Comparative study of Seismic Parameters in Steel and RCC frames with and without Masonry infill walls

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***ABSTRACT* – Structural redundancy is constraint in the analysis which is of paramount importance from seismic consideration. The masonry in the framed structure is used primarily to create an enclosure and safety to occupants. Such masonry walls are known as infill walls. There will be structural interaction between framed members and infill walls. The combined behavior of the infill wall and structural frame is studied by many researchers from previous occurred earthquakes by modeling the masonry infill walls by compression strut elements. The steel frames with infill walls are general systems in the construction of usual residential buildings in some countries. It is obviously found that the seismic performance of structures is getting changed by considering the masonry infill walls in the analysis. In order to investigate the effect of infill walls on the steel frame, constructed with masonry infill walls, the seismic parameters like Time period, Base shear and Displacement were extracted for the frames with masonry infills.**

The present research work aims to study the seismic analysis of steel and RCC plane frames with and without masonry infill walls. The Seven storeyed frames with varying number of bays are analysed by seismic coefficient method for obtaining Time period, Base shear and displacement. It is observed that consideration of brick infill indicates considerable effects on performance as compared to bare frames. It is found that infill wall reduces the time period, displacement for steel as well as RCC frames. The time period is found decreased for frames with infill walls. Base shear has substantially increased for frame with infill wall. The displacement and time period has been found to be reduced for bare frame and infill frame for steel as well as RCC frames when numbers of bays are increased from 2 bays to 10 bays. The inclusion of infill wall produces substantial improvement for steel frame whereas for RCC frames the improvement is marginal.

***Keywords*: Redundancy, Seismic analysis, Masonry infill walls.**

1. INTRODUCTION

Infill masonry walls are commonly constructed in the exterior frames of steel frames buildings. Their effects on the behavior of the steel frame buildings are typically ignored during design process. This study investigates the effect of infills on the seismic parameters of the steel frames. The rapid expansion of today's housing market and the dwindling availability of empty plots in urban areas has prompted the increasing construction of slender buildings.

The strength and energy dissipation capacity of an infilled frame is much higher than that of bare frame. A frame with an infill wall is very effective against an earthquake, even though input force increases because of the higher stiffness. However, these interior walls cause stress concentration in particular members and/or torsional deformation of the frame. Also, the shear distribution throughout the structure is altered.

Bertero R. and Bertero V[2], defined the redundancy degree to investigate the redundancy of frame structures as the number of plastic hinges formed at structural member ends, up to the point of total collapse. C V R Murthy And Sudhir K Jain [3] defined Masonry infills in reinforced concrete buildings cause several undesirable effects under seismic loading: short-column effect, soft-storey effect, torsion, and out-of-plane collapse. Hence, seismic codes tend to discourage such constructions in severe seismic zone. However, in several moderate earthquakes, such buildings have shown excellent performance even though many such buildings were not designed and detailed for earthquake forces.

2. OBJECTIVE OF THE STUDY

The study is carried out by comparing the seismic performance of bare frame with infill wall for both with steel and RCC frames. The specific objectives are mentioned below

1) Two dimensional models of bare frames for 7 storeys with increasing no of bays at the interval of 2 bays up to 10 bays are analysed and studied. All the bare frames are again modelled by providing masonry infill walls.
2) To study & Compare the seismic response of structures through Base Shears, Time Periods, and Displacements for bare and infill frames.
3) To study and compare the seismic parameters in Steel frames with and without infill wall.
4) To study and compare the seismic parameters in RCC frames with and without infill wall

3. THEOROTICAL FORMULATION

Plane frame analysis is performed for all frames. There are different elastic methods of seismic analysis which are briefed below. Appropriate method need to be employed depending on type of structure and ease for interpretation of results. The following are some methods for seismic analysis

3.1. Response Spectrum Analysis:

This method is also known as modal method or mode super position method. This method is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. Generally, the method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have areas of discontinuity or irregularity, in their linear range of behaviour.

3.2. Elastic time history method:

A linear time history analysis overcomes all the disadvantages of a modal response spectrum analysis provided non-linear behaviour is not involved. This method requires greater computational efforts for calculating the response at discrete times. One interesting advantage of such a procedure is that the relative signs of response quantities are preserved in the response histories. This is important when interaction effects are considered among stress resultants

3.3. Seismic Coefficient method:

Seismic analysis of most of the structures is still carried out on the assumptions that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. This method requires less effort because, except for the fundamental period, the periods and shapes of higher natural blocks of vibration are not required. The base shear on the structure is calculated on the basis of the structure's mass, its fundamental period of vibration, and corresponding shape. The base shear is distributed along the structure in terms of lateral forces, according to the code IS 1893:2002.

