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Study on the Behaviour of Multi Storied Infilled Frame

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Abstract: **This project examines the behavior of the infilled frame with the conventional cement mortar interface between the frame and in the infilling wall. The infills will increase the stiffness of the structure which is generally good but during the time of the earthquake it attracts baser shear which is again more vulnerable. So in this project an attempt is made to know the behavior of the infilled frame with the conventional cement mortar interface and study it during the acting of the lateral loads by using the standard software and comparing the analysis with the experimental study. The parametric study is done analytically and its consequences in the analysis results of the frame are compared with the experimental study.**

Keywords: **Infilled Frame, Stiffness, Baser Shear, Bare Frame.**

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1. INTRODUCTION

Infill walls have attracted the attention of many researchers since the early 1950s, and much work has been undertaken to study their behavior and interaction with the surrounding frames. In addition, efforts have been made to utilize infill walls as a means of producing economic designs by reducing the sizes of the members of the bounding frames. Infills are commonly used in buildings for architectural reasons. Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi storey residential uses in seismic regions. Masonry infill typically consists of bricks or concrete blocks constructed between beams and columns of a reinforced concrete frame. The masonry infill panels are generally not considered in the design process and treated as architectural (non-structural) components. The presence of masonry infill walls has a significant impact on the seismic response of a reinforced concrete frame building, increasing structural strength and stiffness (relative to a bare frame). An infill wall reduces the lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. The structural contribution of infill wall results into stiffer structure thereby reducing the storey drifts (lateral displacement at floor level). The multi storeyed frame with infill is shown in Figure1.1

Infilled Frame

Definition: - Infilled frames are a complete structure formed through the complete interactive behaviour of the infill with the bounding frame members under inplane lateral loads.A typical infilled frame is shown in Figure1.2.

Figure 1.1 Multi storeyed frame with infill

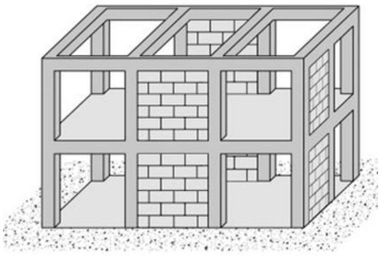


Figure 1.2 Typical Infilled Frame

2. LITERATURE STUDY

Liauw*et al*(1984): have made study on static and cyclic behaviours of multi storey infilled frames with different interface condition. The static and cyclic behaviours of non-integral, partially integral and integral infilled frames have been studied. The study has shown that the provision of connectors greatly improves the structural behaviour of infilled frames. They also found out that the integral infilled frames are superior, they are stiffer and stronger and also are more ductile.

Maurizio papia and Gaetano russo(1988):have made study on behaviour of infilled frame with openings stiffened by surrounding frames. Here a method for evaluating the stiffness to horizontal forces of two dimensional bracing systems is presented. Panel's stiffened by surrounding frames along the boundary of the opening.

Sobaih andAbdin(1988): have conducted seismic analysis of infilled reinforced concrete frame. The conclusion of their report was In general, infill panels increase the stiffness of the structure and the stresses on columns but decreases the lateral displacements of the frame. It has been also found that present code formula over estimates the shear forces along the height of the frame since it does not consider the effect of infill panels.

Marjani and Ersoy(2002): have studied behaviour of brick infilled reinforced concrete frames under reversed cyclic loading. They found out that hollow clay tile infill increases both strength and stiffness significantly, plastering both sides of the infill improves the behaviour of the infilled frame considerably, plaster also improved the ductility significantly

Satyanarayananet al(2009): have conducted the conceptualisation studies on the development of adaptive interface in infilled frames. They found that with the increase in the interface pressure in the pneumatic pressure interface infilled frame the stiffness of the frame is being increased for the same horizontal and other loading condition and with the same size of the frame member.

Tasnimi and Mohebkhah(2009): have made investigation on the behaviour of brick infilled steel frames with openings, experimental and analytical approaches. The cracking patterns were studied experimentally for the lateral loading on the infill containing the openings such as doors.

