The Behaviour of Seven-Storey Infilled RC Frame with Opening in Infill—An Analytical Study

G. Prem Kumar, V. Thirumurugan, and K. S. Satyanarayanan

1 Introduction

The reinforced concrete member [1] and steel members [2] are used as a framed structure nowadays for all type of buildings. The precast members like beams and columns were also used as a framed structure [3]. In the recent research, the conventional reinforced concrete member and steel members were replaced with the glued—laminated timber fiber as a frame in structure [4]. The various frame members were practiced in the construction with infilled masonry as a combo model. The masonry infills are the un-reinforced members which is not having the specific codal provisions for designing. Various studied were made in analyzing the RC infilled frames under the lateral loading for measuring the stiffness, energy dissipation, drift factor, displacement and principal stresses [5, 6]. The masonry infills are the major portion of failure in all tall building structures. Many researchers have studied this effect of lateral loads in RC infilled framed structures and steel framed masonry infilled structures. The failure modes and crack propagation in different areas have been studied in detail by many authors. To overcome this issue, a diagonal strut model is designed at the loading end to the other beam column joint for resisting the lateral load transfer in the structure [6]. The strut models are not that much effective and it's not having the practical ability to implement in the construction fields. Introducing the infill in between the RC members creates damage in the infill when the load is applied acting it. This load transfer is due to reinforced concrete possesses the flexible range where the un-reinforced masonry failed that property. To overcome this flexibility issue, the shear walls are constructed by some researchers and analysed the stiffness and strength properties [7]. This technique possesses greater self-weight that cannot be used in

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high-rise building. In recent days, an elastic medium like cork, lead, gaps, pneumatic and other elastic materials are used in the interface of the reinforced concrete member and masonry infilled panels [8]. These elastic mediums in between the members will resist the structure from damage and prevent the crack propagation and to avoid the structure from collapse. In the realistic models, the infilled walls possess openings for ventilations like door and windows. Some researchers have been made by incorporating the openings in the walls with varying size and location of the openings [4, 5, 7, 9–11]. The stiffness, displacement and stress were compared with the bare frame, RC infilled walls and RC infilled walls with openings. The members are tested by both static loading and cyclic loading [12]. Many researchers have tested the RC infilled frames with openings using up to three storey heights only. This study deals with the tall building effect of seven-storey RC infilled frames with openings in it.

2 Finite Element Model

The seven-storey RC infilled panel is tested using the Finite Element Analysis software (Abaqus). The panel is scaled down to 1/4 of prototype model and it is taken for testing. The dimensions of the specimens are described detail in Table 1.

The frame was cast using M20 grade of concrete for beams and columns, M40 grade of concrete for foundation. The steel used here was 16 mm main reinforcement for foundation, 10 mm main reinforcement for beams and columns and 6 mm bars for stirrups. The model was created using this material and the properties like modulus of elasticity and Poisson ratio were given to the model for respective materials. The openings in the infill are maintained as 50% from the masonry infill area.

Table 1 Dimension of single-bay seven-storey frame [13]

S. no	Specimen	Prototype model (mm)	Scale down model (mm)	Scale adopted
1	Ground floor storey height	2700	675	1/4
2	Other floors height	2400	600	1/4
3	Bay width	4000	1000	1/4
4	Beam dimension	400 × 600	100 × 150	1/4 × 1.5
5	Column dimension	400 × 800	100 × 200	1/4 × 1.5
6	Infill dimension (HxWxT)	3000 × 4720 x 2 30	600 × 1000 x 8 0	1/4 × 1.6x1.5

