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Modeling and Study of Behavior of Infilled Frames with Different Interface Materials under Static Loading

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Abstract

Objective: The aim of this work is to study the linear behavior of infilled frames with different interface materials like cement mortar, cork and lead under static lateral loading. **Method:**This paper presents the analytical study of a two bay three storeyed reinforced concrete infilled frame under static lateral loading.A bare frame and infilled frames with various interface materials (cement mortar, cork and lead) have been analysed.**Findings:**In particular, the paper discusses the lateral stiffness of the frames and gives a comparison on the effect of interface materials on the lateral stiffness of the frames under static lateral load. It is found that cement mortar interface has higher stiffness when compared to lead and cork. **Applications/Improvements:** The results of this paper can become the basis for further studies on the behaviour of these interface materials under seismic loading.

Keywords: Infilled Frames, Interface, Lateral Stiffness and Static Loading

1. Introduction

Infilled frames are reinforced concrete or steel columns and girder frames with masonry or concrete brickwork as infills. These are generally used as exterior walls, partition walls, walls around stairs, etc. Infilled frames with brick masonry panels have found widespread usage in the construction field as it facilitates quicker and easier construction. Brick masonry is generally adopted as the infill material as it is convenient to use and is an accepted traditional construction material.

Infilled frame acts as a composite system in which the frame interacts with the infill wall under the action of in plane lateral load. The infills provide a bracing action against horizontal loads. Generally, the frames are designed for gravity loads only and the infill is assumed to contribute sufficiently to the lateral stability of the structure.

The behaviour of infilled frames is complex as the interface between infill and the frame follows non-linear behaviour. This leads to complexities in the analysis and study of its behaviour. Hence infill panels are treated as non-structural elements despite their contribution to high resistance to lateral loads.

In the absence of recognised design methods, the effect of infill panels was neglected as it was assumed that the panels were brittle when compared to the frame which led to inaccuracy in predicting the lateral stability of the structure. Also, the frames were designed for entire vertical and horizontal loads. From the frequently observed diagonal cracks it was soon inferred that this approach was not valid.

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Frames are generally provided with partition walls for functional purposes. It is found that the walls attract significant bracing loads and modify the structure's mode of behaviour and forces in the frame. Hence the infill walls are to be designed for lateral loads and frames should allow the modified mode of behaviour. In any storey, the infill should be capable of resisting horizontal shear in two orthogonal sections as well as resisting a horizontal torque.

Infill frames perform better in areas of higher seismic zones[1] because they absorb and dissipate more seismic forces. Infill frames have better resistance due to the composite action between frame and infill. If designed properly, taking this composite action into consideration, smaller cross sections of frame members with lesser reinforcement can be achieved. This would prove to be more economical.

Parameters like presence of openings in the infill, lateral load, material of infill and interface affect the stiffness, strength and deformation capacity of the infilled frame[2]. The interface is a gap between the frame and the infill panel. The interface material aids the load transfer between the frame and the infill and is known to improve the ductility of the frame. Figure 1 shows the bracing action of infill frames.

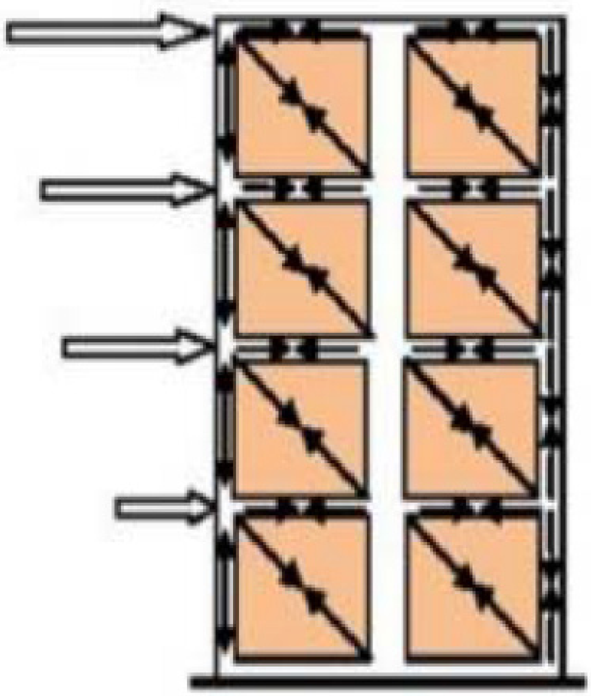

Figure 1. Bracing action of infill.