3. SCOPE OF WORK

To study the behaviour of infilled frame by using the conventional interface, through analytical studies on seven storeyed reinforced cement concrete frame. This includes

1. Bare frame
2. Infilled frame with cement mortar and brick masonry wall.
3. The software used for analysis is ANSYS 14.5
4. The elements used for modelling the seven storeyed frame are SOLID185 for concrete and brick infill, BEAM188 for reinforcement, SHELL63 for interface between the cement mortar and brick infill.
5. The model analysed is an one – fourth scale model of seven storeyed bare and infilled frames tested by Thirumurugan in Structural Engineering Laboratory
6. The following load patterns are considered for analysing the bare and infilled frame on 3rd, 5th and 7th floors are;

I. Pattern 1:- Unit load application.
II. Pattern 2:- Load application of 10N, 20N, 30N and 40N.
III. Pattern 3:- Load application of linearly varying from top to bottom 60N, 40N, 20N.
IV. Pattern 4:-Load application of linearly varying from top to bottom 20N, 40N, 60N.

4. METHODOLOGY

The methodology of investigating the study on the behavior of infilled frames with conventional (cement mortar) interface is presented in this chapter along with the comparison of it between the bare frame and then the infilled frame.

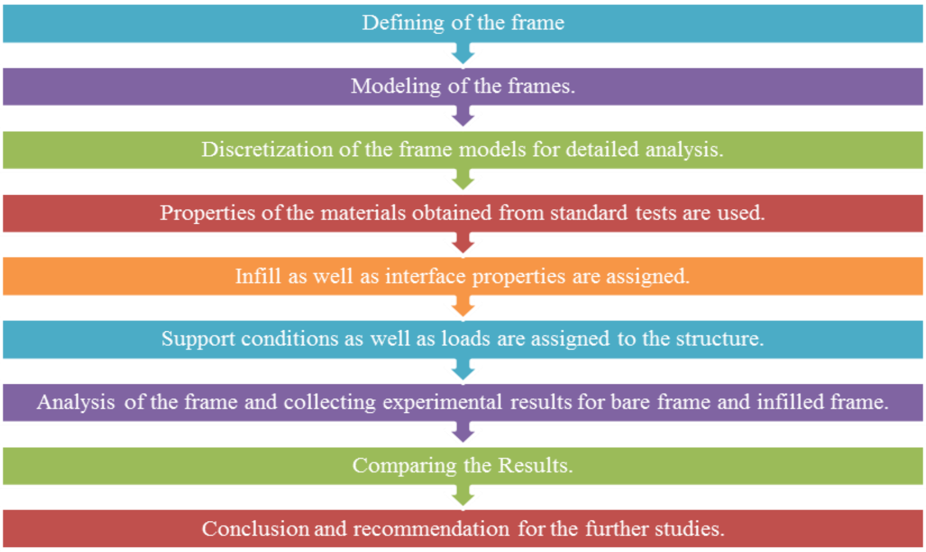


Figure 4.1 Methodology

Software Used:- The analytical investigation of all models is carried out by using a standard software package ANSYS.

Material Properties:- The properties of the frame member and the infill materials that is used for the analysis of the frame is given in Table 4.1.These values are adopted from already published work (Satyanarayanan et al 2009)

Table 4.1 Properties of frame member and infill used for analysis [5]

Properties	**Frame member**	**Brick masonry Infill**
Compressive strength (N/mm^2)	20	1.37
Modulus of elasticity (N/mm^2)	$2.236x10^4$	$0.1020x10^4$
Poisson’s ratio	0.15	0.15
Coefficient of thermal expansion (/°C)	$1.00*10^{-6}$	$1.00*10^{-6}$

Materials used for the interface material :- The properties of the interface materials that are used for the analysis of the frame is given in Table 4.2 as reported in already published literature (satyanarayanan et al 2009)

Table 4.2 Properties of the interface material used for analysis

Properties	**Cement mortar interface**
Compressive strength (N/mm^2)	4.7
Modulus of elasticity (N/mm^2)	1000
Poisson’s ratio	0.15
Coefficient of thermal expansion (/°C)	$1.00*10^{-6}$

MODELING USING ANSYS:- ANSYS is engineering simulation software. Non - Linear finite element analysis has been carried out using ANSYS software. Here in the project the RC members of the frame have been modelled with SOLID185 element, the infill was modelled with SOLID185 element, the reinforcing bars have been modelled with BEAM188 and the connection between the RC element and infill was made with SHELL63 element available in the elements library of the ANSYS software

SOLID185:- SOLID185 is used for 3-D modelling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. The geometry, node locations, and the coordinate system for this element are shown in Figure4.2.

