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Original Article

Experimental and Analytical Investigation of Masonry and Sandwich Wall Infill Effects on Reinforced Concrete Frames: A Comparative Study under Room and Elevated Temperature Conditions

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Abstract - *Infilled frames were made using various infilled materials, commonly masonry. This research paper concentrates on constructing lightweight infilled frames using sandwich wall panels made of polyurethane (PU). In this research, a total of seven Reinforced Concrete (RC) frames were considered, including bare frames, infilled frames using masonry, sandwich wall panels, and frames laminated with GFRP. Elevated temperature, as well as room temperature, was considered to study the thermal characteristics of different configurations of frame structures. This study attempts to evaluate the impact of temperature on the stiffness and load-carrying capacity of bare and infilled frames. Initially, the behavior of the frames at high temperatures was analytically studied using ABAQUS. Experimental tests were carried out to verify the analytical results. At elevated temperatures, experimentation was carried out on sandwich-wall panels and RC frames filled with masonry. Static loading was applied to the frames, and ultimate strength, failure modes, and deformations were noted. The research offers a significant understanding of the behavior of sandwich wall panels and RC frames filled with masonry walls at high temperatures. The masonry infilled frames compared with the sandwich wall panel and the sandwich wall panel show minimal difference in ultimate load-carrying capacity but higher stiffness. Additionally, GFRP laminates were introduced to prevent the failure of the sandwich panel. Infilled frames using sandwich panels with GFRP laminates depict 4.49% higher load-carrying capacity compared to the infilled frame using sandwich panels.*

Keywords - *RC frames, Sandwich panel, Transient temperature, Finite element analysis, Failure modes*.

1. Introduction

RC structures typically consist of a framework of reinforced concrete columns and beams, forming the primary load-bearing structure. These frames are often designed to resist vertical loads like the weight of the building and any applied loads. The bare frame most often fails in a ductile manner while the frame is designed and the details are regulated. Many countries utilize RC frames filled with masonry more frequently for several reasons, including easier access to building materials such as masonry walls' superior insulating qualities against heat and sound and their traditional use in certain areas. Infilled frames are composite structural systems that interact compositely under in-plane lateral loads between the infilling masonry and the bounding frame. Infill material is the non-structural component placed within the frame. Common infill materials include masonry walls (such as brick or concrete blocks), glass or lightweight concrete panels, and sandwich wall panels.

Sandwich panels are advanced construction products that are frequently utilized for modern building designs because of their superior structural as well as thermal characteristics. These panels comprise two stiff outer layers, which are frequently composed of composite, metal, or plastic, and lightweight core material, as shown in Fig. 1. Usually, the outer layers offer strength and protection, and the core material is chosen for its insulating attributes.

The number of collapses of structured buildings in the last few years has been steadily rising. The reason for the frequent collapses is either the utilization of poor structural elements or improper construction. The impact of elevated temperatures is a primary cause of collapse. Wald et al., 2006 conducted research on the tensile membrane action of members and the toughness of steel joints subjected to natural fire. The findings of a real-time fire scenario were used to monitor the heat transfer to members and joints.

These findings are consistent with the fire design guidelines provided by the Eurocode [1]. Ruirui Sun et al., 2012 investigated the static and dynamic behaviour of steel frames while considering local and global structural failure in the event of a fire. Researchers reported that local failure happened with beams of smaller sections, and global collapse happened when larger beam sections experienced elevated temperature failures [2]. Stafford Smith, 1962 tested infill panels made entirely of mortar in a lab setting. Every test was run at a modest scale of roughly 1:20 [3]. The steel sections used for the frames were rectangular shapes with undefined sections. They assessed the infill panels' lateral stiffness that was not adhered to the surrounding frame. Moretti et al., 2014 studied infilled frames with reinforced concrete masonry, and the relevant critical study protocols were developed using the diagonal strut provision as a basis [4]. Energy dissipation occurs in bare frames due to inelastic impacts in RC frame members and joints and in filled frames due to inelastic effects in infills. As a result, an infilled frame dissipates more energy than a bare frame [5].

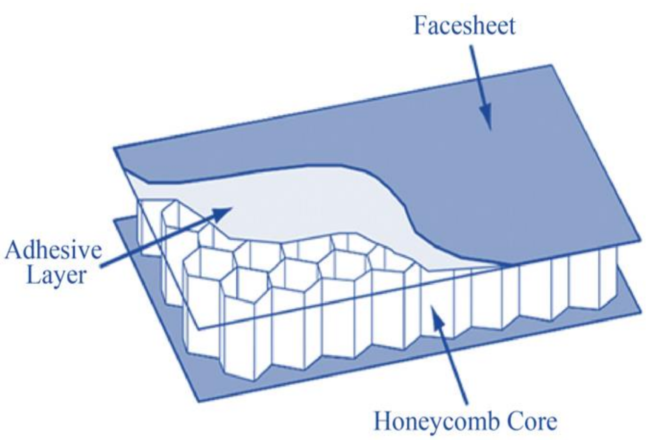


Fig. 1 Sandwich wall panel [26]

A sandwich panel consists of two external layers of high-potency material known as "wythes" or "skin" covering an interior core composed of a low-density material. Superior strength and energy efficiency can be achieved by combining sandwich-wall panels with RC frames to create a high-performance building system. The intended temperature and heat capacity dictate the core's dimensions and composition [6]. Expanded polystyrene (EPS) was used as a composite because it had a smooth surface and an appropriate thickness [7-11]. Corrugated EPS cores have been found to improve when RCSP behavior is compared [12-13]. Wythes are used to produce surface integrity, reinforced covers, load resistors, and anchoring to interconnections [12-13]. Previous researchers used several techniques to build the specimens. Mostly, wythes were constructed by casting concrete [10-11]. In some cases, concrete was poured to create the upper wythe, while concrete was sprayed to create the lower one [8-9]. Because of its low self-weight, it is the best alternative to hollow block walls, brick, and concrete.

