

# **An Investigation of the Fundamental Time Period of Vibration of RC Infilled Frame with Opening**

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**ABSTRACT:** Masonry infilled frames are considered as non-structural element which consists of bricks or concrete blocks. But these walls increase initial stiffness and strength of RC frame buildings. In India, many will be having open first storey for purpose of parking or lobbies and upper storey will have different percentage of opening like windows, doors. These openings reduce the stiffness of the structure. Such buildings are highly undesirable in seismically active areas. In the present study, it is an attempt to assess the performance and to investigate the fundamental time period of vibration of masonry infilled frame with different percentage of opening. To understand the behaviour of masonry infill 5, 10, 15, and 20 storey buildings are modelled as Equivalent diagonal strut in SAP 2000. The co-efficient of time period for each storey is calculated. The results showed that the stiffness of infill panel is 6.4 times higher than that of bare frame. It can reach up to 7 times. The result shows that as opening size increases the stiffness gets reduced. The application of investigated time period is used. This paper highlights the importance of presence opening on lateral stiffness and time period of frames with and without infill panels.

**KEYWORDS:** Masonry Infilled Frame, Response Spectrum Analysis, SAP 2000.

## **1. INTRODUCTION**

Reinforced concrete buildings are the most common residential construction in our country. Earthquake in the past years have caused huge losses in human as well as economical losses. Most of the earthquake was directly related to damage or collapse of buildings. The occurrence of the earthquake damages depends on the strength, period and the duration of the seismic motion in addition to other dynamic properties. The response of the building to the ground motion is determined by the fundamental period of vibration which is the most important factor. The different seismic regulations have decided to represent the simple equations to calculate the fundamental period of the structure so that the designers can use this for the design purpose.

In a framed structure, the frames are infill with stiff materials such as concrete block masonry or brick masonry to create enclosures and to provide safety to the users. These kinds of walls are known as infill walls. For a structure, under gravity load the effect of infilled masonry walls can be neglected since the beams, columns, and slabs gain sufficient strength. But under lateral loads, the infill panels increase the strength, lateral stiffness and energy dissipation capacity. Therefore the effect of infill panels cannot be neglected.

### **1.1 OBJECTIVES**

The objective of this thesis is to investigate the fundamental time period of an infilled masonry frame with and without opening under Response spectrum method. The study on the behavior and response of structure is carried out by creating models and analyzing in SAP 2000.

The main objectives of this project are

- To study the MIF effects for structure subjected to seismic forces.

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- To check the Variation in plane lateral stiffness of the MIF structure with different percentage openings.
- To investigate the fundamental time period for masonry infilled frame structure with different percentage openings.
- To know the variation in frame forces by considering opening in masonry infilled wall for investigated time period and time period as per IS 1893: 2002.

## 1.2 EQUIVALENT STRUT MODEL

In the analysis of the structure, the masonry walls cannot be modelled. Therefore the masonry infill walls will be treated as equivalent diagonal strut as shown in the figure below. The equivalent strut model is the simplified and this is done by modelling the infill panel as a single diagonal strut. This strut is connected to two compressive diagonal corners.

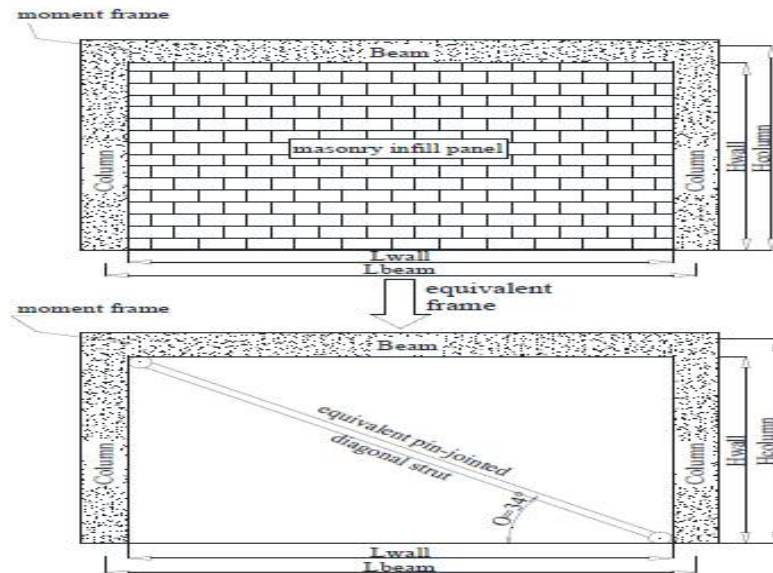


Fig 1 Masonry infill frame and Equivalent strut model for MIF Panels.