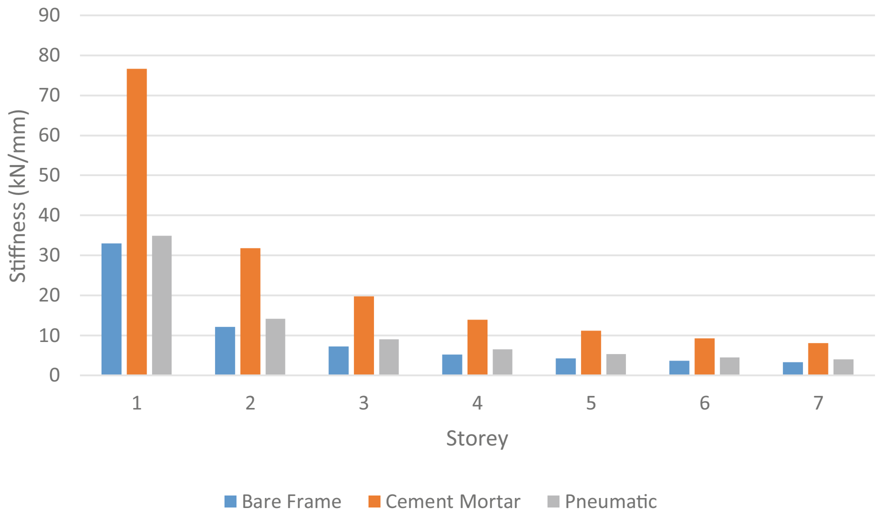


Fig. 1 Comparison of stiffness at various storeys with different interface materials

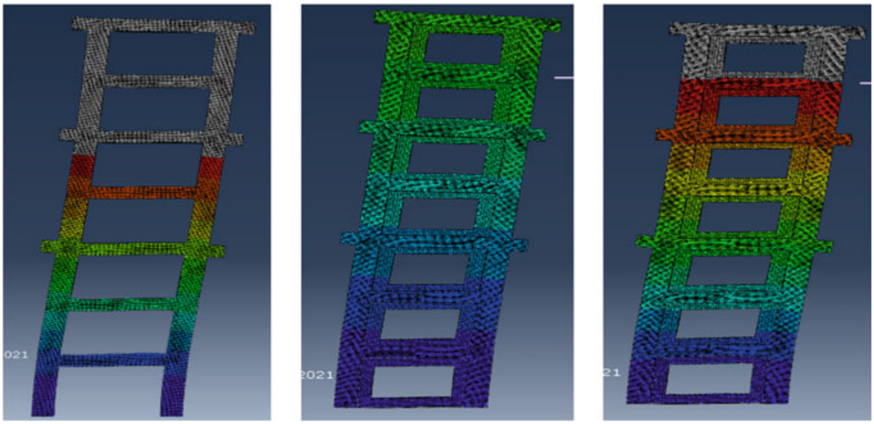
3 Results and Discussion

3.1 Lateral Stiffness

The stiffness value is calculated by the load applied in the seven-storey frame at three different points and to the displacement. The stiffness is compared to the three different specimens like RC bare frame, RC infilled frame with opening comprising the cement mortar as interface material and RC infilled frame with opening comprising the pneumatic interface material. The variation in stiffness for bare frame another infilled frame with different interface materials is shown in Fig. 1. The stiffness is more in cement mortar interface RC frame when compared to bare frame and pneumatic interface frame. There is only a slight difference in bare frame and pneumatic interface frame. The peak shows that there is high stiffness in cement mortar interface frame due to more rigidity in interface materials. The stiffness for IFCMO is 54.5% higher than the bare frame and IFPO frame due to the rigidity property of the cement mortar interface. When comparing the stiffness for bare frame and IFPO the stiffness is 5.5% more in IFPO than the bare frame.

3.2 Lateral Displacement

The displacement results shows that there is a peak in bare frame when comparing to other frames (Fig. 2). This peak is due to the flexibility in RC member with



(a) Bare frame **(b)** IFCMO **(c)** IFPO

Fig. 2 Displacement in RC bare frame and infilled seven-storey frames

having infill in between the RC members. There is less displacement in RC infilled frame with opening in the masonry infill with cement mortar interface due to the high stiffness in the interface medium when comparing to pneumatic interface. The displacement for the IFCMO is 55.8% lesser when compared to bare frame and IFPO due to the higher stiffness by cement mortar having better bonding with the masonry infilled materials than the IFPO (Fig. 3).

3.3 Minimum Principal Stress

Figure 4 clearly shows the stress is initially at the opposite end to the loading point. The initial stress is starts at the point where the columns are supported. The minimum principal stress is compared with the infilled frame cement mortar interface with opening (IFCMO) and infilled frame pneumatic interface with opening (IFPO). Figure 5 represents that there is an increase in stress for IFCMO when compared to IFPO. This result is due to the increase in stiffness by cement mortar interface bonded with the masonry infill than the pneumatic interface.