In order to understand and critically evaluate the research work done on infilled frames and their behaviour under static loading a detailed review of literature was undertaken. A substantial amount of work has been carried out in the field of infilled frames. The focus of the research work has been on the effect of infill on the frame's capacity to withstand lateral load. It has been proved that the infill provides a diagonal strut bracing action[3] thereby improving the stiffness of the structural system. The type of analysis and the modelling adopted affects the results of the study[4]. The constructional details and the interface conditions affect the behaviour of infilled frames[5].

This paper presents the modelling and analysis of a two bay three storey infilled frame with various interface materials, i.e., conventional cement mortar, cork and lead, subjected to static lateral loading. The RC frame is infilled with brick masonry. The analysis has been carried out using the SAP2000 (v14.0) software. The effect of interface materials on the lateral stiffness of the infilled frame has been studied.

2. Modelling and Analysis

The modelling and analysis has been done using a FEM based software package. A two bay three storey bare frame was modelled first[6]. The frame dimensions and the reinforcement details are given in Table 1 and Table 2 respectively.

The frame elements were modelled using 2 noded beam elements of 2 degrees of freedom. Fixed supports are provided at the foundation beam and at the foundation

Table 1. Dimensions of the bare frame

Description	Values
Bay width	0.425m
First Storey height	0.5875m
Second and Third storey height	0.400m

Table 2. Details of bare frame

Elements	Depth (mm)	Width (mm)	Main reinforcement	Shear Reinforcement
Beams	75	75	#4, 6mm dia	6mm dia at 40mm c/c
Columns	100	75	#4, 6mm dia	6mm dia at 40mm c/c
Foundation Beam	300	200	#8, 8mm dia	8mm dia at 100mm c/c

beam intersections that are 0.1m from the foundation edges. The properties of the materials used in modeling the RC bare frame are given in Table 3.

The two bay three storey bare frame modelled using the FEM based software is shown in Figure 2. The fixed supports at the foundation beam were replaced with spring elements. A static lateral load of 1kN was applied at the topmost node on the left column. The boundary spring stiffness values were varied and the top storey deflection values were noted down. A graph plotted with these values results in a convergence graph as shown in Figure 3 and the frame stiffness is obtained from the slope of the load versus top storey deflection graph in Figure 4.

From the graph it was concluded that the stiffness of the two bay three storey bare frame is 7.43 kN/mm under a static lateral load.

The infilled frame was modelled next. The dimensions of the frame were unchanged. The material properties used to model the infill and the interface materials (cement mortar, cork and lead) are given in Table 4.

The interface material was modelled using link elements and the infill panel was modelled as a thin shell element. Four noded plane stress area elements and two noded link elements of two degrees of freedom were used. The thickness of the interface was taken as 5mm in all cases.

The infill panels and the interface are discretized. Discretization is an FEM concept of division of an element into smaller elements. Each division is studied individually and the cumulative behaviours of all the divisions are taken into account to obtain a more accurate result. The two bay three storey infilled frame model is shown in Figure 5.

The interface material modelled first was cement mortar. A static lateral load of 1kN was applied at the topmost node on the left column. The internal spring stiffness values were varied and the top storey deflection values were

Table 3. Properties of materials of the frame

Name of Materials	Properties of Materials		
	Modulus of Elasticity (N/mm2)	**Density (kN/mm3)**	**Poisson's Ratio**
Concrete	23320	25.18	0.15
Steel	2x105	76.96	0.3