3.4. Problem formulation:

The 2D frames of 7 storeys with different nos. of bays are considered for study. These plane frames have only fundamental mode of vibration. So Seismic coefficient method is feasible for analysis of such frames. Time period, displacement and base shear are calculated by Seismic coefficient method in order for comparison. The 7 storey is kept constant and the different bays are (2, 4, 6, 8, 10) considered for formulation of problems. The structural sections of frame are designed as per IS-456; 2000. The storey height and bay width is kept 3.2m and 4m respectively for all frames. Steel frame used in the present study are designed as per IS-800; 2007. The sizes of beams, columns are kept same in all cases.

3.5. Determination of Effective Width of Diagonal Strut:

Infill walls are modelled as diagonal struts. There are four different approaches of Calculation of Effective Width of Diagonal Strut by various researchers. These approaches are briefed as follows.

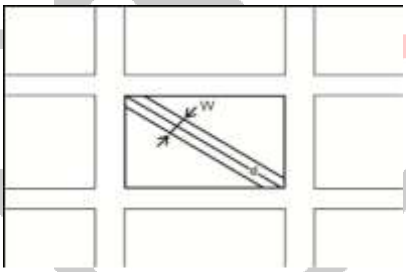


Fig 1: Equivalent Diagonal strut model

1. W=d/3 by Holmes's (1961) approach (1)

2. W=0.25d by Pauley and Priestley's(1992) approach (2)

Where W is the width of equivalent strut and d is the diagonal length of the infill

3. By Smith(1968) approach:

$$W = \tfrac{1}{2}\sqrt{\alpha_h^2 + \alpha_L^2} \quad (3)$$

Here the parameters α_h and α_L are calculated as below

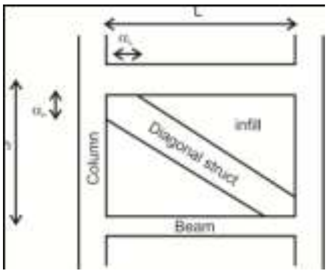


Fig 2. Equivalent Diagonal strut model (Smith, 1968)

$$a_h = \pi \sqrt[4]{\frac{4E_f I_b L}{E_m t \sin 2\theta}}$$

$$\alpha L = \pi/2 \, \pi \sqrt[4]{\frac{4E_f I_c L}{E_m t \sin 2\theta}}$$

4. By Demir and Sivri's (2002) approach :

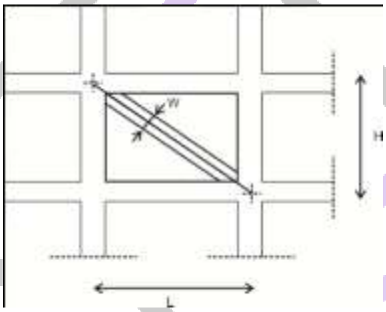


Fig 3. Equivalent Diagonal strut model (Demir and Sivri, 2002)

The effective width of diagonal is computed as

$$W=0.175\,(\lambda_h H)^{-0.4}\sqrt{H^2+L^2} \quad (4)$$

Different approaches for computation of effective width of diagonal strut for masonry infill wall are presented above. Different values of effective width of infill walls are given by above mentioned various approaches. The Pauley and Priestly approach gives minimum width of diagonal strut which is not exaggerating the performance of infill wall in the analysis. So it is considered for calculation of effective width of diagonal strut.

4. PARAMETRIC STUDY

In this analysis, 5 models are analysed with different number of bays namely 2 bays, 4 bays, 6 bays, 8 bays, 10 bays and storey 7 is kept constant. Various seismic parameters such as Time period, Base shear and Displacement are studied to investigate the effect of infill walls. The equivalent diagonal strut is modeled by using Pauley and Priestly proposal. The study is carried out on steel frames and RCC frames. All the results are tabulated and presented in graphical format. The models & their descriptions are given in the following table.