3.4 Maximum Principal Stress

The stress is distributed along the masonry infills which is transferred from the reinforced concrete member (Fig. 6). The maximum principal stress is measured when the peak load is applied to it. The stress is high for the IFCMO than the IFPO

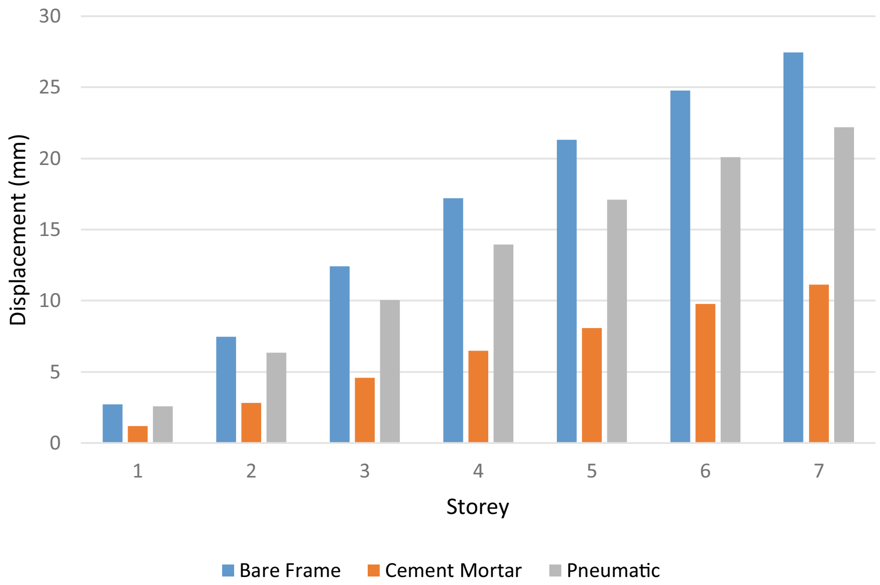


Fig. 3 Comparison of displacement at various storeys with different interface materials

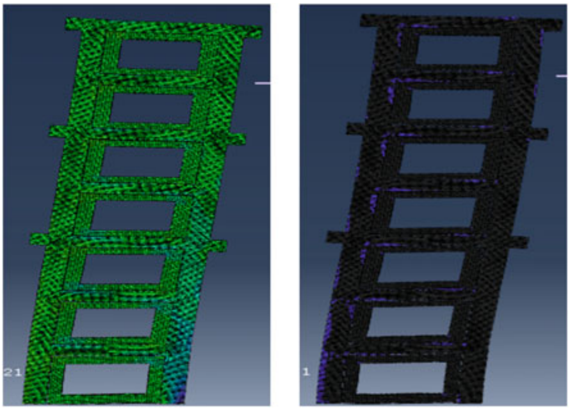


Fig. 4 Minimum principal stress in RC infilled seven-storey frame

due to the increase in rigidity of interface material comparatively (Fig. 7). The infilled frame have the poor resistance in lateral load due to its stress distribution through the masonry infills.

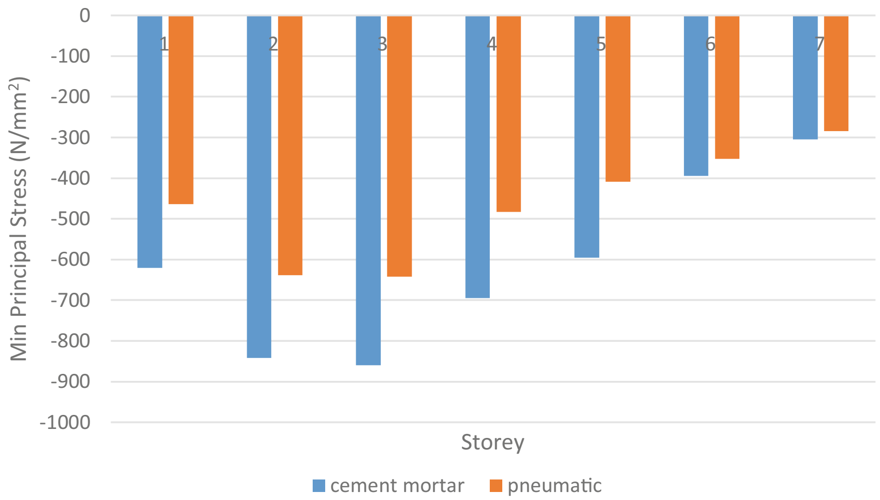


Fig. 5 Comparison of minimum principal stress at various storeys with different interface materials

