ANALYSIS OF RC FRAME WITH AND WITHOUT MASONRY INFILL WALL WITH DIFFERENT STIFFNESS WITH OUTER CENTRAL OPENING

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Abstract

In reinforced concrete frame building, masonry wall are generally used in as infills and specified by architects as partitions in such a way that they do not contribute to the vertical gravity load-bearing capacity of the structure. Infill walls protect the inside of the buildings from the environment hazards and create separation insides. In addition to this infills have a considerable strength and stiffness and they have significant effect on the seismic response of the structural systems. Mostly two common structural damages observed caused by masonry infill walls in earthquakes i.e soft stories and short columns. In office or residential building outer side central opening are used. In this case central opening are provided in periphery wall with different percentage i.e. 15% and 25% and brick compressive strength are used as per IS : 1905-1987 i.e. 5.0 and 12.5 N/mm^2 and Brick Masonry strength is 0.50 and 1.06N/mm^2. In ETABS software G+9 R.C.C framed building models has been prepared, Seismic coefficient method(SCM) and time-history(TH) has been performed for analysis as per IS 1893:2002. Story displacement, base shear, story drift, axial force with and without soft story considering effect of infill walls with different percentage of opening are the parameters considered in this study. For Macro model, Equivalent diagonal strut (EDS) method is used to find out width of strut using FEMA approach method. The results of bare frame, soft story and infill wall panel are discussed and conclusions are made in this studies.

Key Words: *Base shear, Displacement, Equivalent Diagonal Strut, Storey Drift, Soft storey.*

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1. INTRODUCTION

In RC frame brick walls is just architectural point of view and to make partition and other aspect. In multistory buildings, the ordinarily occurring vertical loads i.e. dead or alive, do not cause much of a effects, but the lateral loads due to wind or earthquake tremors are a matter of great concern and need special consideration in the design of buildings. These lateral forces can produce the critical stress in a structure, set up undesirable vibrations, and in addition, cause lateral sway of the structure which can reach a stage of discomfort to the occupants. In many countries situated in seismic regions, reinforced concrete frames are infilled fully or partially by brick masonry panels with or without openings. Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not taken into account because of the lack of knowledge of the composite behavior of the frame and the infill. During the elastic response phase, the presence of brick infill walls increases in plane lateral stiffness of the structure and reduced its fundamental period, and as a result leads to larger shear forces.

In residential building RC frame structure are infill by brick panels on all four sides and resisting the lateral earthquake loads on building. By experimentally it has been shown that brick walls have high initial lateral stiffness (Moghaddam and Dowling 1987, Drysdale et al. 1999, Paulay and Priestley 1992,). Hence masonry infills in RC frames different lateral load transfer mechanism of the structure from predominant frame action to predominant truss action (Murty and Jain 2000). Shown in Figure 1 below. Thus it is responsible for increase in axial forces in the RC frame.

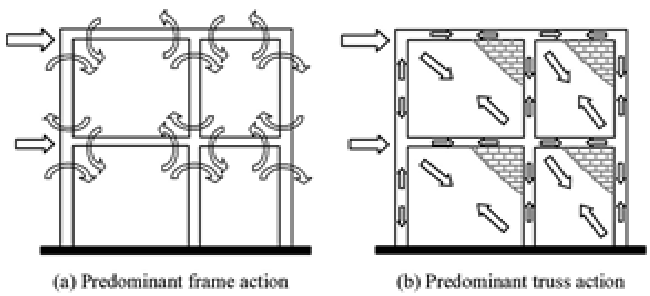


Fig -1: Change in lateral-load transfer mechanism due to masonry infill (Murty and Jain 2000)

2. LITERATURE REVIEW

From several research paper studies it shows that Equivalent diagonal strut method is used for modeling the brick infill wall to easy represent the effect of inplane during lateral load and its equations for Equivalent diagonal strut width for full infill given by various researchers are,

