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EVALUATION OF THE EFFECT OF MASONRY INFILL ON LOW, MEDIUM AND HIGH-RISE BUILDINGS

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Abstract:

When a structure is subjected to Lateral Loads (wind, earthquake etc.), its response depends on the effect the Masonry Infill (MI) has on the RC frame. A number of researches in this regard have been made to model the MI and analyse the structure under lateral loads. The analytical analysis included the MI walls which were modelled as Equivalent strut the width of which was calculated based on the equations proposed by various researchers. When laterally loaded the Infill (IF) behaved like a compression strut carrying axial forces in them. This completely changed the frame action of the structure to truss action, reducing the Bending moments and the Shear forces on the columns and beams. In the present study, an attempt was made to study the effect of Masonry Infill on Low, Medium and High-rise frames. Static pushover analysis is being performed on a 4-storey, 8-storey and a 12-storey frames, and the results are compared in terms of Time periods, Base shear, Roof displacement, Storey drifts, Inter-storey drifts, Storey shears and Capacity curves. All the analysis is being carried out using the software ANSYS.

Keywords: Masonry Infill (MI), Static pushover analysis, Roof displacement, Time period, Base shear, Storey drifts, storey shear.

1. INTRODUCTION

Civilisation and modern methods of construction technology, has led to the development of the cities increasing the demand of High-Rise buildings and initiating the vertical growth. The most common construction methodology adopted is the RC frames which were infilled with masonry walls. The presence of IF walls is often being neglected because of the complications involved in understanding their interaction with the surrounding frame. When the interaction of MI with the RC frame was being considered, it was found that the strength and stiffness of the structure increased, thereby increasing the load carrying capacity in the lateral direction and changing the response of the structure. For this, Pushover analysis is a favoured tool for studying the responses and structural assessment of the structure. It can be demarcated as a method where the structure is subjected to monotonically increasing lateral forces with height wise distribution. The roof displacement is plotted along with the Base shear to get the Capacity curves of the structure [1].

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2. OBJECTIVES

In order to evaluate the effect of MI on low, medium and High-rise building, a 4-storey, 8-storey and a 12- storey single bay frames were being considered. Non-linear pushover analysis is being performed on the 2D frames. The obtained results of the analysis were compared based on terms of Time period, Base shear, Roof displacement, Storey displacement, Inter-storey Drifts, Storey shears and Capacity curves.

3. METHODOLOGY

A single bay with 4, 8 & 12 storeys were being considered. These frames were analysed for both - Bare and Infilled condition.

3.1) The cross sections and properties adopted for the structural elements of the frame are given below.

1)	Plan Size	= 4.0m X 4.0m
2)	Column Dimension	= 0.2 m X 0.3 m
3)	Beam Dimension	= 0.2 m X 0.4 m
4)	Density of concrete	= 25 kN/m^3
5)	Elasticity Modulus of Concrete	= 25 x 10^6 kN/m^2
6)	Concrete Poisson's ratio	= 0.2

3.2) Shape and size of the infill panel:

The shape of the infill panel in a building would either be square or rectangular which depended upon the function of the building, headroom required, spacing of columns etc. The details of the IF considered were as follows:

1)	Thickness of brick masonry wall	= 0.1 m
2)	Span of the bay	= 4.0 m.
3)	Height of the floor	= 3.0 m
4)	Density of brick infill	= 18 kN/m^3
5)	Modulus of elasticity of brick	= 4.5 x 10^6 kN/m^2
6)	Poisson's ratio of brick infill	= 0.19
7)	Compressive strength of brick	= 15 x 10^3 kN/m^2

3.3) Properties of mortar:

1)	Compressive strength	= 5.0 x 10^3 kN/mm^2
2)	Modulus of elasticity of mortar	= 1.0 x 10^6 kN/mm^2

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3.4) Loads on the structure:

1) Dead Loads: The structural elements i.e., beams, columns & slab self-weights.

2) Live Loads: An imposed load of 3.0 kN/m^2 was considered.