BEAM 188 :- BEAM188 is suitable for analyzing slender to moderately stubby/thick beam structures. The element is based on Timoshenko beam theory which includes shear-deformation effects. The element provides options for unrestrained warping and restrained warping of cross-sections. The element is a linear, quadratic, or cubic two-node beam element in 3-D. BEAM188 has six or seven degrees of freedom at each node. These include translations in the x, y, and z directions and rotations about the x, y, and z directions. A seventh degree of freedom (warping magnitude) is optional. This element is well-suited for linear, large rotation, and/or large strain nonlinear applications. The geometry, node locations, and the coordinate system for this element are shown in Figure4.3.

SHELL 63:-SHELL63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analyses. The geometry, node locations, and the coordinate system for this element are shown in Figure4.4.

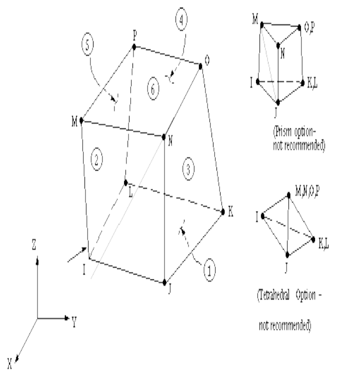


Figure 4.2 SOLID 185 Element

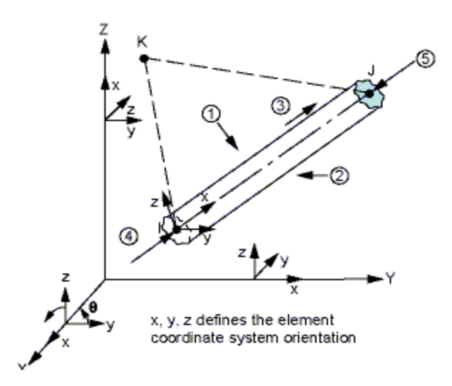


Figure 4.3 BEAM188 Element

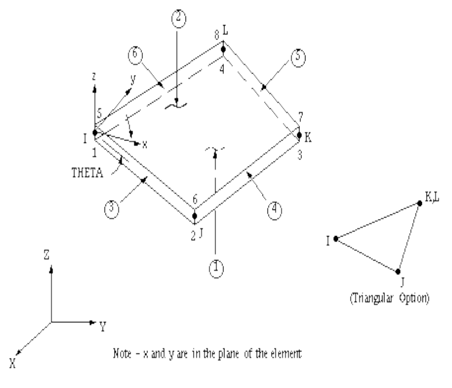


Figure4.4 SHELL63 Element

5. ANALYTICAL INVESTIGATION

Finite Element Analysis (FEM) is a computer based method of simulating analysing the behaviour of engineering structures and components under a variety of conditions. This is an advanced engineering tool that is used in design. The technique is based on the premise that an approximate solution to any complex engineering problem can be reached by subdividing the structure into smaller more manageable (finite) elements. FEM is a technique for predicting the response of structures and materials to environmental factors such as forces, heat and vibration. FEM helps in producing stiffness and strength visualizations

DETAILS OF FRAME :- The frame member infill interaction is established to increase the lateral stiffness and strength of infilled frame. To quantify the effect of infilling on the frame it is proposed to carry out an analytical investigation by using ANSYS 14.5 software as outlined in this chapter. The Table 5.1 shows the details of seven storey single bay frame.The Figure5.1 shows the plan and elevation of seven storey single bay frame .The Figure5.2 shows the reinforcement details of seven storey single bay frame used for analysis.The details of 7 storey single bay frame are presented in Table 5.1.

Table 5.1 Details of 7 storey single bay frame.

Sl.no	Particulars	Values
1	Ground level storey height (mm)	675
2	Other floors (mm)	600
3	Bay width (mm)	1000
4	No. of stories (no)	7
5	No of bays (no)	1
6	Beam dimension (mm)	100X150
7	Column dimension (mm)	100X200