The formation of single strut occurs when the width is larger as the panels considered as rectangular. If height of panel is increased, the MS formation occurs as in the below figure. As the depth of opening increases there will be a chance of formation multiple struts.

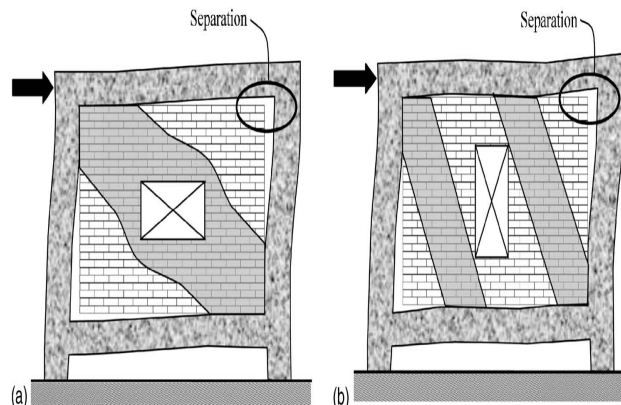


Fig 2 Formation of diagonal strut (a) single strut (b) multi struts

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## II. METHODOLOGY

A five, ten, fifteen and twenty storey building, with ordinary moment resisting frames on level ground in two orthogonal directions, was selected for the study. The building had a one brick thick exterior infill wall along the periphery with and without openings. It was considered to be located in severe zone on type II soil as per IS 1893: 2002. The multistory building consists of slab, beam and column. Slab was modeled as membrane shell element and beam and column was modeled as frame element. Footing for the columns was assumed as isolated footing and assigned as fixed support. Floor loads were assigned as a two way frame load on slabs. The masonry (main) wall load and parapet wall loads were converted to uniformly distributed load and then assigned on beam.

Following methodology is used to achieve the defined objectives.

- Different storey buildings will be designed for gravity loadings only, the designed beam and column details such as sizes and reinforcement details will be assigned for seismic analysis.
- The effect of the infilled edge can be spoken to by a SEDS, the width of strut will be calculated for different percentage of openings by using width correction factor.
- The dynamic linear analysis will be carried out for the first series models to think about the impact of stone work infilled outline structure subjected to seismic strengths.
- Different size of openings will be considered in infill panel for second series models to know the variation in plane lateral stiffness as compare to infilled frame without openings.
- Equation of fundamental time period will be arrived for the same series models by performing dynamic linear analysis.
- The frame is analysed with openings in infill panel both time period will be considered in third series analysis models to know the variation frame forces ( Bending moment, Axial forces in columns and beams)

### 2.1 BUILDING DESCRIPTION

Table 1 Building Details

Bays along X and Y 6 at each 4.0m	
Type of building	General
Seismic zone	V
Type of frame	Ordinary moment resisting frame (OMRF)
Soil	Medium
Importance factor	1
Support condition	Fixed
Storey height	3.3m
Slab	150 mm
Beams	230×400mm, 250×400mm, 300××400 mm
Columns	300x300mm, 400x400mm, 500x500mm, 600mmx600mm
Main wall	230,250,300 mm

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Opening Size		1.2×1.2m, 1.5×1.2m, 1.5×1.5m
Partition wall		115 mm
Unit weight of brick infill		20kN/m <sup>3</sup>
Unit weight of concrete		25kN/m <sup>3</sup>
In KN/ m <sup>2</sup>	Live Load	Floor Finish
Storey	4	0.75
Roof	2	1.5
$f_{ck}$		20 N/mm <sup>2</sup>
$f_y$		415 N/mm <sup>2</sup>

## 2.2 CALCULATIONS

**Size of opening Area of opening ( $A_o$ )**

in(m)	in( m <sup>2</sup> )
1.2x1.2	1.44
1.5x1.2	1.80
1.5x1.5	2.25

Depth of strut = diagonal length of infill panel/3 in m,

Percentage of opening =  $\frac{\text{Area of opening} \times 100}{\text{Area of infill panel}}$

Strut Width Reduction factor = 1-2.6x Percentage of opening

Width of strut = Strut width reduction factor x depth of strut

By using above formulae, the required data for modelling were tabulated in the below table.