3) Seismic loads: Calculations of seismic load was dependant on the following parameters:

- **Structure Type:** Frame type considered for the analysis was an ordinary moment resisting frame. Hence, the response reduction factor considered was, R = 3.0, from table 7, IS 1893 (part-1) 2002.
- **Importance of the structure:** As the frame was a regular building, importance factor of the structure considered was, I = 1.0, from table 6, IS 1893 (part-1) 2002.
- **Type of Soil:** The spectral response acceleration coefficient (Sa/g) depended on type of soil in which the frame was located and the fundamental natural time period (Ta) of buildings. Therefore, the soil type becomes a guiding criterion for computation of lateral load. In the current study, it was assumed that the structure was located in type II (medium soil).
- **Seismic zone:** In the current study, the behaviour of frames was being considered for seismic zone V with a zone factor Z = 0.36, as per IS 1893 (part I): 2002.

3.5) Method of analysis: Non-linear pushover analysis was adopted in the current analysis.

The method of analysis was by using ESLM (Equivalent-Static Lateral Force Method). The procedure involved in equivalent lateral load calculation was one of the simplest analysis methods and requires less computational effort because the forces depended on the code (IS 1893 - (Part 1): 2002), based on the fundamental period of the structures with some empirical modifier. The design base shear would first be computed as a whole, and then be distributed along the height of mass and stiffness. The design lateral force obtained at each floor level would then be distributed to individual lateral load resisting elements depending upon floor diaphragm action.

3.6) Software used:

The push over analysis was being be carried out using ANSYS. 3D Elastic beam 4 element was being used for modelling the beams and columns, Plane 42 was being used for modelling the IF and Link 10 was used at the interface between the frame and the infill. For the purpose of meshing the Aspect ratio of 1 was adopted.

4. TABULATION OF RESULTS

Non-Linear Pushover analysis on a single bay 4, 8 and 12-storey frame with infills were being carried out using ANSYS software package.

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The parameters of the results of the analysis considered for the study were as follows:

a) Time Period.

b) Base shear.

c) Roof displacement.

d) Storey drift.

e) Inter-storey Drifts.

f) Storey shears.

g) Capacity curves.

The results of bare frame are compared with IF frame to evaluate the effectiveness of the infill. The results were represented in the form of ratios R_1, where,

R_1 = (Force in the str. member of IF frame) / (Force in the str. member of Bare frame).

4.1) Variation in the Time period of the frames:

The time periods of all the frames were calculated as per IS: 1893 (part 1) 2002. The calculated values are tabulated in the Table 1 and the variation is shown in the fig.1.

Table 1: Variation in the Time period (sec)

TYPE	DESCRIPTION	TIME PERIOD	RATIO	% INCREASE
LOW	BARE FRAME	0.484	1	11.66
	IF FRAME	0.540	1.1166	
MEDIUM	BARE FRAME	0.813	1	29.11
	IF FRAME	1.050	1.2911	
HIGH	BARE FRAME	1.102	1	46.97
	IF FRAME	1.620	1.4697	

From the above table 1, it had been observed that,

- The Time period of an IF frame was higher in comparison to that of a Bare frame.
- The Time period of an IF frame of a Low-rise frame increased by 11.66% than that of Bare frame.
- The Time period of an IF frame of a Medium rise frame increased by 29.11% than that of Bare frame.
- The Time period of an IF frame of a High-rise frame increased by 46.97% than that of Bare frame.
- The Variation in the graph of Time period of Low, Medium and High-rise frames is as shown below in fig.1.