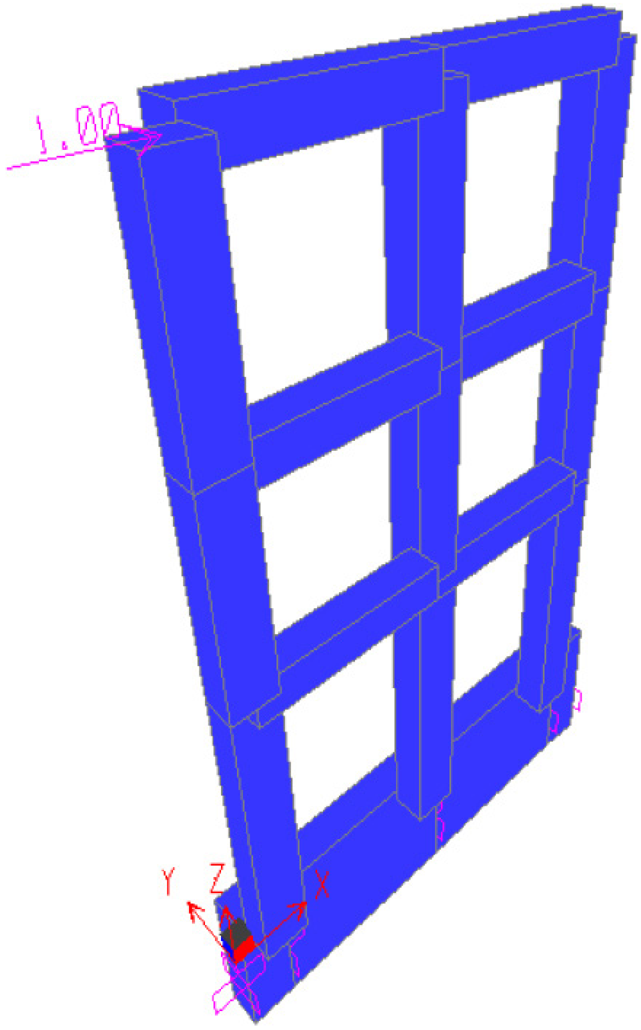

Figure 2. Bare frame model.

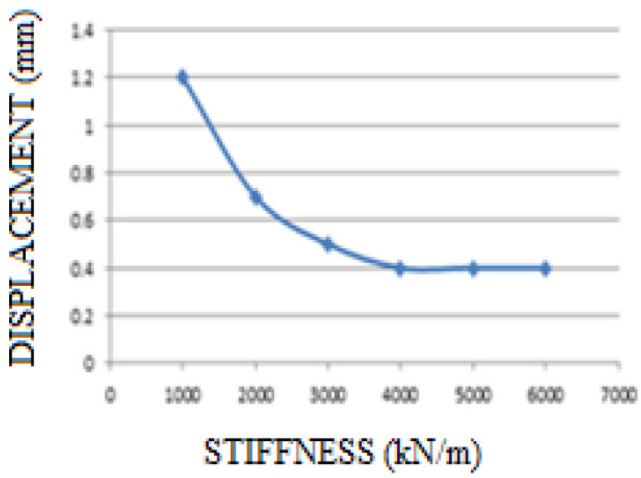

Figure 3. Boundary spring stiffness v/s top storey displacement.

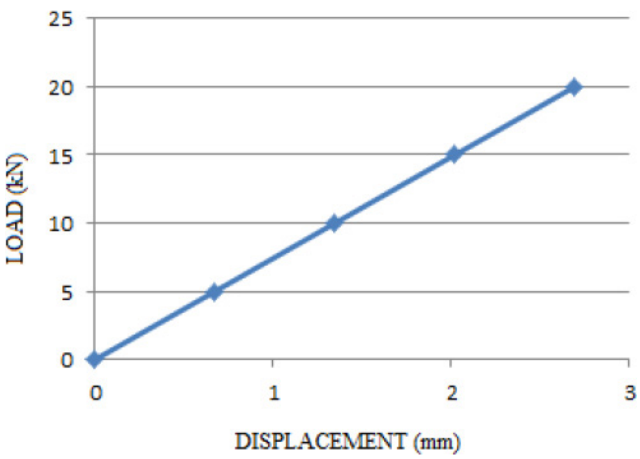

Figure 4. Load v/s top storey displacement.