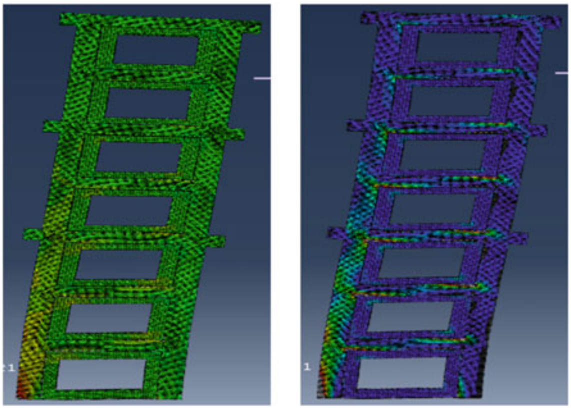


Fig. 6 Maximum principal stress in RC infilled seven-storey frame

4 Conclusion

The conclusions were made with the comparative results using different interface mediums:

1. The RC fully infilled frame increases the poor resistance in lateral loading which is clearly proved by many researchers. So, this study deals with the partial infill in the high-rise buildings and their characteristics were studied in detail.
2. The stiffness for IFCMO is 54.5% higher than the bare frame and IFPO frame due to the rigidity property of the cement mortar interface.

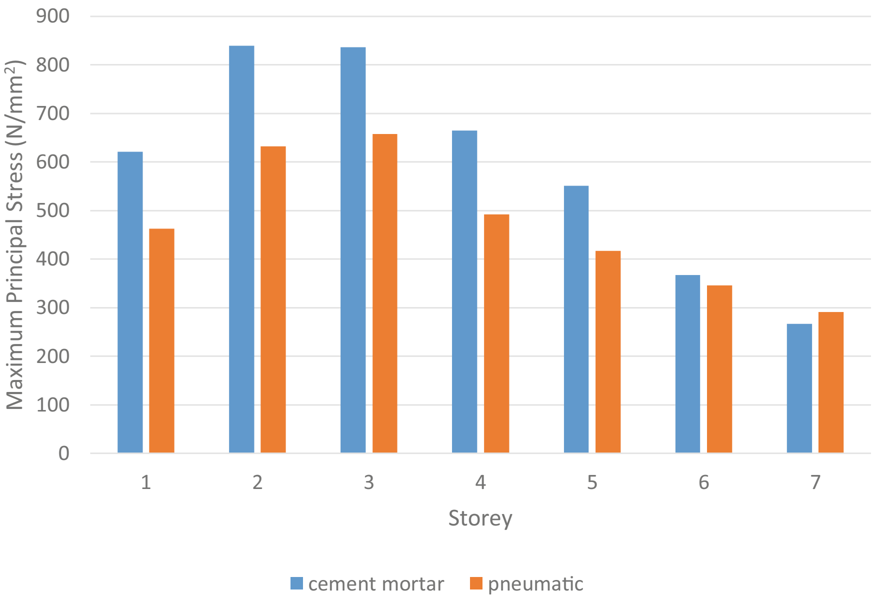


Fig. 7 Comparison of maximum principal stress at various storeys with different interface materials

3. When comparing the stiffness for bare frame and IFPO the stiffness is 5.5% more in IFPO than the bare frame.
4. The displacement for the IFCMO is 55.8% lesser when compared to bare frame and IFPO due to the higher stiffness by cement mortar having better bonding with the masonry infilled materials than the IFPO.
5. The IFPO frame is displaced more when comparing to IFCMO frame is due to the flexible interface material in between the masonry infill and RC member which transfers the load from RC member to the Pneumatic interface.
6. The displacement has slight difference by 19.06% lesser when comparing the bare frame due to absence of infill in the bare frame.
7. The maximum and minimum principal stresses show that the IFCMO has the maximum stress distribution due to its bonding and rigid property than IFPO.

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