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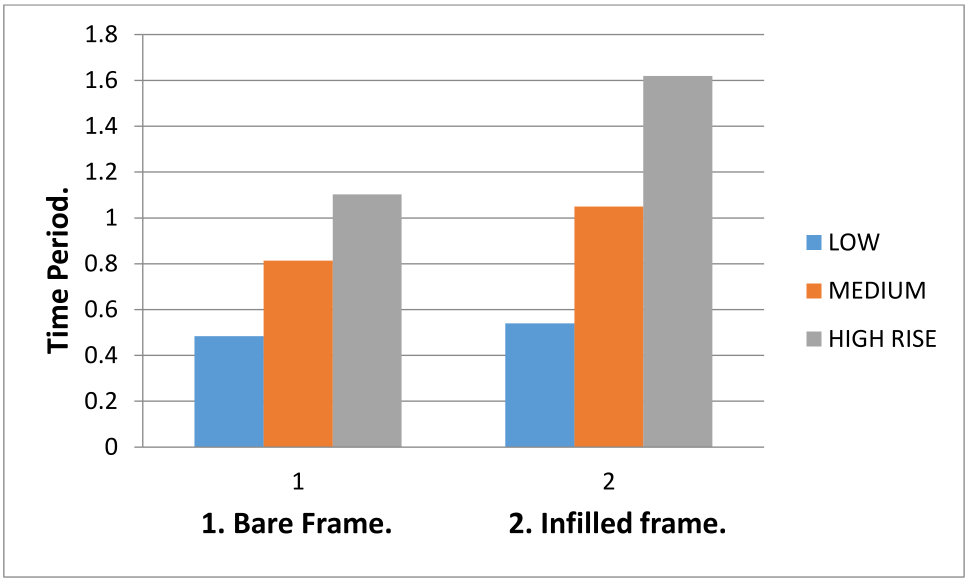
Figure 1: Variation in the Time period.



It had been observed from fig.1 that,

- The irrespective of the number of floors, the time period of an IF frame was more than the that of a bare frame.
- The Time period of an IF High rise frame increased drastically.

4.2) Variation in the Base shear of the different frames:

The base shear of all the frames were calculated and tabulated in the Table 2 and the variation is shown in the fig.2.

Table 2 - Variation in the Base shear (kN)

TYPE	DESCRIPTION	BASE SHEAR	RATIO	% INCREASE
LOW	BARE FRAME	84.06	1	
	IF FRAME	120.99	1.4394	43.94
MEDIUM	BARE FRAME	202.82	1	
	IF FRAME	298.36	1.4710	47.10
HIGH	BARE FRAME	304.77	1	
	IF FRAME	451.53	1.4815	48.15

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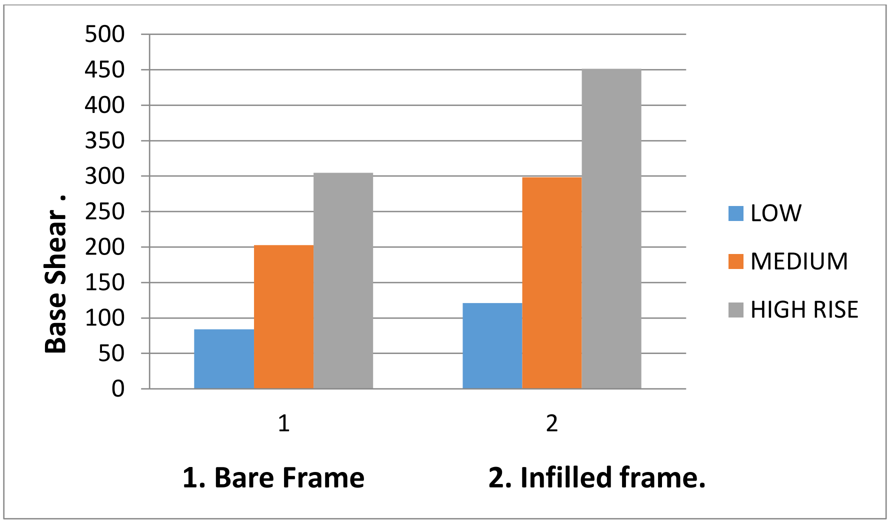
From the above table 2, it had been observed that,

- The base shear of an IF frame was higher than that of a bare frame.
- The base shear of an IF frame of a Low-rise frame increased by 43.94% than that of Bare frame.
- The Base shear of an IF frame of a Medium rise frame increased by 47.10% than that of Bare frame.
- The Base shear of an IF frame of a High-rise frame increased by 48.15% than that of Bare frame.

