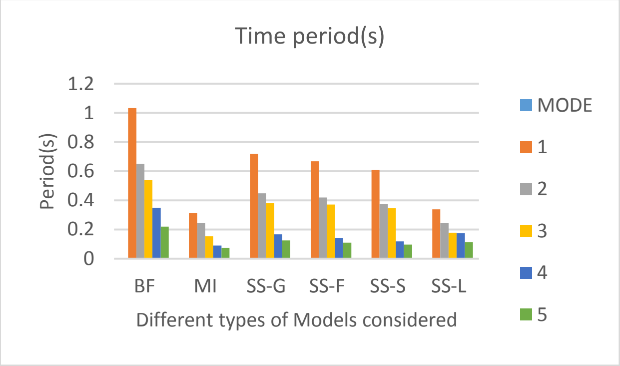


Fig 8: Comparison of time period of all models

ii. DISPLACEMENT

Table 9: Tabulation of Displacement of all models

Models	BF	MI	SS-G	SS-F	SS-S	SS-L
Displacement(mm)	60.65	9.746	22.176	22.07	22.39	11.23

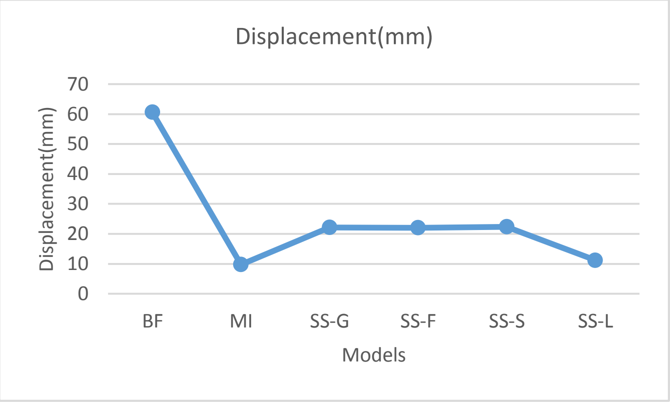


Fig 9: Comparison of Displacement of all models

The BF had maximum displacement while in MI have least displacement. Displacement in SS is more than MI and lowers than BF model. The displacement in the structure depends on location of the soft storey. The displacement is more in BF than MI and SS as shown in fig:9.

iii. AXIAL FORCES

The infill increases the axial forces in columns, storey 4 has chosen. For the location of columns refer fig: 3. Due to presence of infill the stiffness also increases in frame with increase of axial forces in column. The BF has minimum value of axial forces in columns compared to MI and SS as shown in fig: 10.

Table 10: Tabulation of Axial Force of all models

	Axial Force (KN)					
Column No.	**BF**	**MI**	**SS-G**	**SS-F**	**SS-S**	**SS-L**
C-1	152.311	333.362	333.153	333.795	336.8	242.776
C-6	269.932	401.423	400.862	398.416	395.768	389.200
C-11	269.932	403.980	400.862	398.416	395.768	389.200
C-14	182.261	344.971	345.126	344.775	343.514	325.004

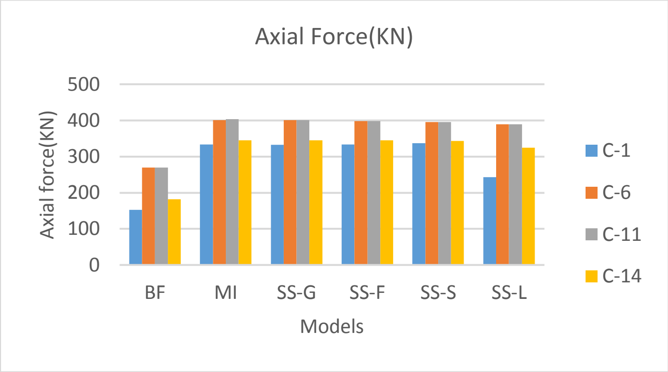


Fig 10: Comparison of Axial forces on different column location of all models

6. CONCLUSIONS

The RC frames are designed and detailed as per the relevant Indian standard codes. A reference taken on the thesis Tri-axial shake table is used for the comparison of numerically formed using SAP2000 and experimental work to find natural frequency. These results are compared with the empirical formulae given in national and international codes for finding the natural frequencies. And a comparative study is carried out on 3D RC frames structures of six different models of BF, MI and SS to know the effect of infills on buildings in seismic regions. Infills are modelled by single strut method and response spectrum analysis is carried out to find the lateral stiffness of the structure. The following are the major conclusions:

1. The natural frequency of the structure with complete infill is significantly higher than the natural frequency of the bare framed structure..
2. The reduction in the natural frequency is more, when the infill is removed in the lower floor as compared to the removal of infill in the upper floors as can be seen from the 2B3SA & 2B3S and 2B3SB tests
3. Similarly, there is an increase in the natural frequency when the infill is removed from the upper floors as observed from 1B3SA, 1B3S & 1B2S. From this we can conclude that the contribution of infill towards the mass being more in the upper floors as compared to the lower floors.
4. Increase in stiffness the time period is decrease. The RC frame with Bare frame(BF) having highest value of time period compared to masonry infill without soft storey(MI) and masonry infill with soft storey(SS).
5. The performance of masonry infill without soft storey(MI) was significantly better to that of BF and masonry infill with soft storey(SS) models.
6. The displacement is more in bare frame due to less stiffness compare to infill walls.
7. The axial forces are high due to presence of infill leads to stiffness in the frame. And bending moment and shear force are minimum in masonry infill without soft storey and masonry infill with soft storey and it is maximum in bare frame.
8. Infill walls increase the strength and energy dissipation capacity of the frame.

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