Table 2 Calculations

Storey	5	10	15	20
Infill panel size(m)	3.7x2.9	3.6x2.9	3.5x2.9	3.4x2.9
Area of panel(m <sup>2</sup> )	10.73	10.44	10.15	9.86
Diagonal length of infill panel,d	4.7	4.62	4.55	4.47
Depth of strut(d/3)	1.57	1.54	1.52	1.49

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% of opening	13.42	13.79	14.19	14.60
	16.78	17.24	17.73	18.26
	20.97	21.55	22.17	22.82
Strut width reduction factor	0.65	0.64	0.63	0.62
	0.56	0.55	0.54	0.53
	0.45	0.44	0.42	0.41
Width of strut, (m)	1.02	0.99	0.96	0.92
	0.88	0.85	0.82	0.78
	0.71	0.68	0.64	0.61

### III. RESULTS & DISCUSSIONS

**3.1** To study the effect of masonry ifilled frame subjected to seismic forces, 5, 10, 15 and 20 storey bare frame and masonry infilled frame buildings are analysed by doing response spectrum analysis using SAP software. The base shear and lateral displacements are recorded for all the models. The graph below shows that the displacement of the building increases as the storey height is increased. The displacement linearly increases with increase in the storey height. The maximum displacement occurs in bare frame.

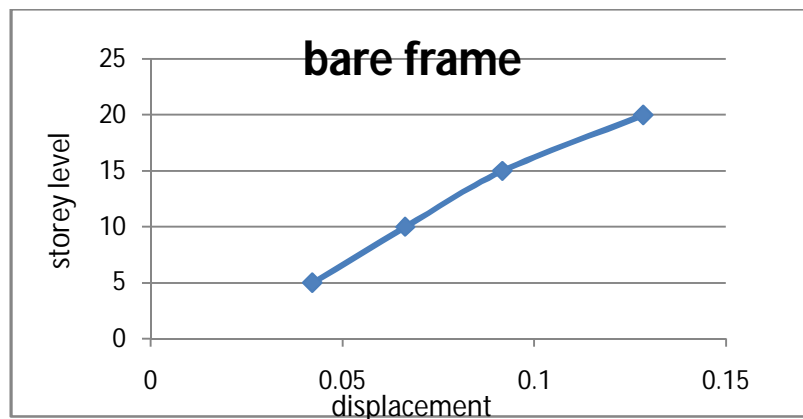


Fig 3 Displacement with respect to storey height for bare frame

The graph below shows that the displacement of the building increases as the storey height is increased. The displacement in the infill frame is lesser compare to bare frame by comparing the two graphs.

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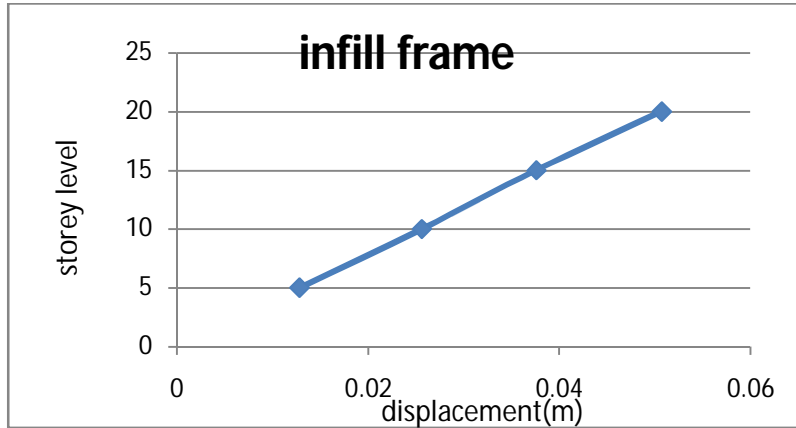


Fig 4 Displacement with respect to storey height for bare frame

The graphs below are drawn stiffness versus number of stories for bare frame. It shows that stiffness of the building decreases as the storey height increases. We know that deflection of a structure under loading is dependent on the stiffness of structure. The deflection is the ratio of load to stiffness. When the stiffness gets reduced it leads to increase in the deflection of the structure. The structure fails when it is insufficiently stiff to have acceptably small deflection.