The Variation in the graph of Time period of Low, Medium and High-rise frames is shown below in fig.2.

Figure 2: Variation in Base shear



It was observed from fig.2 that, the Base shear calculated for an IF frame was more than the Bare frame. This was due the addition of the self-weight of the IF wall in calculating the base shear. With the increase in the number of floors, the base shear also increased.

4.3) Variation in the Roof displacement of the frames:

The roof displacement of all the frames were calculated and tabulated in the Table 3 and the variation is shown in the fig.3.

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Table 3: Variation in the Roof displacement (mm)

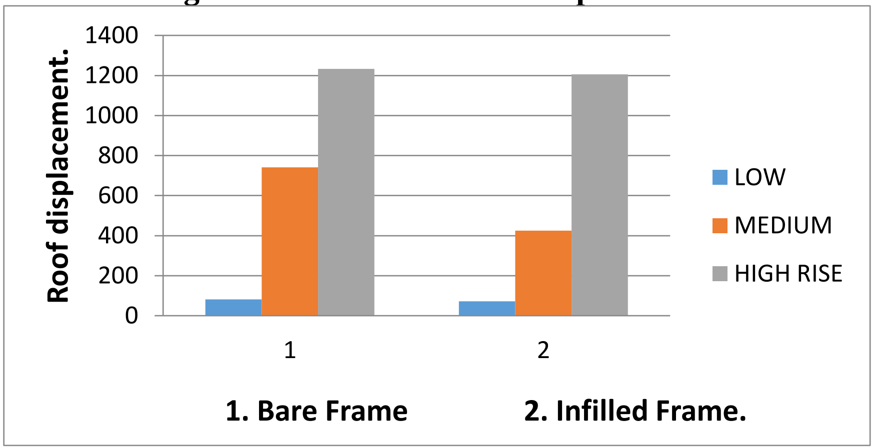
TYPE	DESCRIPTION	ROOF DISPLACEMENT	RATIO	% DECREASE
LOW	BARE FRAME	81.39	1	
	IF FRAME	71.75	0.8816	11.83
MEDIUM	BARE FRAME	740.64	1	
	IF FRAME	425.59	0.5746	42.53
HIGH	BARE FRAME	1233.00	1	
	IF FRAME	1205.00	0.9772	2.27

From the above table 3, it had been observed that,

- The Roof displacement of an IF frame was lesser than that of a bare frame.
- The Roof displacement of an IF frame of a Low-rise frame decreased by 11.83%.
- The Roof displacement of an IF frame of a Medium rise frame decreased by 42.53% than that of Bare frame.
- The Roof displacement of an IF frame of a High-rise frame decreased by 2.27% than that of Bare frame. Only a small amount of decrease in the roof displacement was observed in case of High rise frames.

The Variation in the graph of Roof displacement of Low, Medium and High rise frames is shown below in fig.3.

Figure 3: Variation in Roof displacement



It was observed that the Roof displacement of an IF frame was less than that of a bare frame, irrespective of the number of floors (i.e. low, medium & high rise).

4.4) Variation in the storey drifts the frames:

The storey displacements of all the frames are calculated and the variation is shown in the fig.4. It had been observed that,

- The Storey drifts of an IF frame was lesser than that of a bare frame.
- The Storey drift of an IF frame of a Low-rise frame decreased by an average of 11.4%
- The Storey drift of an IF frame of a Medium rise frame decreased by an average of 42.08% than that of Bare frame.
- The Storey drift of an IF frame of a High-rise frame decreased by an average of 5.38% than that of Bare frame. Only a small amount of decrease in the Storey drift was observed in case of High-rise frames.

The Variation in the graph of Storey drift of Low, Medium and High-rise frames is shown below in fig.4 (a, b, c).