Table 1. Frames formulated for study

Sr. No.	Model no.	Description
1	7S 2B	7 Storey 2 Bays frame
2	7S 4B	7 Storey 4 Bays frame
3	7S 6B	7 Storey 6 Bays frame
4	7S 8B	7 Storey 8 Bays frame
5	7S 10B	7 Storey 10 Bays frame

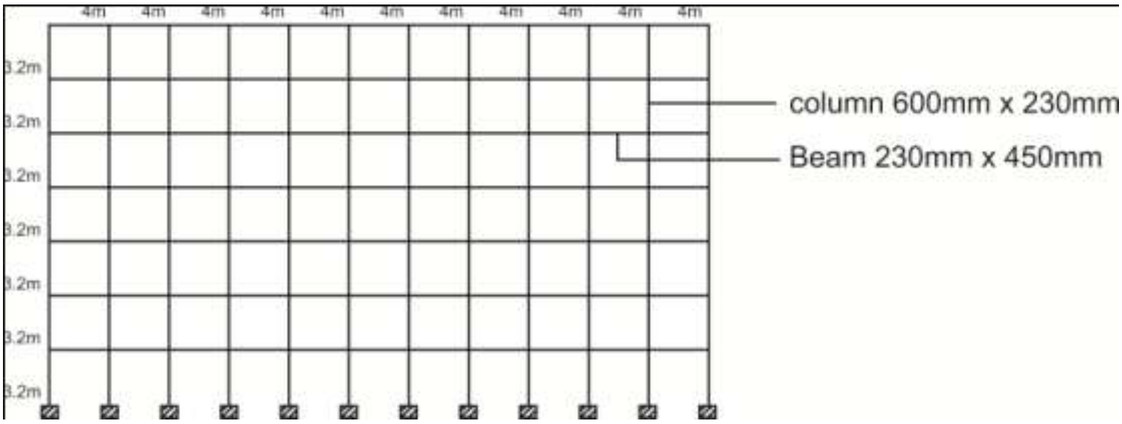


Fig 4. Schematic Representation of 7 Storey 10 Bays RCC Frame Without Infill wall.

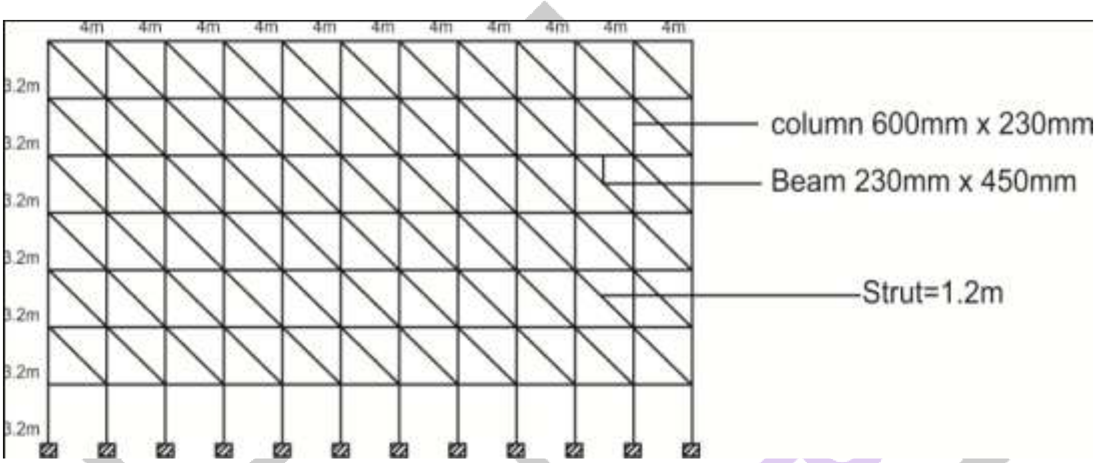


Fig 5. Schematic Representation of 7 Storey 10 Bays RCC frame With Infill

4.1. Material Properties

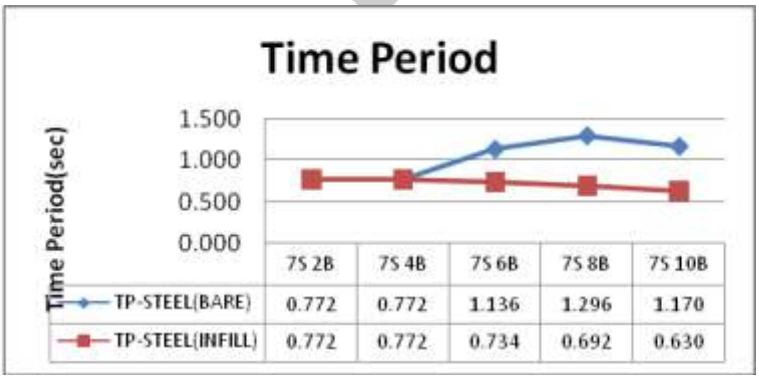
1. Modulus of elasticity = 1500 kN/m²
2. Poisson's ratio =0.3