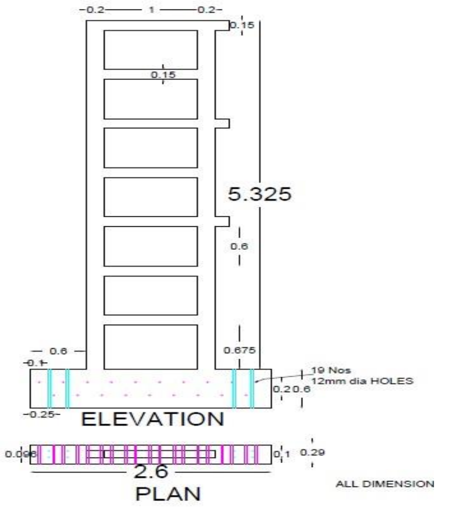


Figure 5.1Plan and elevation of seven storied single bay frame

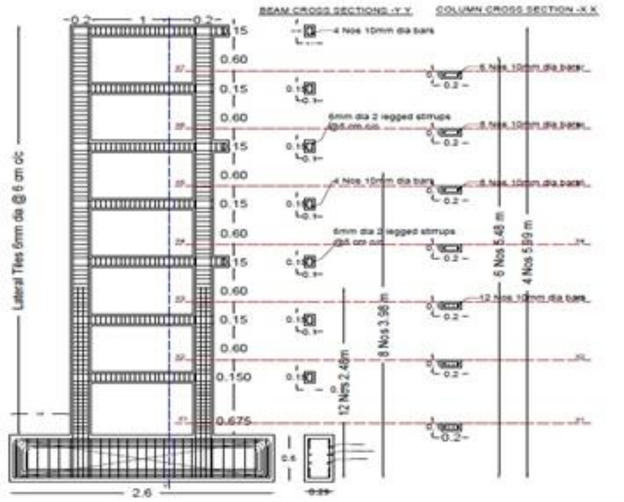


Figure 5.2 Reinforcement details of the seven storied single bay frame

Loading Condition:- Static Analysis Is Performed Using The Software.

Bare frame:-

1. The load considered for the frame is only horizontal load.
2. Self weight and all other loads are neglected, and comparisons are made for the horizontal loads only.
3. The following load patterns are considered for analysing the bare and infilled frame on 3rd, 5th and 7th floors are;

Pattern 1:- Unit load application.

Pattern 2:- Load application of;

(i). 10N

(ii). 20N

(iii). 30N

(iv). 40N.

Pattern 3:- Load application of linearly varying from top to bottom 60N, 40N, 20N.

Pattern 4:-Load application of linearly varying from top to bottom 20N, 40N, 60N.

Infilled frame

1. The load considered for the frame is only horizontal load.
2. Self weight and all other loads are neglected, and comparisons are made for the horizontal loads only.
3. The following load patterns are considered for analysing the bare and infilled frame on 3rd, 5th and 7th floors are;

Pattern 5:- Unit load application.

Pattern 6:- Load application of ;

(i).10N

(ii). 20N

(iii).30N

(iv).40N.

Pattern 7:- Load application of linearly varying from top to bottom 60N, 40N, 20N.

Pattern 8:-Load application of linearly varying from top to bottom 20N, 40N, 60N.

6. RESULTS AND DISCUSSION

Unit Load Application:- This analysis deals with the results obtained from the bare frame model for the seven storey frame. From the obtained results, it is observed that maximum deflection occurs at the top of the frame with a magnitude of 5.75x10^{-4}mm. Stiffness of the frame is 5217.39N/mm. Figures 6.1, 6.2shows the meshing, deflection and principal stress variations of bare frame respectively

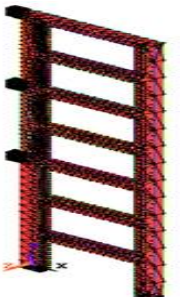


Figure6.1 Bare frame showing meshing

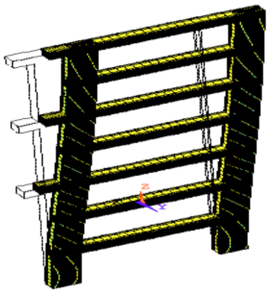


Figure 6.2.The deflected shape of the bare frame

Load application of 10N:- The deflected shape of the bare frame with 10N load is shown in the Figure6.3.