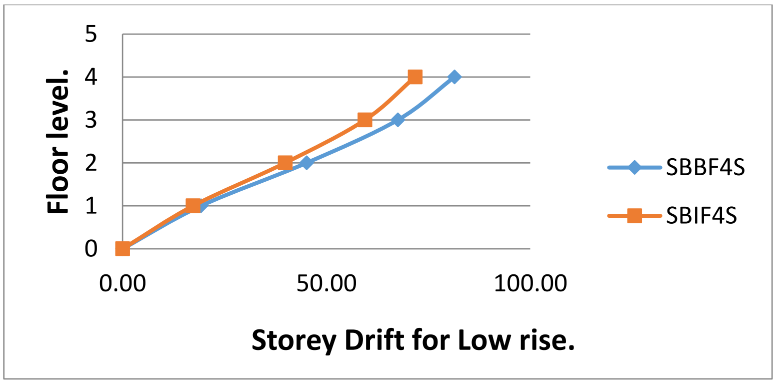


Figure 4.a: Variation in Storey drift for Low rise frame

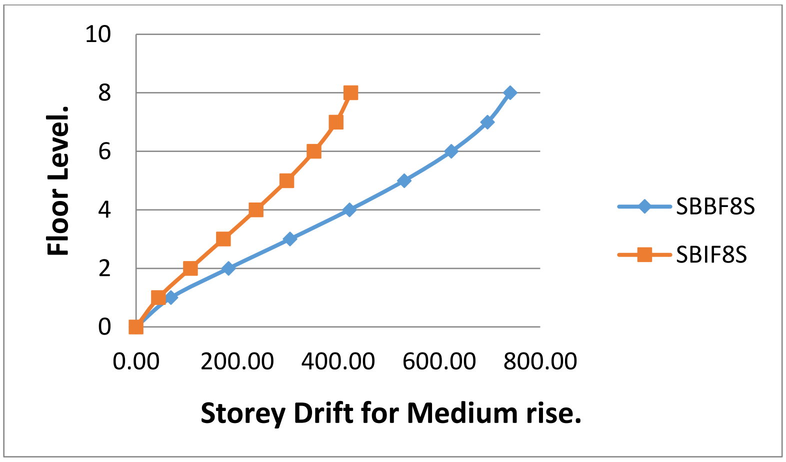


Figure 4.b: Variation in Storey drift for Medium rise frame

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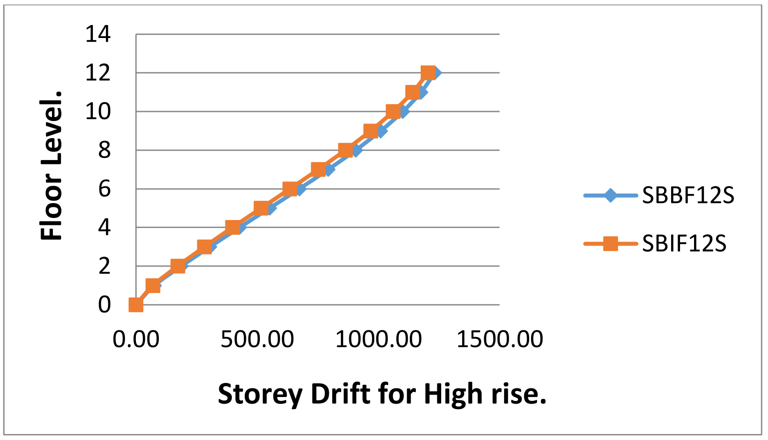

Figure 4.c: Variation in Storey drift for High rise frame

From the above fig.4.a, fig.4.b and 4.c, it had been observed that,

- The storey drift of an IF frame at every floor was less than that bare frame.
- A considerable decrease in the Storey drift was being observed in Low rise IF frames.
- A Large decrease in the Storey drift was being observed in Medium rise IF frames.
- The variation in the Storey drifts had not much effect in the High rise IF frames. The decrease in the Storey drifts was very small in this case.

4.5) Variation in the Inter-storey drifts of the frames:

The Inter-storey displacement of all the frames were calculated and the variation is shown in the fig.5.