In 1961 Holmes,

w = dz/3 where, dz = Diagonal length of infill panel

In 1962 Equivalent diagonal strut according to Smith,

$$W_o = \sqrt{\alpha_h^2 + \alpha_L^2}$$

$$\frac{\alpha_h}{L'} = \frac{\pi}{2}.\frac{1}{\lambda_h.L'} \qquad \lambda_h.L' = L'\sqrt[4]{\frac{E_{panel}.t}{4.E_p.I_p.h}sen(2\theta)}$$

$$\frac{\alpha_L}{L'} = \pi.\frac{1}{\lambda_L.L'} \qquad \lambda_L.L' = L'\sqrt[4]{\frac{E_{panel}.t}{4.E_p.I_b.L}sen(2\theta)}$$

In 1969 Smith and Carter,

$$w = 0.58\left(\frac{1}{H}\right)^{-0.445}(\lambda_h H')^{0.335 d_z\left(\frac{1}{H}\right)^{0.064}}$$

$$\lambda_h = \sqrt[4]{\frac{E_z t \sin 2\theta}{4E_b I_s H}}$$

In 1971 Mainstone,

$w = 0.175dz\,(\lambda_h H')^{-0.4}$

In 1984 Liaw and Kwan,

$w = (0.95H\cos\theta)/\sqrt{\lambda hH'}$

In 1992 Paulay & Priestley,

w = dz/4

3. RESEARCH OBJECTIVES

The main objective of this paper is to simplify the analysis concept of the building industry. And also carry out the effect of brick masonry infilled walls for the static linear analysis and Time history analysis of the R.C.C high rise building with single diagonal strut approach as per IS 1893:2002 and IS 456:2000. The result would be carried out and compare for G+9 story R.C.C. building.

4. METHOD OF ANALYSIS OF THE BRICK INFILL WALL

4.1 Data Taken

Table -1: Data for Building

Story =	G+8 4x3 bay
Ground floor height =	3.0m
Typ. story height=	2.9m
Basement height=	3.0m
Beam=	230 x 450 mm
Column=	500 x 500mm
Spacing of frame X direction=	3m
Spacing of frame Y direction=	3m
Live load=	1.5 kn/m^2 for terrace 3.0 kn/m^2 for typ floor
Dead load=	2.0 kn/m^2 for terrace 1.0 kn/m^2 for typ floor
Response Reduction Factor, R=	3 for SMRF
Importance factor, I=	1.0
Type of soil=	Medium
Damping of structure=	5%
Grade of concrete=	M30
Steel=	Fe 415
Density of concrete=	25 kn/m^3
Density of brick wall=	20 kn/m^3
Modulus of elasticity of concrete, Ec=	27.386 x 10^6 kn/m^2
Modulus of elasticity masonry, Em=	1)0.275 x 10^6 kn/m^2 2)0.583 x 10^6 kn/m^2
Thick. of outer Brick wall=	115 mm
Thick. of inner Brick wall=	115 mm
Thick. of slab=	125mm
Poisson ratio of concrete=	0.2
Poisson ratio of brick wall=	0.17
Seismic zone=	V
Z =	0.36
Time history	Bhuj_Ahmedabad

4.2 Types of Model

Table -2: Types of Model

ID (The First value indicates masonry comp. stress, N/mm^2)	Description
0.5BFGSS15%	Bare frame ground soft story with 15% outer central opening
0.5SFGSS15%	Strut frame ground soft story with 15% outer central opening
1.06BFGSS15%	Bare frame ground soft story with 15% outer central opening
1.06SFGSS15%	Strut frame ground soft story with 15% outer central opening
0.5BFGSS25%	Bare frame ground soft story with 25% outer central opening
0.5SFGSS25%	Strut frame ground soft story with 25% outer central opening
1.06BFGSS25%	Bare frame ground soft story with 25% outer central opening