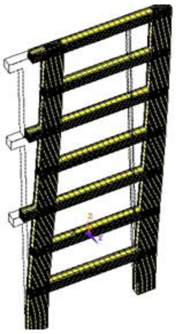


Figure 6.3 Deflected shape of bare frame with 10N

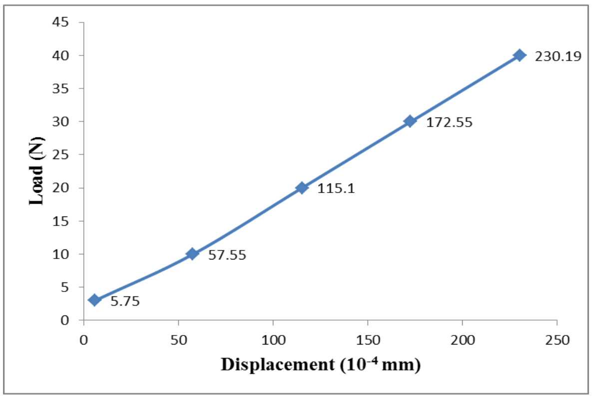


Figure 6.4 Load vs deflection graph of pattern 2 on bare frame on 3rd, 5th and 7th floor.

Bare frame is applied with pattern 2 of loads on 3rd, 5th and 7th floor respectively and during analysis only horizontal loads are considered. Load vs displacement graph for pattern 2 is obtained as shown in Figure 6.4.

Load vs principal stress graph for pattern 2 is obtained as shown in Figure 6.5.

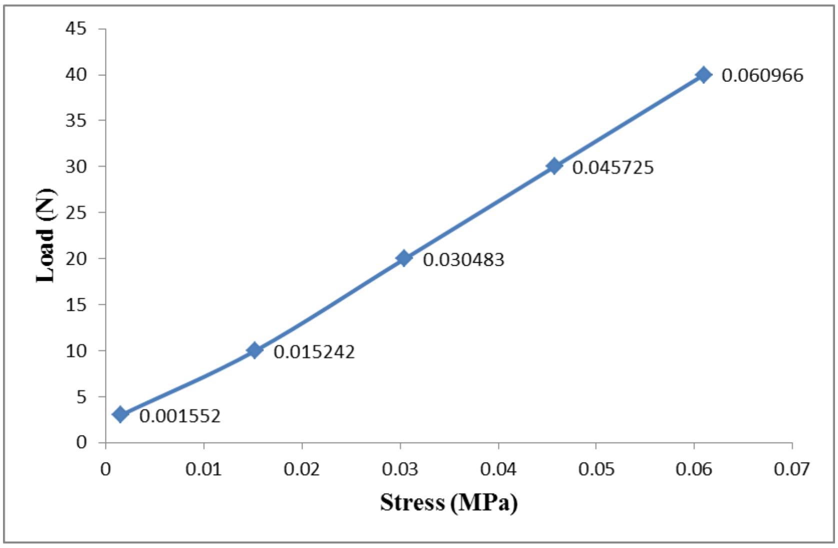


Figure 6.5 Load vs principal stress graph of pattern 2 for bare frameon 3rd, 5th and 7th floor.

Pattern 3:- Load application of linearly varying from top to bottom 60N, 40N, 20N.

Load is applied as linearly varying load descending from top to bottom on bare frame of different set of load values are applied.Figure6.6 and Figure 6.7 shows deflected shape and principal stress variation of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor. The deflected shape of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor is shown in Figure 6.8 The stress variation of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor.

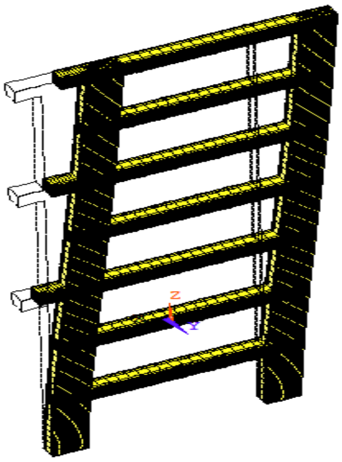


Figure 6.6 Deflected shape of analysis

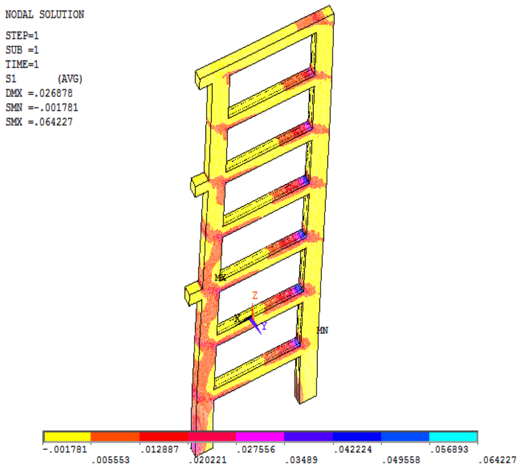


Figure 6.7 Principal stress variation of analysis

Pattern 4:- Load application of linearly varying from top to bottom 20N, 40N, 60N.