It had been observed that,

- The Inter-storey drifts of an IF frame was lesser than that of a Bare frame.
- The Inter-storey drift of an IF frame of a Low-rise frame decreased by an average of 11.75%
- The Inter-storey drift of an IF frame of a Medium rise frame decreased by an average of 41.25% than that of Bare frame.
- The Inter-storey drift of an IF frame of a High-rise frame decreased by an average of 1.25% than that of Bare frame. Only a small amount of decrease in the Inter-storey drift was observed in case of High-rise frames.

The Variation in the graph of Storey drift of Low, Medium and High-rise frames is shown below in fig.5 (a, b, c).

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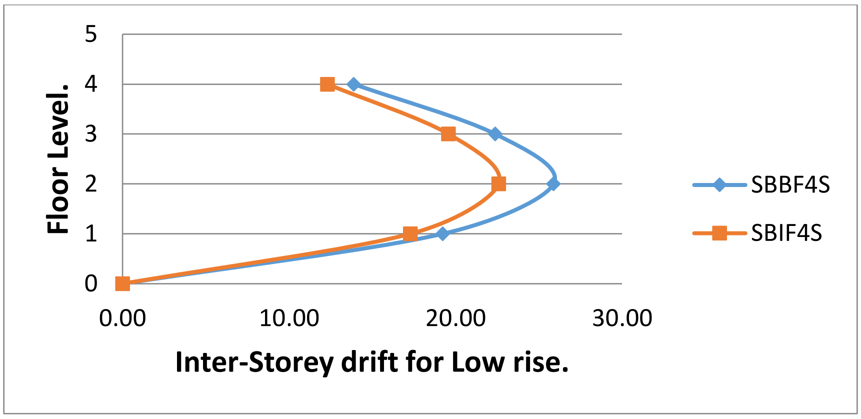

Figure 5.a: Variation in Inter-storey drift for Low rise frame

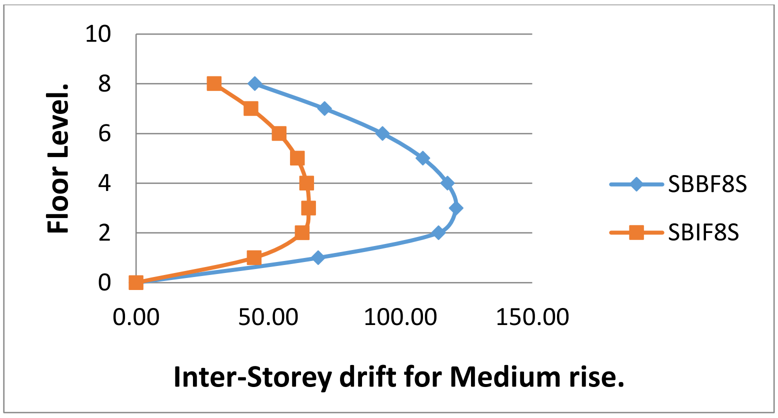

Figure 5.b: Variation in Inter-storey drift for Medium rise frame

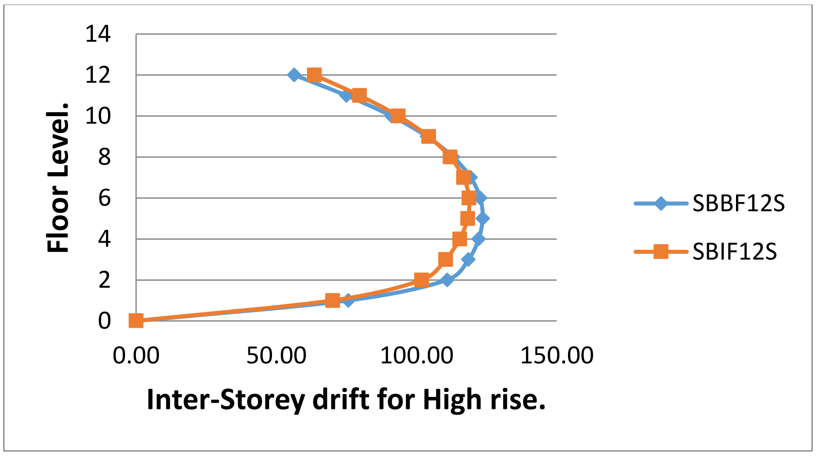

Figure 5.c: Variation in Inter-storey drift for High rise frame

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From the above fig.5.a, fig.5.b and 5.c, it had been observed that,