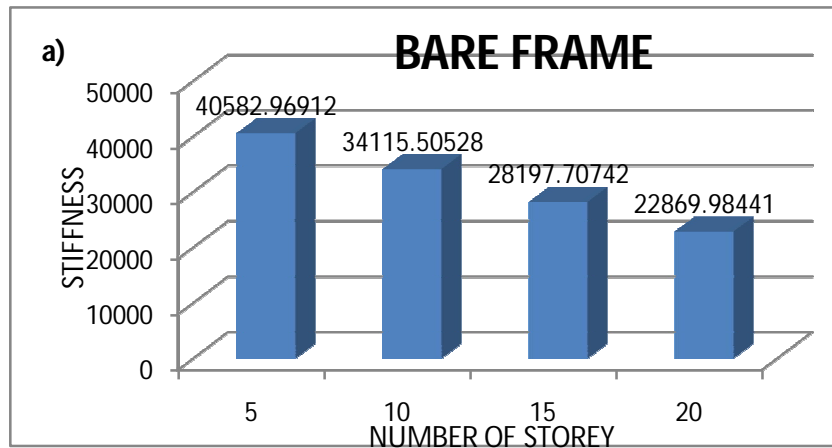


Fig 5 Effect of masonry infill frame subjected to seismic force a) Bare frame

The graphs below are drawn stiffness versus number of stories for infill frame. By comparing the two graphs, we can conclude that the infill panel increases the stiffness of bare frame by 6.4 times. It can reach up to 7 times that of the bare frames.

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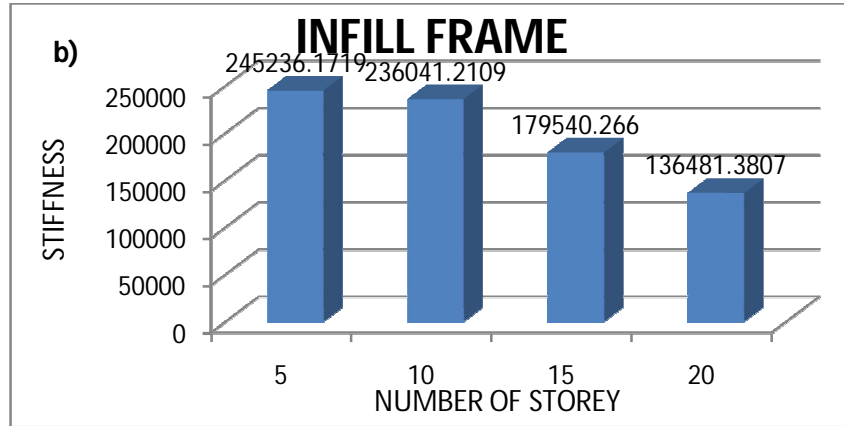


Fig 6 Effect of masonry infill frame subjected to seismic force b) Infill frame.

**3.2** To study the variation of plane lateral stiffness of masonry infilled frame structure with different percentage of opening. For 5, 10, 15 and 20 storey buildings, the graphs are plotted stiffness versus percentage of opening as shown below. For 5 storey building, for infilled frame with no opening the stiffness is more, later it goes on decrease with increase in the percentage of opening. Since it is 5 storey building the height is lesser therefore the stiffness is more.

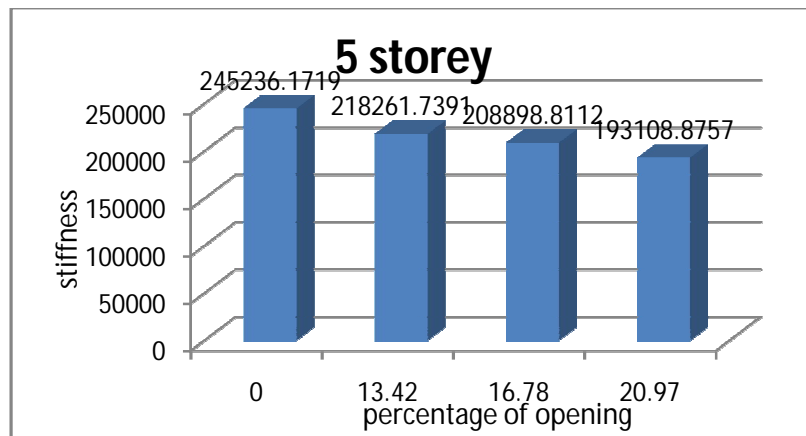


Fig 7 Effect of opening on stiffness for 5 storeys

For 10 storey building, the graph is plotted below. The stiffness is more for infilled frame without opening and it goes on decreases as the percentage of opening is increased. Compare to 5 storey, the stiffness is less in 10 storey building because we know that as the height of the building increases, the stiffness gets reduced.