1.06SFGSS25%	Strut frame ground soft story with 25% outer central opening
0.5BFWSS15%	Bare frame without soft story with 15% outer central opening
0.5SFWSS15%	Strut frame without soft story with 15% outer central opening
1.06BFWSS15%	Bare frame without soft story with 15% outer central opening
1.06SFWSS15%	Strut frame without soft story with 15% outer central opening
0.5BFWSS25%	Bare frame without soft story with 25% outer central opening
0.5SFWSS25%	Strut frame without soft story with 25% outer central opening
1.06BFWSS25%	Bare frame without soft story with 25% outer central opening
1.06SFWSS25%	Strut frame without soft story with 25% outer central opening

4.3 Modelling of Brick Infill Wall

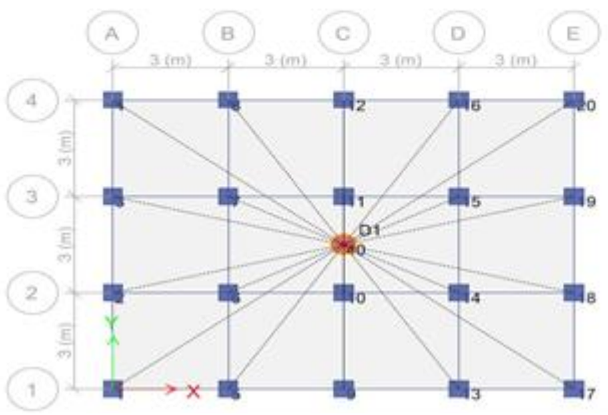


Fig -2: Plan

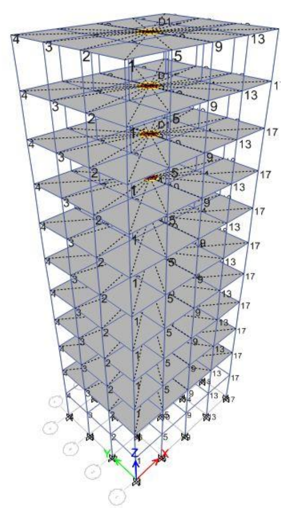


Fig- 3 3D View of Bare Frame

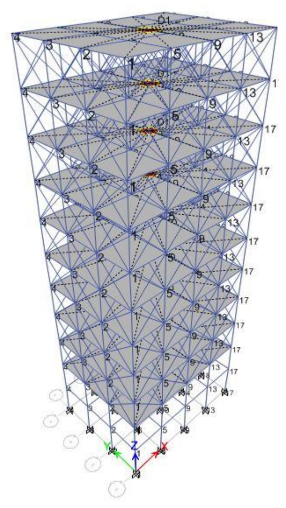


Fig- 4 3D View of Strut Frame

4.4 FEMA Approach

Equivalent diagonal strut method is used for modeling the brick infill wall according to FEMA273.The infill frame in this model was assumed as an equivalent diagonal strut with frame the pin joint(hinge joint) at the corners of the RC frame(See Fig.5).

In this method the brick infill wall replaced by diagonal strut. The frame is analyzed as truss element.

The equivalent diagonal strut width is given as:

$$w = 0.175(\lambda_1 h_{col})^{-0.4} r_{inf} \quad \text{eq}^n\ 1$$

Where, $\lambda_1 =$

$$\left\{\frac{E_{me} * t_{in}}{4E_{ef} * I_{c}}\right.$$

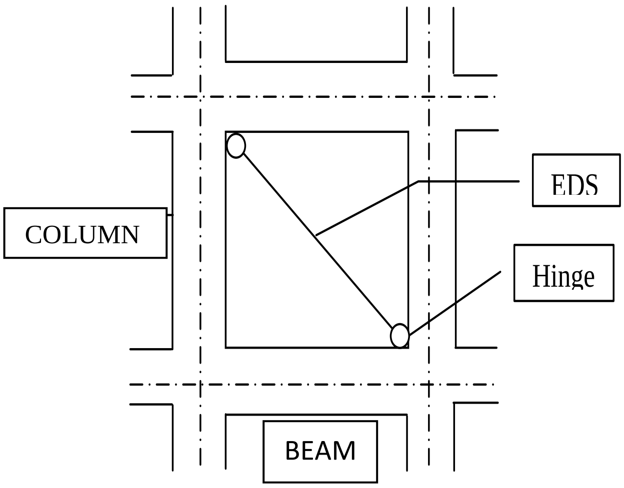


Fig- 5 Diagonal strut with pinned joint

And

h_{col} =Column height between centerlines of beams,m

h_{inf} = Height of infill panel, m

E_{fe} =Expected modulus of elasticity of frame material,kn/m^2

E_{me} =Expected modulus of elasticity of infill material, kn/m^2

I_{col} = Moment of inertia of column, m^4

L_{inf} = Length of infill panel, m

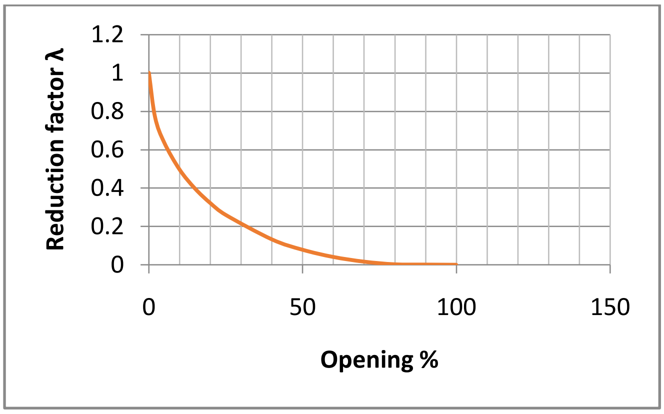
r_{inf} = Diagonal length of infill panel, m

t_{inf} =Thickness of infill panel and equivalent strut, m

θ =Angle whose tangent is the infill height-to-length aspect ratio, radians

λ_1 = Coefficient used to determine equivalent width of infill strut

4.5 Strut Reduction Factor



Reduction factor

$$\lambda = 1 - 2\alpha_w^{0.54} + \alpha_w^{1.14}$$

The above coefficient (ʎ) could be used to find the equivalent width of a strut for the case of an infill with opening by multiplying the results of Eqns. 1 above for central opening.

4.6 Modulus of elasticity of brick masonry

In lieu of prism tests, values for the modulus of elasticity of masonry in compression shall be taken as, 550 times the expected masonry compressive strength, f_{me}.

i) Compressive strength, f_{me} = 0.5MPa
(IS 1905:1998, Table-8)
Em= 550 x f_{me} = 550 x 0.5 x 10^3 = 0.275 x 10^6 kn/m^2

ii) Compressive strength, f_{me} = 1.06MPa
(IS 1905:1998, Table-8)
Em= 550 x f_{me} = 550 x 1.06 x 10^3 = 0.583 x 10^6 kn/m^2

4.7 Fundamental Natural Period of Vibration, (Ts)

Ts= 0.09h/sqrt(d)
Tx = 0.8314 s, Ty = 0.96 s
Where, h = Height of building, in m
d = Base dimension of the building at the plinth level, in m

4.8 Average Response Acceleration Coefficient

(Sa/g)x = 1.36/T = 1.635826
(Sa/g)y = 1.36/T = 1.416667

5. RESULT AND DISCUSSION

5.1 Base Shear

The design base shear V_b as per IS: 1893 shall be calculated by following formula,

Vb = Ah x W

Where, $Ah_{x,y}$ = ZIS/2RG

Ah_x = 0.069949

Ah_y = 0.049461

Table -3: Base shear

BASE SHEAR IN X-DIRECTION(KN)		
ID	**SCM**	**TH**
0.5BFGSS15%	1549.31	1222.84
0.5SFGSS15%	1549.31	1178.59
1.06BFGSS15%	1549.31	1222.84
1.06SFGSS15%	1549.31	1379.87
0.5BFGSS25%	1519.63	1196.86
0.5SFGSS25%	1519.63	1155.00
1.06BFGSS25%	1519.63	1196.86
1.06SFGSS25%	1519.63	1348.81
0.5BFWSS15%	1595.76	1233.61
0.5SFWSS15%	1595.77	1202.23
1.06BFWSS15%	1595.76	1233.61
1.06SFWSS15%	1595.77	1693.92
0.5BFWSS25%	1566.01	1208.23
0.5SFWSS25%	1566.01	1186.65
1.06BFWSS25%	1566.01	1208.23
1.06SFWSS25%	1566.01	1652.86