- The Inter-storey drift of an IF frame at every floor was higher than that bare frame.
- A considerable decrease in the Inter-storey drift was being observed in Low rise IF frames.
- A Large decrease in the Inter-storey drift was being observed in Medium rise IF frames.
- The variation in the Inter-storey drifts had not much effect in the High rise IF frames. The decrease in the inter-storey drifts was very small in this case.

4.6) Variation in the storey shear of the frames:

The storey shears of all the frames were calculated and the variation is shown in the fig.6.

It had been observed that,

- The storey shear of an IF frame was greater than that of a Bare frame.
- The storey shear of an IF frame of a Low-rise frame increased by an average of 38.25%.
- The storey shear of an IF frame of a Medium rise frame increased by an average of 43.125% than that of Bare frame.
- The storey shear of an IF frame of a High-rise frame increased by an average of 45% than that of Bare frame.

The Variation in the graph of Storey Shear of Low, Medium and High-rise frames is as shown below in fig.6.

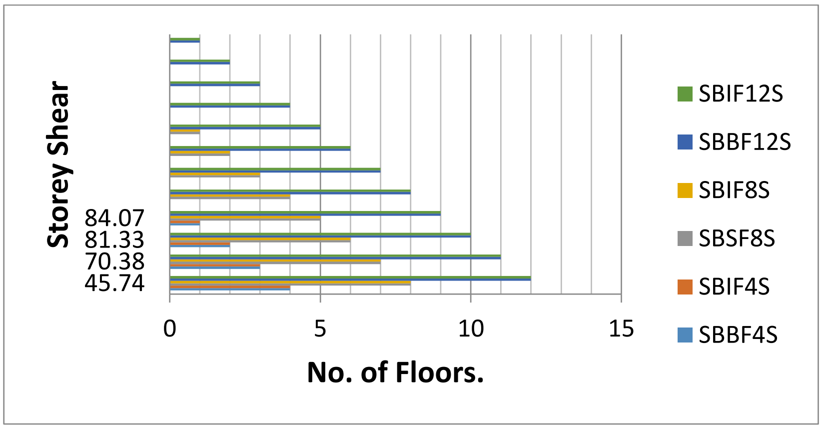

Figure 6: Variation in Storey shear for Low, Medium and High-rise frame

With respect to the fig.6, it was inferred that, irrespective of the number of floors, the storey shears in an IF frame was found to increase as we moved towards the lower floors as compared to that of a bare frame.

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4.7) Variation in the Capacity curve of the frames:

The base shear and corresponding displacement of all the frames (both bare and IF frame, for all the three i.e. low, medium and high-rise frames) were noted and the Pushover curves were as shown in the fig.7 (a, b, c).

It had been observed that as the Load on the frame was being increased, there was an increase in the displacement of the frame also, this increase was irrespective of the number of floors.

The Variation in the graph of Load v/s Displacement (Pushover curves) of Low, Medium and High-rise frames is shown below in fig.7 (a, b, c).