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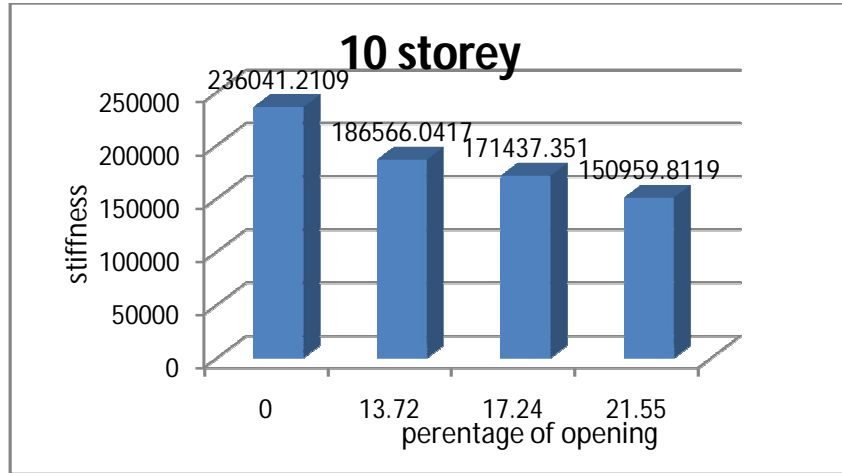


Fig 8 Effect of opening on stiffness for 10 storeys

For 15 storey building, the graph is plotted below. The stiffness is more for infilled frame without opening and it goes on decreases as the percentage of opening is increased. Compare to 5 and 10 storeys, the stiffness of 15 storey building is lesser because we know that as the height of the building increases, the stiffness gets reduced.

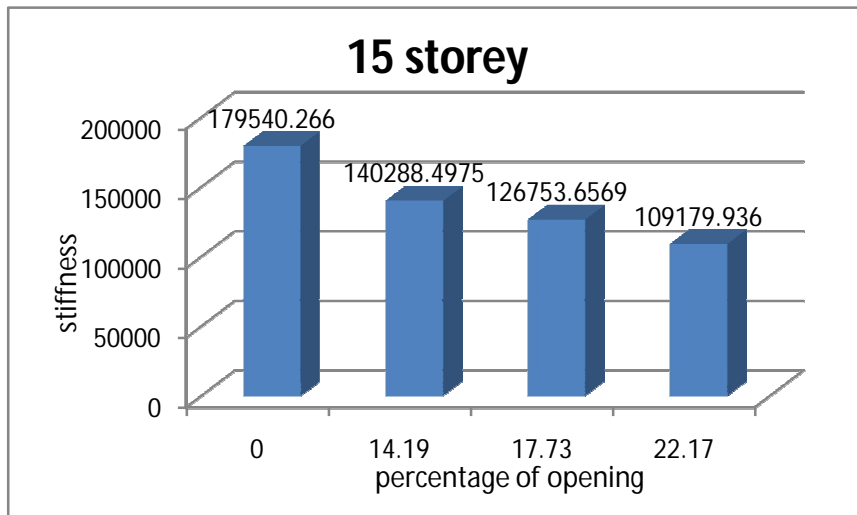


Fig 9 Effect of opening on stiffness for 15 storeys

For 20 storey building, the graph is plotted below. The stiffness is more for infilled frame without opening and it goes on decreases as the percentage of opening is increased. Compare to 5, 10 and 15 storey, the stiffness is less in 20 storey building because we know that as the height of the building increases, the stiffness gets reduced.