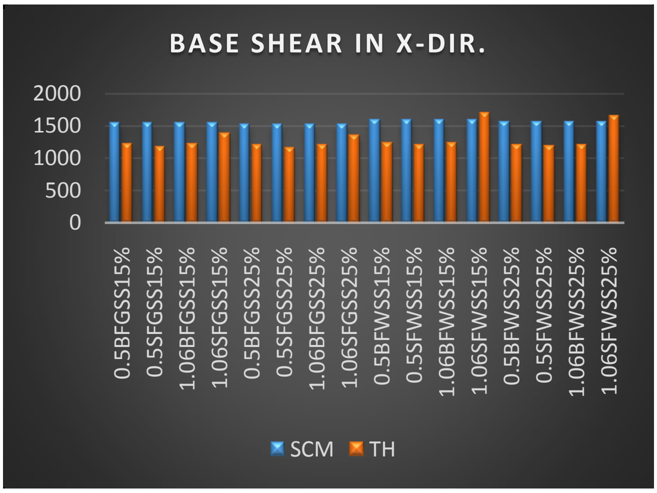


Chart -1: Base shear at base in X Direction (Kn)

We can conclude from this analysis that with increase in stiffness of infill wall base shear of building also increase thus stiffness of wall is should be minimum.

5.2 Displacement

Table -4: Displacement at the top level

DISPLACEMENT AT ROOF LEVEL IN MM			
SR NO.	ID	SCM	TH
1	0.5BFGSS15%	51.2	31.55
2	0.5SFGSS15%	44.59	27.37
3	1.06BFGSS15%	51.2	31.55
4	1.06SFGSS15%	39.42	31.21
5	0.5BFGSS25%	50.28	31.45
6	0.5SFGSS25%	44.34	27.64
7	1.06BFGSS25%	50.28	31.45
8	1.06SFGSS25%	39.56	31.19
9	0.5BFWSS15%	52.7	31.69
10	0.5SFWSS15%	44.74	28.95
11	1.06BFWSS15%	52.7	31.69
12	1.06SFWSS15%	38.63	32.58
13	0.5BFWSS25%	51.78	31.6
14	0.5SFWSS25%	44.52	29.19
15	1.06BFWSS25%	51.78	31.6
16	1.06SFWSS25%	38.81	32.61

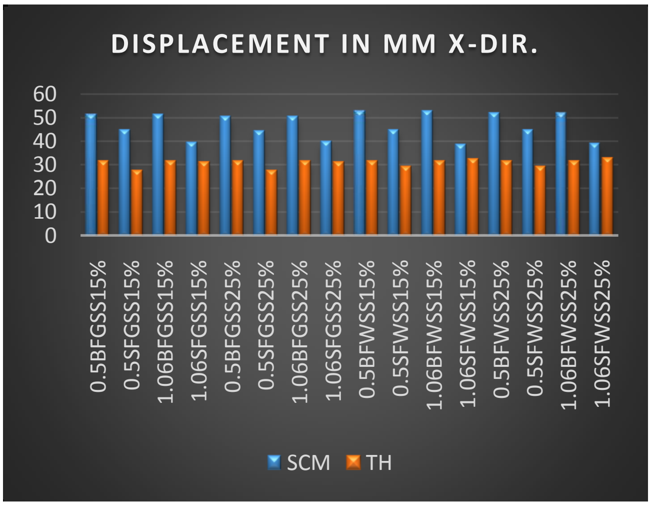


Chart -2: Displacement at the top in X Direction

The displacement in X direction for diff. models are shown in Graph 2. From graph it can be concluded that with increase in stiffness of infill wall displacement of building decreased by 12% to 25 %(see Table 4) in Static and Dynamic analysis.