Table 4. Properties of infill and interface

Name of Materials	Properties of Materials		
	Modulus of Elasticity (N/mm2)	Density (kN/mm3)	Poisson's Ratio
Brick	1030	18	0.15
Cement Mortar	10360	17.8	0.15
Cork	20	1.765	0.097
Lead	8000	111.2	0.447

noted down. A graph plotted with these values resulted in a convergence graph. From the graph it can be concluded that the initial stiffness of the two bay three storey infilled frame with cement mortar interface is 30kN/mm under a static lateral load of 1kN. The frame stiffness obtained from the slope of the load versus top storey deflection graph was 24.50kN/mm (Figure 6).

Cement mortar interface was replaced by cork and lead and the analysis was carried out in the similar manner. The internal spring stiffness value was taken as 30kN/mm. The frame stiffness was found to be 14.60kN/mm and 23kN/mm respectively for cork and lead interfaces. The load v/s top storey deflection graphs are shown in Figure 7 and Figure 8 for cork and lead respectively.

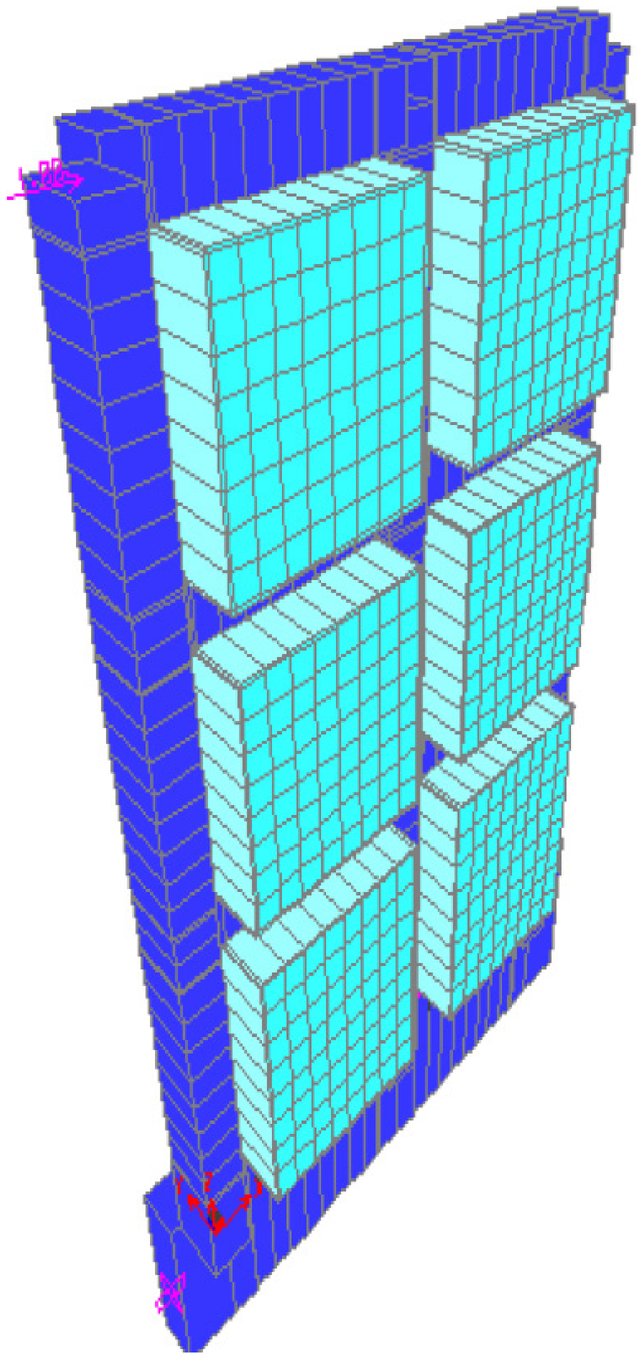

Figure 5. Infilled frame model.