4.2. Load Combinations

1) Load combinations for steel & RCC frames are taken as per IS-800; 2007 and IS 456:2000

4.3. TIME PERIOD

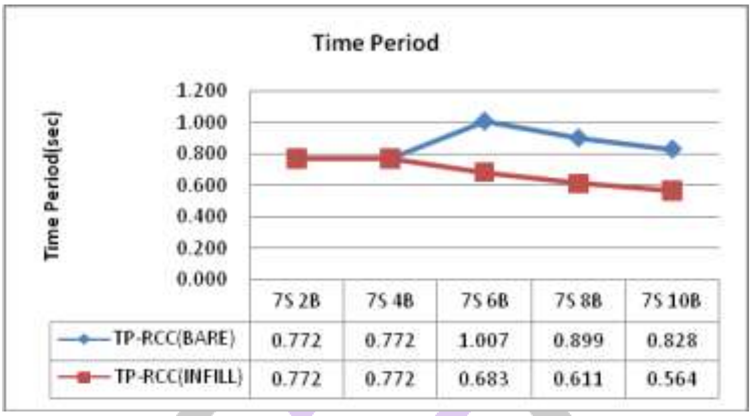
The variation in Time Period of structure for bare frame and infill frame are presented in Graph 1 and 2 for G+6 building frame.



Graph 1. Time Period Of Steel Frames With And Without Infill

Graph 1, shows the results of time period and its variation for all models of Steel G+6 storey bare & infill frames.

In case of bare frames, it is observed that time period is same and constant for bare frame for 2 bays and 4 bays, time period has increased by 32% from model 7S4B to 7S6B, from 7S6B to 7S8B by 12% which is highest. With further increase in nos. of bays from 7S8B to 7S10B time period is found decreased by 9% in comparison with 8 bays model.
Also for infill frames it is observed that time period is same for 2 bays and 4 bays. The time period is further decreasing as numbers of bays increase beyond 4. The variation is nearly linear with mild slope. The decrement in time period from model 7S4B to 7S6B, from 7S6B to 7S8B and from7S8B to 7S10B is @ 5%.
The significant effect of infill wall is observed from 6 bays onwards. The inclusion of infill wall in the analysis has reduced the time period for 7S6B by 35%, 7S8B and 7S10B by 46% respectively when compared with bare frames.

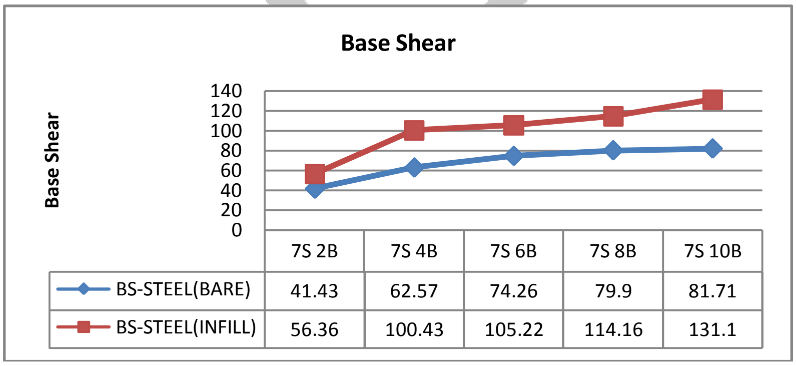


Graph 2. Time Period Of RCC Frames With And Without Infill

Graph 2, shows the results of time period and its variation for all models of RCC G+6 storey bare frame and infill frames.
In case of bare frames, it is observed that time period is same and constant for 2 bays and 4 bays models. The change in time period is observed for model 7S6B and onwards. The sudden rise in time period of bare frame is observed from 7S4B to 7S6B by 23% & which is highest time period also. Afterwards mild reduction in time period is observed from model 7S6B to7S8B and 7S8B to 7S10B by 10% and 7% respectively.
In case of infill frames, it is observed that time period is same for 2 bays and 4 bays models. The reduction in time period from 7S4B to 7S6B, 7S6B to 7S8B and 7S8B to 7S10B is 11%, 10% and 3% respectively.
The results of bare and infill frames reveals the inclusion of infill walls in the analysis is effective beyond 4 bays model. The reduction in time period is @ 32% for models 7S6B, 7S8B and 7S10B.
The variation in time period due to increase in nos. of bays is marginal for steel bare frames, however it is significant for RCC bare frames. Even reduction in time period due to increase in nos. of bays is higher for RCC bare frames. However the nature of variation of time period for infill steel frames & infill RCC frames is almost similar.