5.3 Story Drift

The drift value for SCM and TH analysis results are shown in followings different chart in mm (see Chart 3 to 6).

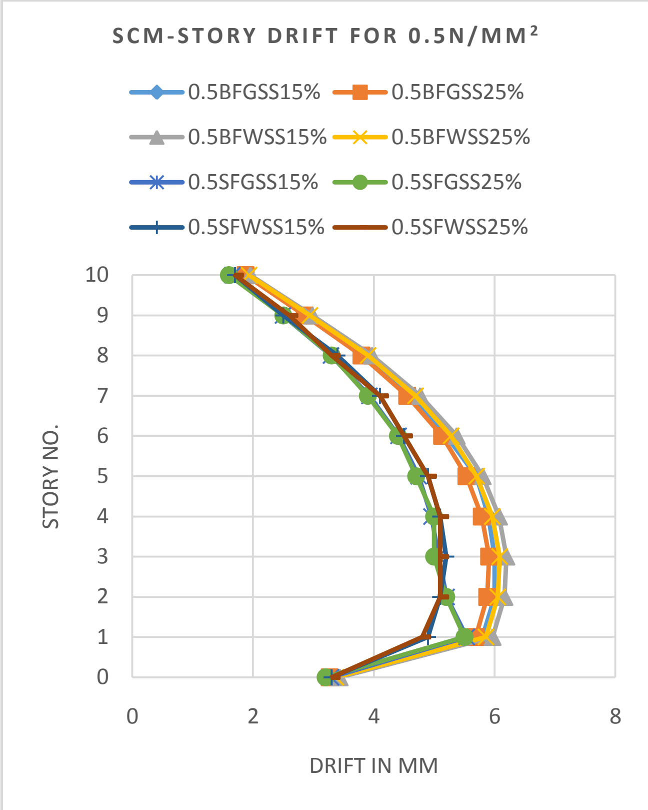


Chart-3: Story Drift for SCM in X direction (0.5)

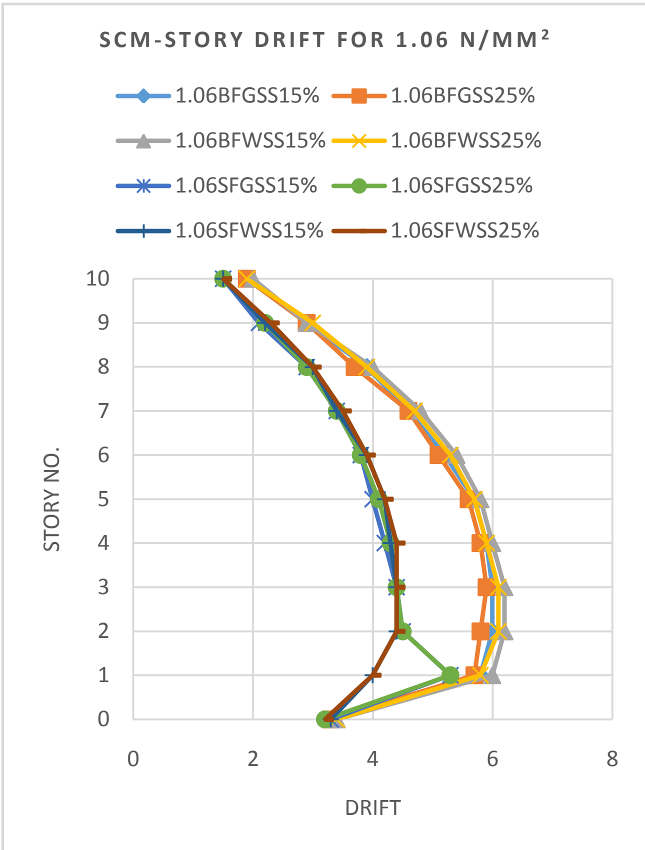


Chart-4: Story Drift for SCM in X direction (1.06)