Load is applied as linearly varying load ascending from top to bottom on bare frame of different set of load values are applied. Figure 6.8 and Figure 6.9 shows deflected shape and principal stress variation of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor. The deflected shape of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor is shown in Figure 6.8, The stress variation of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor is shown in Figure 6.9.

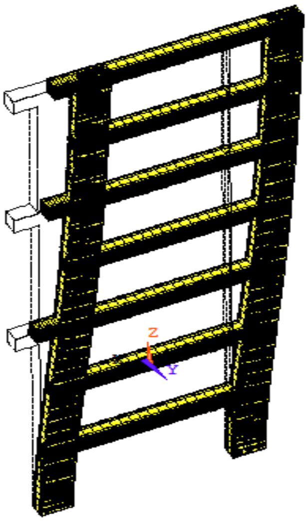


Figure 6.8 Deflected shape of analysis

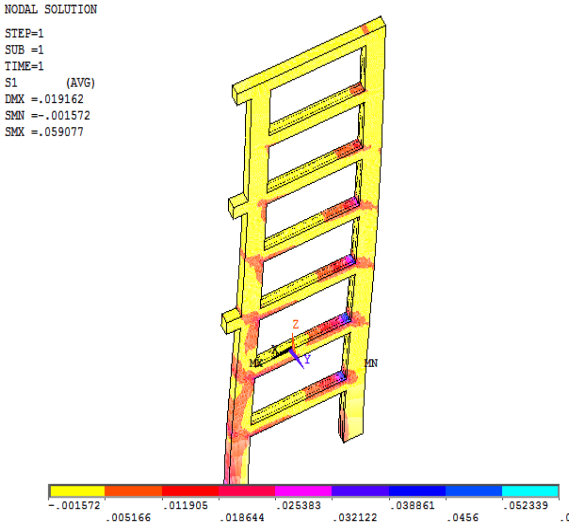


Figure 6.9 Principal stress variation of analysis

Pattern 5 Unit Load Application in Infilled Frame

This analysis deals with the results obtained from the Infilled frame model for the seven storey frame. From the obtained results, it is observed that maximum deflection occurs at the top of the frame with a magnitude of 2.96x 10^{-4} mm. Stiffness of the frame is 10135.14 N/mm. Figure6.11, and 6.12 shows the deflection and maximum principal stress variations of Infilled frame respectively. The deflected shape of the infilled frame is shown in the Figure 6.11. The maximum principal stress of the Infilled frame is shown in the Figure 6.12

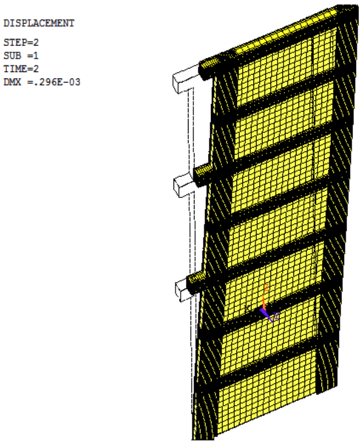


Figure 6.11 Displacement of the infilled frame

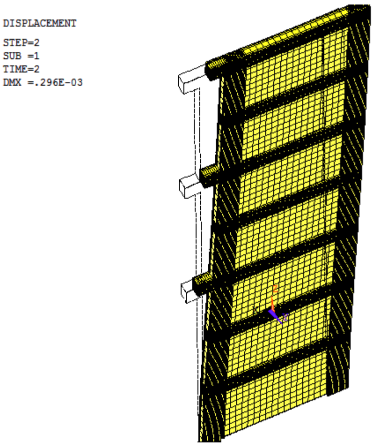


Figure 6.12 Principal stress variation of the infilled frame

From the obtained results it is observed that the maximum displacement occurs at the top of the frame with a magnitude of 2.96 x 10^{-4} mm. Stiffness of the frame [K] = load / deflection