4.4. BASE SHEAR

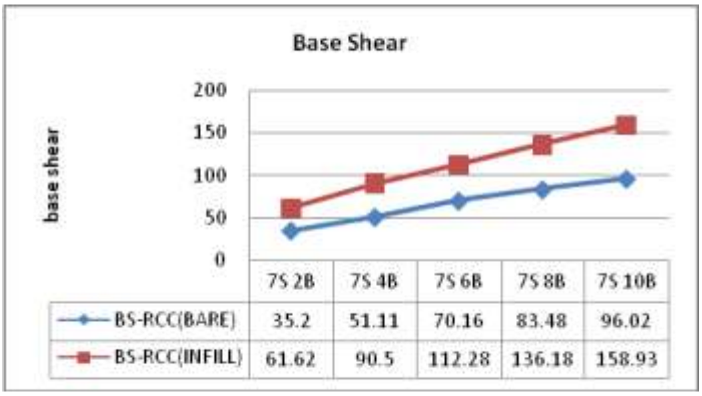
The variation in base shear for bare frame and infill frame are presented in Graph 3 and 4 for G+6 storey building frame.



Graph 3. Base Shear Of Steel Frames With And Without Infill

Graph 3, shows the results and variation of base shear for all models of Steel G+6 storey bare and infill frames.
For bare frames it is observed that base shear increases from model 7S2B to 7S4B by 35%. Then the base shear increases by 15% from the model 7S4B to 7S6B which further increases again by 7% & 3% from model 7S6B to 7S8B and from 7S8B to 7S10B respectively.
For infill frame it is observed that the base shear increases by 43% from model 7S2B to 7S4B. Then afterwards the base shear increases by 5%, 7% and 12% from the models 7S4B to 7S6B, 7S6B to 7S8B and 7S8B to 7S10B respectively. The variation is initially steep for model 7S4B, mild for models 7S6B and 7S8B and then little rise is observed for 7S10B.

The base shear for infill frames is observed to be higher in comparison with bare frame. The base shear of infill frame is higher by 26%, 37%, 29%, 51% and 53% with its corresponding models namely 7S2B, 7S4B, 7S6B, 7S8B and 7S10B of bare frame respectively.



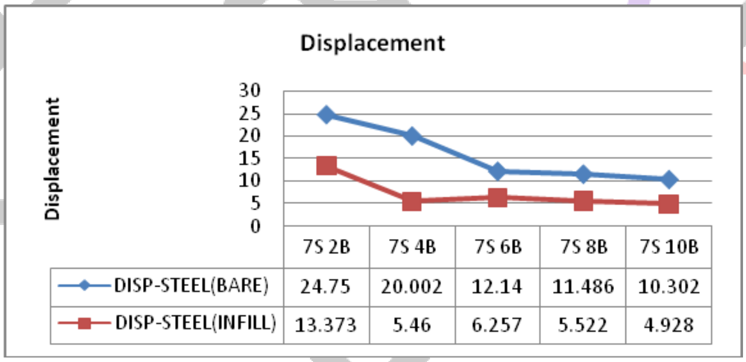
Graph 4. Base Shear Of RCC Frames With And Without Infill

Graph 4. shows the results and variation of base shear for all models of RCC G+6 storey bare and infill frame.
For bare frame it is observed that the base shear increases from model 7S2B to 7S4B by 31%, from model 7S4B to 7S6B by 27%, from model 7S6B to 7S8B by 15%. Further base shear increases from model 7S8B to 7S10B by 13%.
In the graphical variation for infill frame it is observed that the base shear is increasing steeply from models 7S2B to 7S4B by 31%. With further addition of the bays base shear increase is nearly linear for all the models from 7S4B to 7S10B and this increase in base shear for every addition of 2 bays is around 16%.