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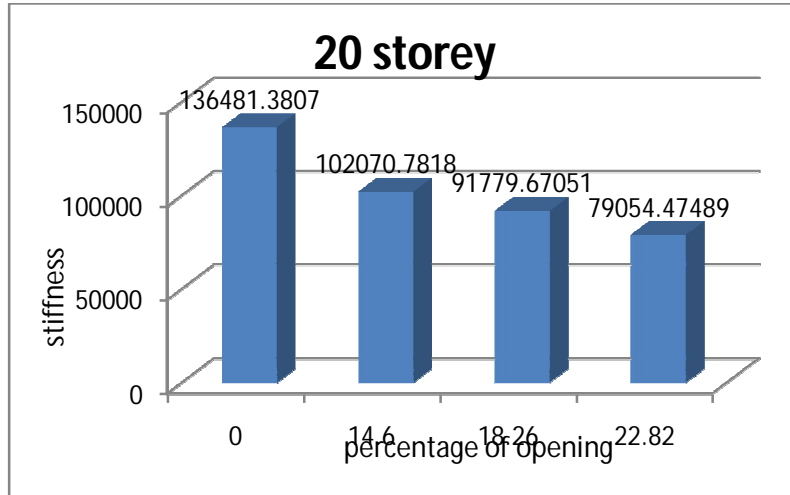


Fig 10 Effect of opening on stiffness for 20 storeys

**3.3**To investigate the fundamental time period for masonry in filled frame structure with different percentage of openings.

By codal provision, the expression for fundamental time period is  $T_c = 0.09h/\sqrt{d}$

Coefficient of time period,  $\alpha = T_p/T_c$

Where,  $T_p$  – time period by analysis

$T_c$  - time period by codal provisions

For an infilled frame with a given size of opening, for all 5, 10, 15, 20s graphs are plotted.

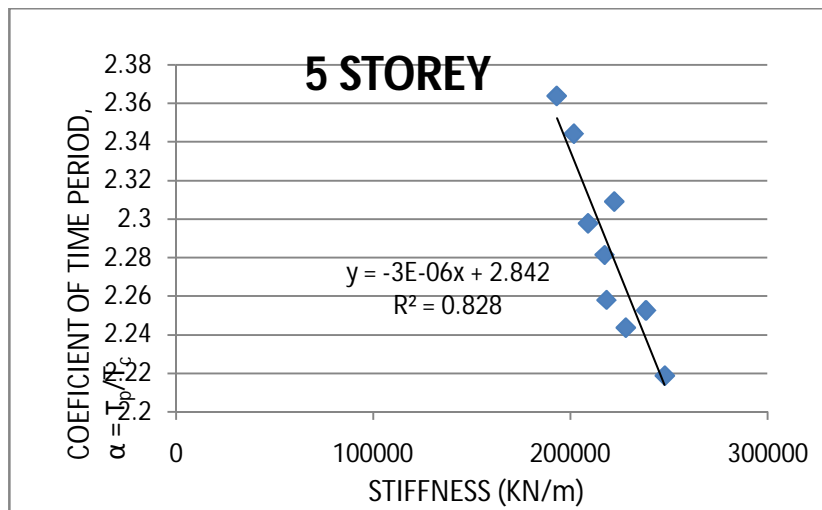


Fig 11 Effect of stiffness on fundamental time period for masonry frame for 5 storeys

For 5storey,

Equation of trend line,  $y = -3E-06x + 2.842$

coefficient of correlation,  $R^2 = 0.828$

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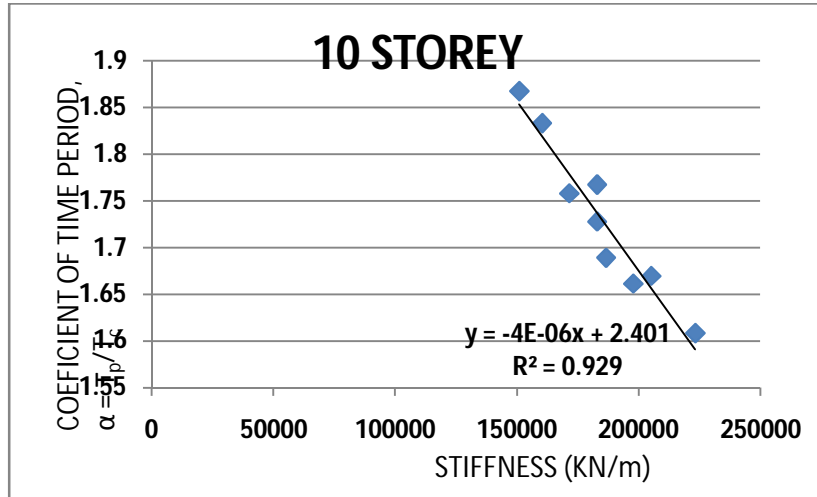