= 3/2.96 x 10^{-4}

= 10135.14 N/mm

Pattern 6:- (i) Load application of 10N

The deflected shape of the infill frame with 10N load is shown in the Figure 6.13 Infilled frame is applied with pattern 6 of loads on 3rd, 5th and 7th floor respectively and during analysis only horizontal loads are considered. Load vs deflection graph for pattern 6 is obtained as shown in Figure 6.14, The Load vs displacement graph of Infilled frame is shown in the Figure 6.14, Load vs principal stress graph for pattern 6 is obtained as shown in Figure 6.15

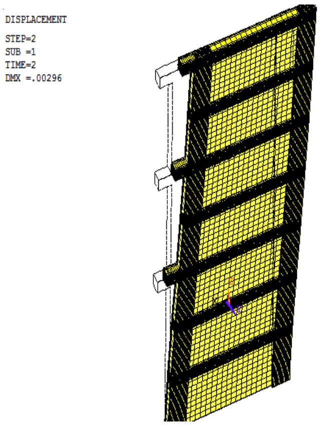


Figure 6.14 Deflected shape of Infilledframe with 10N

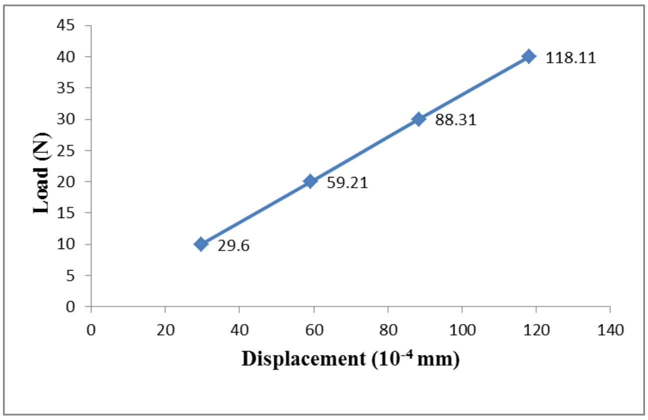


Figure 6.15 Load vs deflection graph of pattern 6 on Infilled frame with 10N, 20N, 30N and 40N on 3rd, 5th and 7th floor.

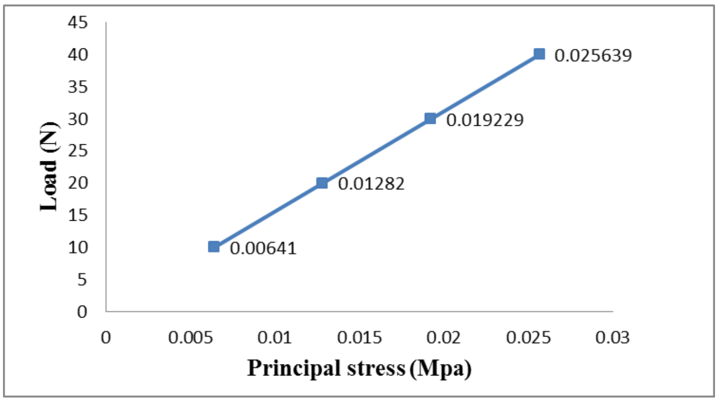
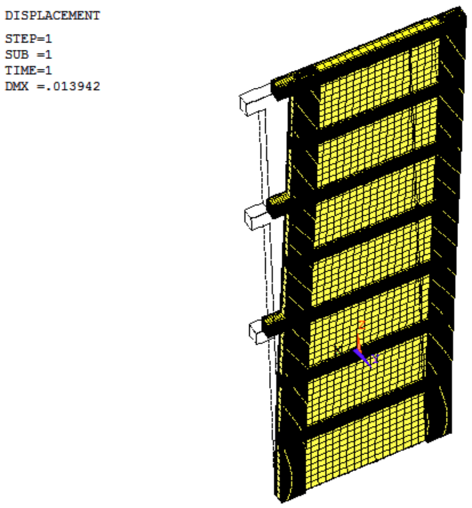


Figure 6.16 Load vs principal stress graph of pattern 6 on Infilled frame with 10N, 20N, 30N and 40N on 3rd, 5th and 7th floor.