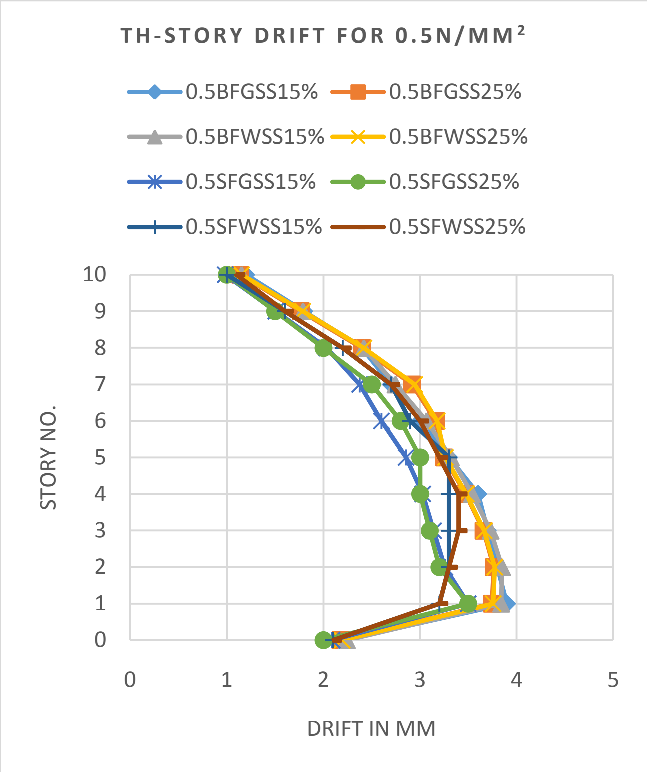


Chart-5: Story Drift for TH in X direction (0.5)

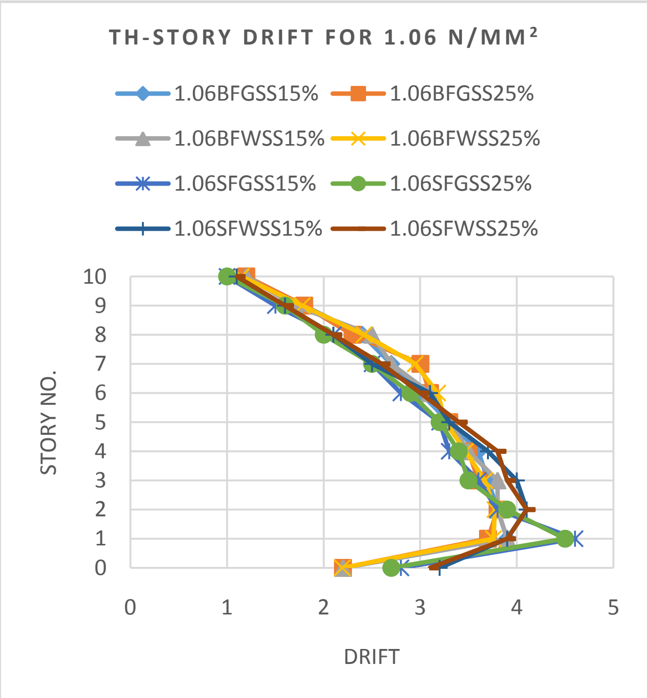


Chart-6: Story Drift for TH in X direction (1.06)

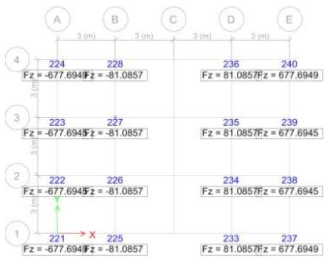
The drift value has a particular importance of serviceability requirement. According to Indian seismic code IS 1893 Part-1 :2002, The story drift in any story due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 * h, where h = story height.

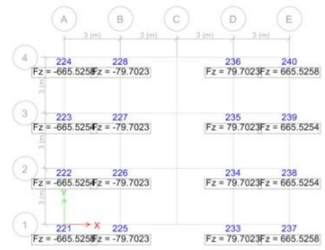
In building with strut, Story drift is less as compared to without considering strut type building in both direction, i.e. and Y.(See Chart 3 to 6). All story drift are found to be within permissible limit i.e. 1.2 cm.