For infill frames the results reveals the inclusion of infill wall in analysis has increased the base shear for models 7S2B, 7S4B, 7S6B, 7S8B and 7S10B by 42% , 43% , 37%, 38% and 39% in comparison with its corresponding bare frame.
The variation in base shear due to increase in nos. of bays is nearly linear. However this variation is marginal for both steel and RCC bare frames. However this variation is significant for both steel and RCC infill frames.

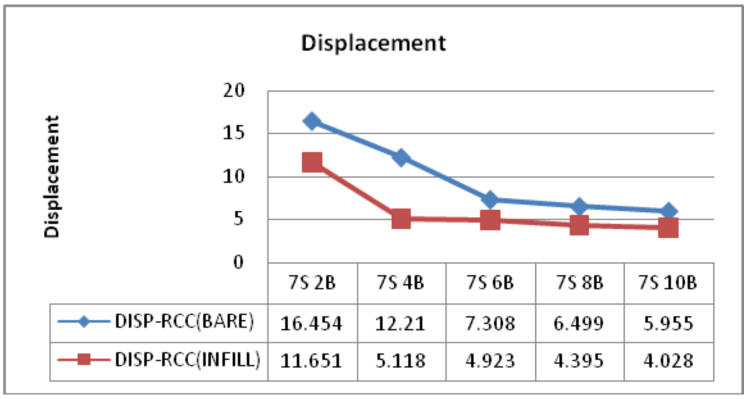
4.5. DISPLACEMENT

The variations for displacement of bare and infill frame for G+6 storey building are presented in Graph 5 and 6.



Graph 5. Displacement Of Steel Frames With And Without Infill

Graph 5, shows the results and variation of Displacement for all models of Steel G+ 6 storey bare and infill frame.
In bare frame it is observed that displacement decreases steeply from model 7S2B to 7S4B by 19%, whereas from 7S4B to 7S6B it is 39%. Further decreases again from 7S6B to 7S8B becomes mild and is @ 5%, from 7S8B to 7S10B it is @ 10%.
In infill frame it is observed that the displacement decreases by 57% from models 7S2B to 7S4B. There afterwards the displacement increases mildly by 12% from the model 7S4B to 7S6B. Further the decrease in displacement for models 7S8B and 7S10B is nearly linear and which is @ 10%.
The results of bare and infill frames are compared which reveals the inclusion of infill wall in analysis has reduced the displacement by 45% for model 7S2B and 72% for model 7S4B, 48% for model 7S6B, 52% for models 7S8B and 7S10B.



Graph 6. Displacement Of RCC Frames With And Without Infill:

Graph 6, shows the results and variation of Displacement for all models of RCC G+ 6 storey bare and infill frames.
In bare frames it is observed that displacement decreases from model 7S2B to 7S4B by 25%, from 7S4B to 7S6B by 40%, which further decreases @ 11% for rest of the models i.e 7S8B and 7S10B.
Further for infill frame it is observed that, initially the displacement decreases from 7S2B to 7S4B by 56%, 7S4B to 7S6B by 4%, 7S6B to 7S8B by 10% and 7S8B to 7S10B by 8%. The displacement reduces steeply for all models upto 7S6B, there afterwards it becomes milder for further models

The results of bare and infill frames are compared which reveals the inclusion of infill wall in analysis has reduced the displacement for model 7S2B by 45% and 58% for 7S4B, 32% for 7S6B, 7S8B and 7S10B. The reduction in rate of displacement is steeper for 2 bays and 4 bays but milder for 6, 8 and 10 bays.
The reduction in displacement due to increase in number of bays is substantial up to model 7S6B but marginal for models 7S8B, 7S10B in both steel and RCC bare frames.

5. CONCLUSION

From the present investigations following conclusions are drawn:
The influence of infill walls on the seismic parameters of steel and RCC frames is studied. The obtained results can be summarized as following conclusions.

1) Time period for both bare and infill frame is same upto 4 bays models for steel and RCC frames
2) The effect of number of bays is marginal on Time Period, whereas it is significant on Base Shear and displacement.
3) The inclusion of masonry infill wall reduces the Time period and displacement significantly for steel as well as RCC frames. However, the base shear is increasing.
4) Significant variations in the seismic performance is observed from 4 bays and onwards for infill frames and in case of bare frames it is from 6 bays and onwards.
5) Overall inclusion of infill wall improves seismic performance. The inclusion of infill wall in the analysis shows higher seismic performance for steel frames in comparison with improved performance of RCC frames.

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