Pattern 7: Load application of linearly varying from top to bottom 60N, 40N, 20N. Load is applied as linearly varying load descending from top to bottom on bare frame of different set of load values are applied.Figure 6.17 and Figure 6.18 shows deflected shape and principal stress variation of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor. The deflected shape of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor is shown in Figure 6.17 The stress variation of analysis in which 60N at 7th floor, 40N at 5th floor and 20N at 3rd floor is shown in Figure 6.18



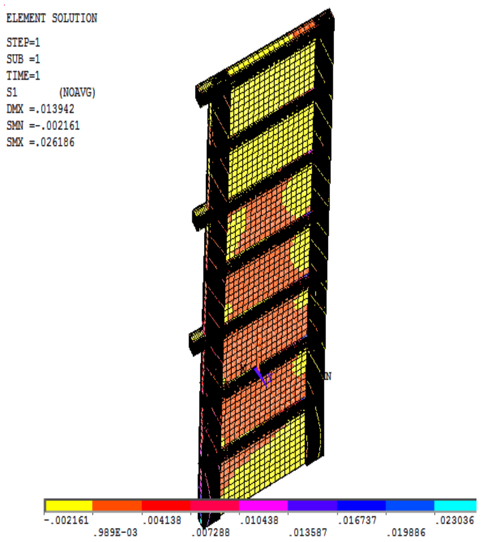
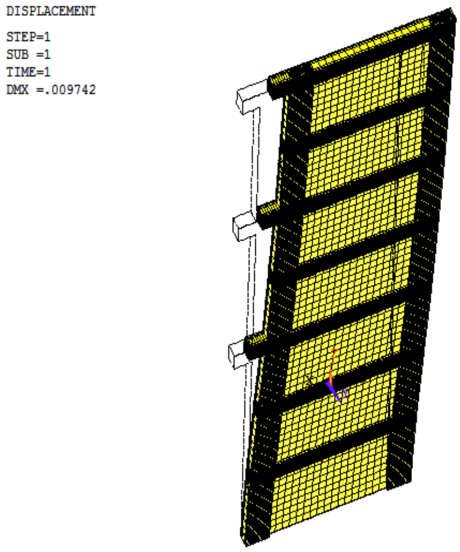


Figure 6.17 Deflected shape of analysis **Figure 6.18 Principal stress variation of analysis**

Pattern 8:- Load application of linearly varying from top to bottom 20N, 40N, 60N.

Load is applied as linearly varying load ascending from top to bottom on infilled frame of different set of load values are applied. Figure6.19 and Figure 6.20 shows deflected shape and principal stress variation of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor. The deflected shape of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor is shown in Figure 6.19 The stress variation of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor is shown in Figure 6.20**,** The stress variation of analysis in which 20N at 7th floor, 40N at 5th floor and 60N at 3rd floor is shown in Figure 6.20



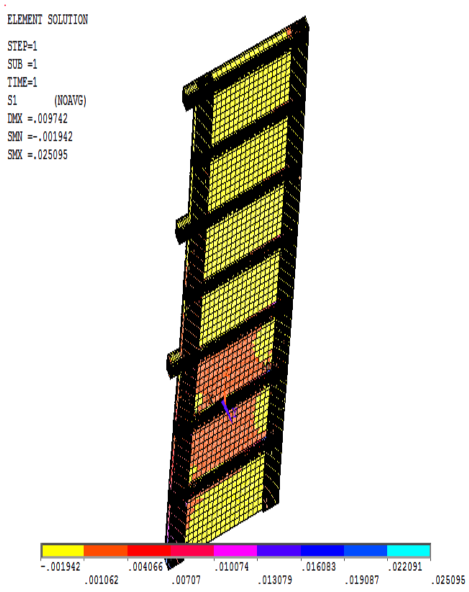


Figure 6.19 Deflected shape of analysis **Figure 6.20 Principal stress variation of analysis**

COMPARISON WITH EXPERIMENTAL RESULTS

The experimental result of bare and infilled frame tested by Thirumurugan at Structural Engineering Laboratory of SRM University are compared with the analytical stiffness values obtained from this investigation as shown in Table 6.1

Table 6.1 Comparison of stiffness from analysis and experimental .

Frame	**Stiffness (N/mm)**	
	Analytical	**Experimental**
Bare	5217	4820
Infilled	10135	8760

7. CONCLUSIONS

The analysis of the bare frame, infilled frame with cement mortar interface were carried out with same support condition and the loading condition. The analysis was done by using ANSYS 14.5 and the results of analysis are found out, and stiffness is compared.

(i). In comparison to the bare frame the stiffness of the infilled frame is 1.96 times higher.

(ii). The results of the study demonstrate that masonry infill highly increases the stiffness and strength of a structure for seismic action as well as action.

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