Fig 12 Effect of stiffness on fundamental time period for masonry frame for 10 storeys

For 10 storey,  
Equation of trend line,  $y = -4E-06x + 2.401$   
coefficient of correlation,  $R^2 = 0.929$

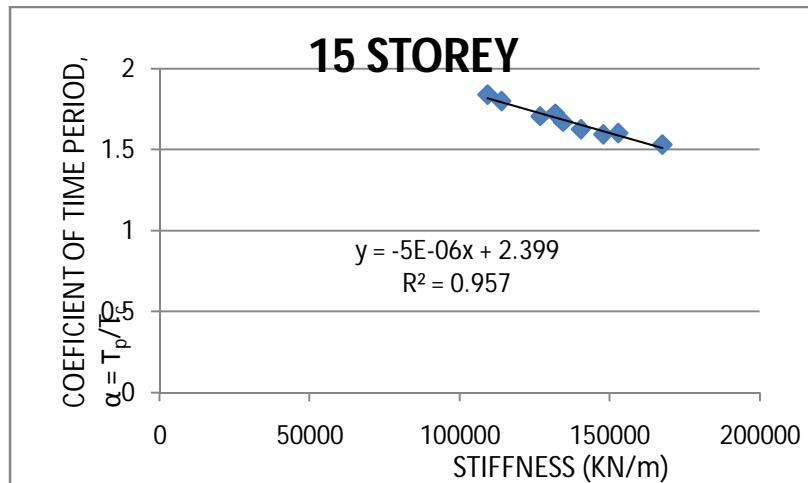


Fig 13 Effect of stiffness on fundamental time period for masonry frame for 15 storeys

For 15 storey,  
Equation of trend line,  $y = -5E-06x + 2.399$   
coefficient of correlation,  $R^2 = 0.957$

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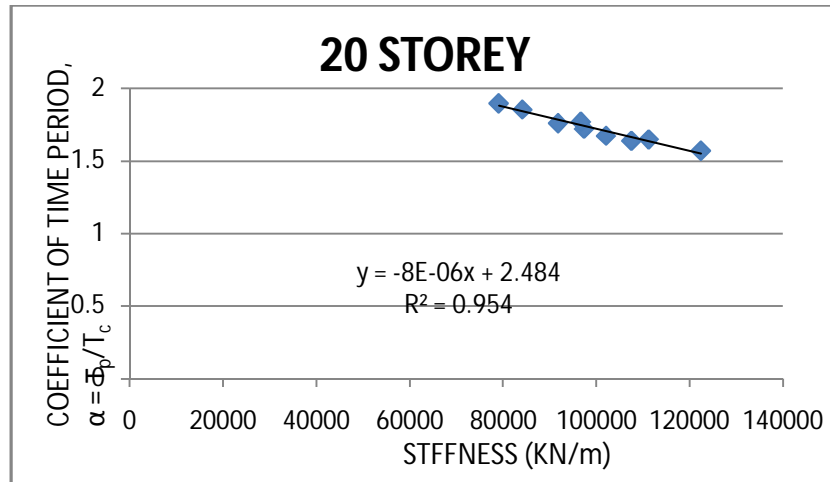


Fig 14 Effect of stiffness on fundamental time period for masonry frame for 20 storeys

For 20 storey,

Equation of trend line,  $y = -8E-06x + 2.484$

coefficient of correlation,  $R^2 = 0.954$

To study the response of structure to dynamic loading, estimation of fundamental period is essential. The fundamental time period is based on the evaluation of building's stiffness and mass and also it depends on number of stories, height of the building, openings in the vertical element. No expressions are provided by the IS codes for fundamental natural time period of masonry infill frame with opening. To calculate the time period fundamental period for different percentage of opening the above expressions can be used. The above expressions can be valid only for building height ranges between 5 to 20 storeys and for 13 to 22 percent of opening. One example is explained in the fourth objective.

**3.4** To know the variation in frame forces by considering opening in masonry infilled wall for investigated time period and time period as per IS 1893:2002.