5.4 Axial Force

The maximum axial force in the column are as shown in following,

Table 5: Maximum Axial Force (kn) on column at Base in EQ-X

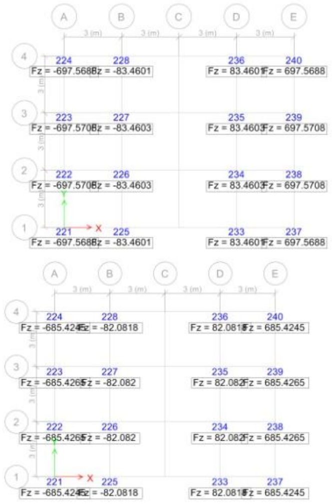




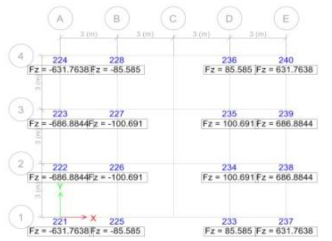
0.5BFGSS15% & 1.06BFGSS15% 0.5BFGSS25% & 1.06BFGSS25%

0.5SFGSS15%

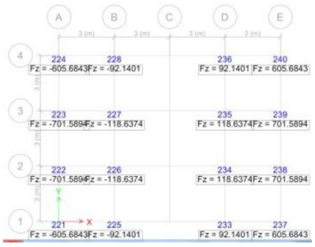
1.06SFGSS15%



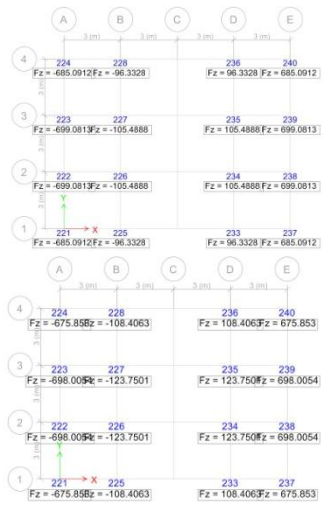
0.5BFWSS15% & 1.06BFWSS15% 0.5BFWSS25% & 1.06BFWSS25



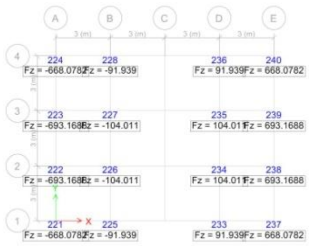
0.5SFGSS25%



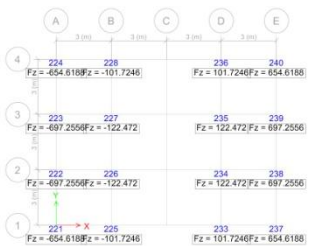
1.06SFGSS25%



0.5SFWSS15% 1.06SFWSS15%



0.5SFWSS25%



1.06SFWSS25%

From the analysis we can conclude that for the models with Strut Frame has quite higher axial force on the ground column as compared to Bare Frame. And it's depending on infill stiffness. The values are given in Table.5 for X direction only in EQ-X.

6. CONCLUSION

In this paper sixteen models are prepared for Static Linear analysis and Dynamic analysis (TH) results of models i.e. without strut and with strut of infill wall with central outer opening with 15% and 25% are compared. From this analysis it can be concluded that diagonal strut will change the seismic performance of RC building. Axial force in column increased, story displacement and story drift are decreased and base shear is increase with higher stiffness of infill. *If in the ground level at least periphery wall is provide then soft story effect can be minimized.* It can also be concluded, the increase in the percentage of opening leads to a decrease in the lateral stiffness.

7. ACKNOWLEDGEMNET

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BIOGRAPHIES

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Dr. V. R. Patel is an assistant professor in the Faculty of Technology and Engineering, The M. S. University of Baroda. He has a broad experience in the field of structure engineering. He has also designed more than 2500 projects which includes industrial, High rise building.