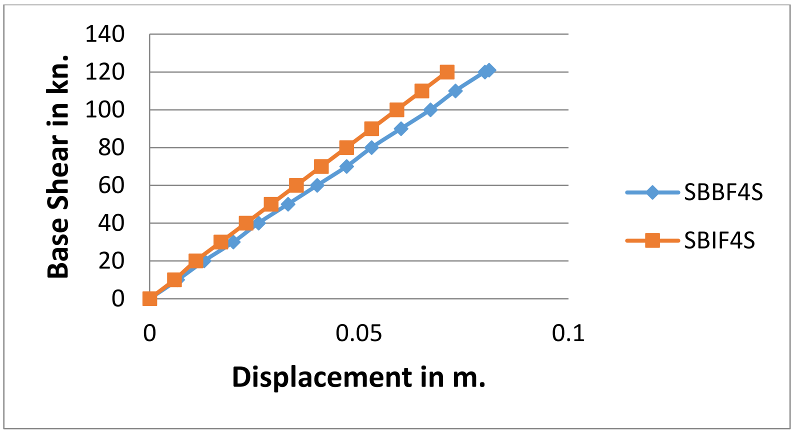

Figure 7.a: Pushover curve for Low rise frame

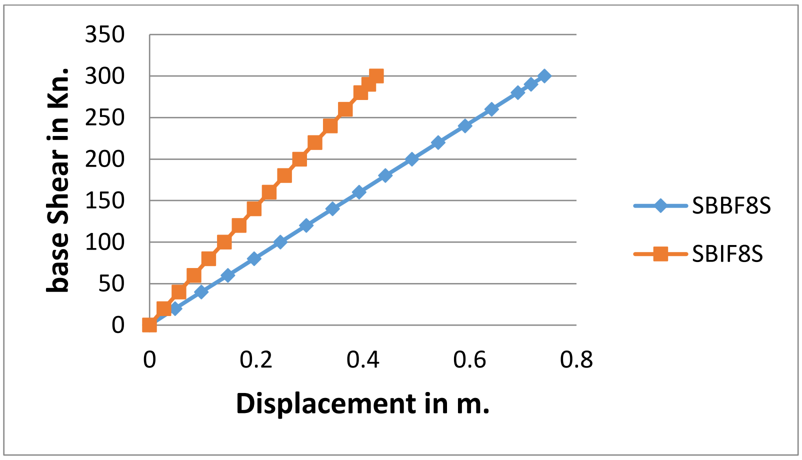

Figure 7.b: Pushover curve for Medium rise frame

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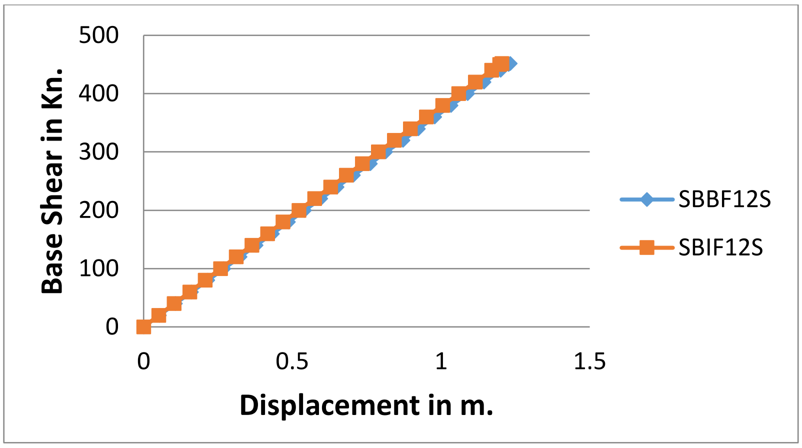

Figure 7.c: Pushover curve for High rise frame

An identical response was observed in all the frames as depicted in fig.7.a, fig.7.b and fig.7.c.

5. CONCLUSIONS

- It was observed that, the Time period of an IF frame was higher than that of a bare frame, irrespective of the number of floors.
- The Base shear of an IF frame was higher when compared to that of a bare frame, more the number of floors - greater was the base shear for the IF frame.
- The Roof displacement of an IF frame was found to be lesser than that of a Bare frame. It could be concluded that, the decrease in the Roof displacement was more distinct in medium rise frame.
- The Inter-storey drifts of an IF frame was lesser than that of a Bare frame, irrespective of the number of floors. It could be concluded that, the decrease in the Inter-storey drift was more distinct for a medium rise frame, whereas only a small amount of decrease in the Inter-storey drift was observed in case of High-rise frames.
- It was observed that, the storey shear of an IF frame was higher than that of a Bare frame, irrespective of the number of floors used for the analysis.

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