3. Results

The comparison of stiffness for the two bay three storey frames (with and without infill) modelled and analysed is given in Table 5.

It can be concluded from Table5 that bare frame has lesser stiffness compared to the infilled frames. Also, the infilled frame with cement mortar interface is found to have the highest stiffness of the frames studied.

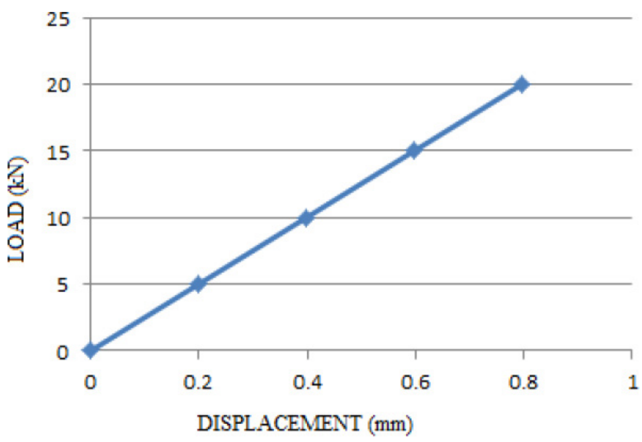

Figure 6. Load v/s top storey displacement (cement mortar interface).

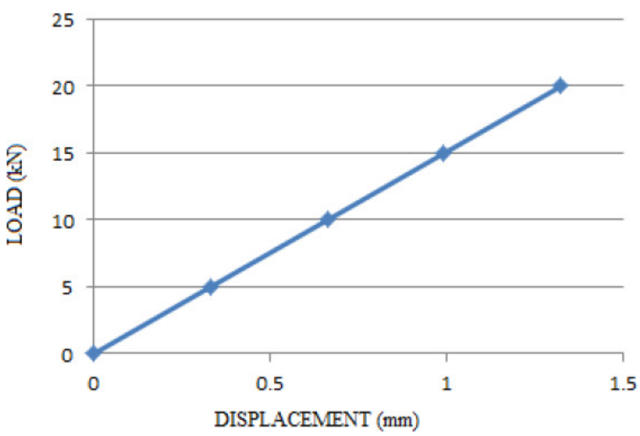

Figure 7. Load v/s top storey displacement (cork interface).

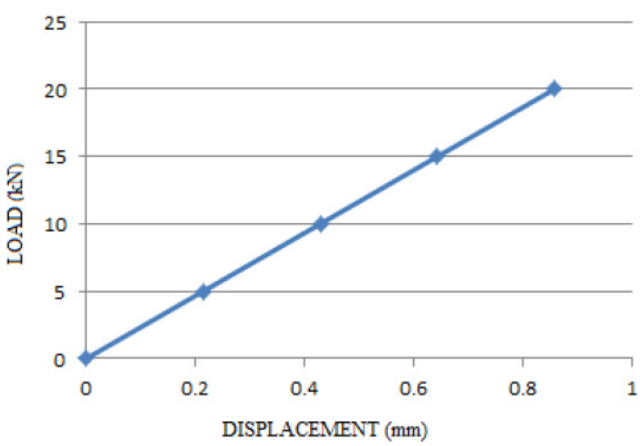

Figure 8. Load v/s top storey displacement (lead interface).

Table 5. Comparison of stiffness of the two bay three storey frames

Type of frame	Stiffness (kN/mm)
Bare frame	7.43
Infilled Frame with Cement Mortar Interface	24.50
Infilled Frame with Cork Interface	14.60
Infilled Frame with Lead Interface	23.00
Lead	0.447

4. Conclusion

A two bay three storey bare frame and three infilled frames (with cement mortar, cork and lead interfaces) were modelled and analysed using the FEM based software package.

From the comparison of the results given above for the four frames it can be inferred that:

1. Infilled frame exhibits more lateral stiffness than bare frame.
2. Infilled frame with cement mortar interface has more stiffness than the ones with lead and cork interfaces.

Hence, infilled frames with conventional cement mortar have the maximum stiffness of the frames considered.

5. Acknowledgement

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