Here we have considered 5 storey building model to know the variation in frame forces. The fundamental time period according to codal provision is given by  $T_a = 0.340s$

As per 1893-2002, Base shear = 3542.982KN

Roof displacement = 0.019266m

Initial stiffness by analysis,  $x = 208967.4444KN$

For 5 storey building, from graph equation of trend line is given by  $y = -3E-06x + 2.842$

Therefore  $\alpha = 2.2154$

Corrected time period,  $T_a =$  coefficient of time period  $\times$  time period by codal provision

$$\text{i.e, } T_p = \alpha T_c = 0.753s$$

As per IS 1893-2002, for this corrected time period,  $T_p = 0.753s$  the value of base shear will be 2559.604KN. This is corrected base shear value which is lesser than the actual value.

Similarly, the actual roof displacement is 0.019266m. After applying the correction we will get roof displacement as 0.013919m.

Earthquake load is considered in x-direction, the values of axial force, shear force and bending moment for actual time period and after application of correction are tabulated below,

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Table 3 Forces in Base Column (Grid 4G)

	AF (KN)	SF (KN)	BM KN/m
Eqx	-468.635	152.755	173.7926
Eqx Corrected values	-338.563	110.357	125.5554

These above results show that the values of BM, SF and AF reduced after applying correction for time period. This shows that the time period play a major part in earthquake resistant buildings.

The figure below indicates that the BM and SF values for 5storey building model. Here the actual time is considered and BM and SF values are noted.

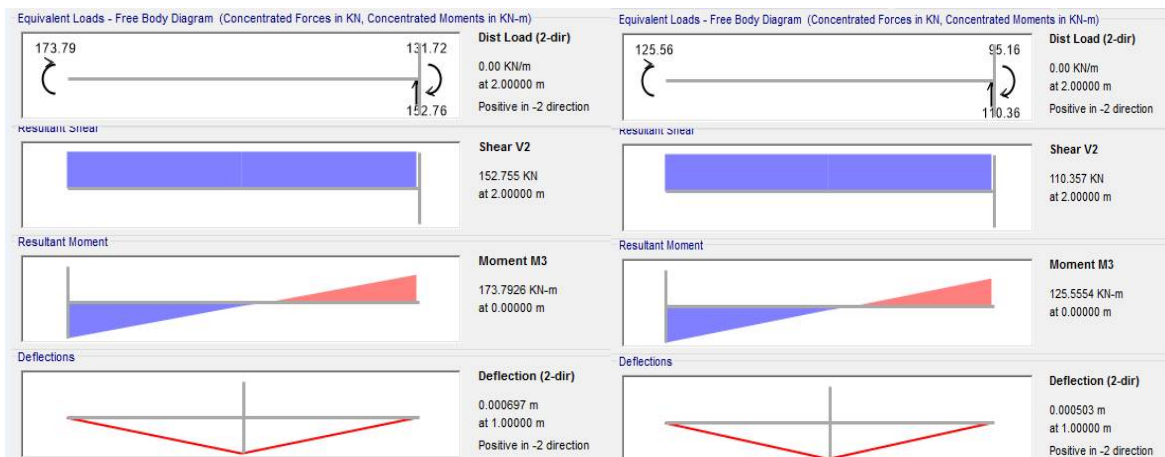


Fig 15 BM AND SF diagram before correction Fig 16 BM AND SF diagram after correction

By using the equation which we got for 5storey building from above objective, we got a corrected BM and SF values. The below figure indicates the corrected values of BM and SF after applying correction for time period for 5storey building.

## IV. CONCLUSION

- i. The effect of masonry infilled frame structure subjected to seismic forces is studied for 5, 10, 15 and 20 storey. During response spectrum analysis, we got results that infill panel expands the stiffness of bare frame by 6.4 times. The results shows that increase in the initial stiffness of infill frames can reach up to 7 times that of the bare frames.
- ii. The variation in plane lateral stiffness of MRF structure with different percentage of openings is studied. Its shows as open in panel increases, stiffness of frames get reduces.
- iii. For 20% open in panel, the reduction in stiffness are as follows, For 5S, reduction is 1.27times, for 10S - 1.56, for 15S - 1.64, for 20S - 1.73.
- iv. The fundamental time period for masonry infilled frame structure with various rate of of opening is concentrated on. And application this period is explained for 5 storeys.

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