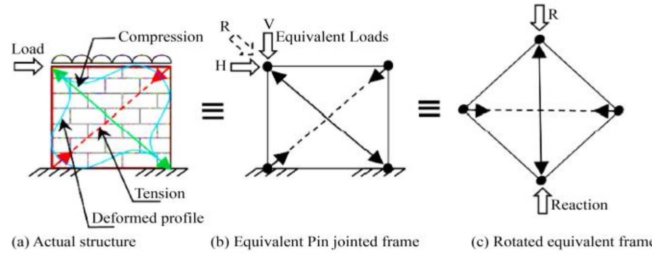


Fig. 2 Justification of square model [20]

It is important to note that sandwich structure panels and slabs are rarely subjected to compressive forces in the fields of structural and civil engineering. The lateral behavior and stiffness of the confined masonry wall were enhanced by infilled RC frames made of sandwich composite panels, as reported by De Luca et al., 2014 [14]. The structural behavior of precast sandwich panels under flexure was studied by Benayoune et al., 2007 [15]. CoDyre et al., 2018 provide a case study and analysis of structural components using sandwich panels and found that the composite stiffness was enhanced with the addition of a stiffener [16]. The low thermal conductivity of polyurethane foam effectively impedes heat transfer through the material under steady-state conditions [17]. Through experimental investigation, Rajeshwaran and Logeshwari, 2023 studied the behaviour of framed structures infilled with sandwich walls. They concluded that the load capacity of the structural system was increased compared to the conventional wall system while the core thickness was 25 mm [18].

The current study examines the behaviour of square-infilled frames (Fig. 2) using masonry and sandwich wall panels that interact with RC frames and are compared to bare frames. Moreover, current research provides vital insights into the interaction of these elements, taking into account factors such as load-bearing capacity and stability. A number of studies have focused on the behaviour of RC frames infilled with masonry at both room and higher temperatures. However, there is a gap in the literatures on the behavior of RC frames infilled with sandwich panels at high temperatures. A comparative study of RC frames infilled with sandwich wall panels and masonry was carried out using nonlinear analysis. This research intends to evaluate the interaction between polyurethane (PU) sandwich wall panels with RC frames scaled down by 1/4th. [19].

2. Materials and Methods

The steel coupon that was used to build the sandwich panel was made as per the recommendation of ASTM A370-11 [21] and E8-04 [22] guidelines. The concrete mix design was made based on the specifications of IS 10262:2009 [23]. The proportions of the final mix are listed in Table 1. The properties of associated materials, such as brick masonry and polyurethane foam, were tested in the laboratory, and the obtained properties were used for the simulation of analytical models.

Table 1. Mix proportions of concrete

Concrete grade	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	w/c
M30	462	903	803	0.45

Table 2. Strength of brick masonry

Compressive Strength (N/mm^2) (Prism)	Flexural Bond Strength (N/mm^2)	Shear Bond Strength (N/mm^2)
6.79	0.69	0.95

The strength of brick masonry was tested using building stacks made up of five bricks joined by a layer of rich mortar, with a height-to-thickness ratio of 3.45 (shown in Fig. 3a). The bricks were covered in wet burlap and rewetted for 28 days. In addition to this, flexural bond strength was evaluated using prism stacks of five bonded bricks under a simply supported configuration, shown in Fig. 3b. A triple brick specimen was utilized (Fig. 3c) to evaluate the shear bond strength of the mortar joints between the bricks. The test configuration showed that the center brick had unrestricted movement while the top and bottom bricks had restricted mobility. The compressive testing machine's piston rod was used to apply force progressively until the mortar and brick joints partially collapsed. At that point, the shear bond strength was estimated. The strength of brick masonry was tabulated in Table 2.

(a) (b) (c)

Fig. 3 Testing of Brick Masonry

Sandwich panels often include polyurethane foam as one of their constituent materials. This term refers to a group of foams made up of cellulose molecules and polymers united by urethane bonds. It typically has a low density, but it can be either rigid or elastic. While rigid polyurethane foam finds application in vehicle panels and as an insulation material, expanded polystyrene foam finds widespread use in mattresses and textiles. Their significant deformation ability and low compressive stiffness allow them to absorb energy very well. The material properties of polyurethane and steel are listed in Table 3.

Steady-state and transient-state analyses were the two phases of this investigation. An applied heat flux and the corresponding temperature were recorded during the steady-state analysis. The crucial temperature at which the material fails was determined. A transient state analysis with respect to time was carried out based on the maximum temperature. The methodology of the present investigation is shown in Figure 4.

Table 3. Properties of steel and polyurethane [24]

Properties	Polyurethane	Steel	Unit
Conductivity	0.5	50	W/mK
Density	1.7×10^{-9}	7.8×10^{-9}	Ton/mm^3
Specific heat	1.57	0.466	J/g °C

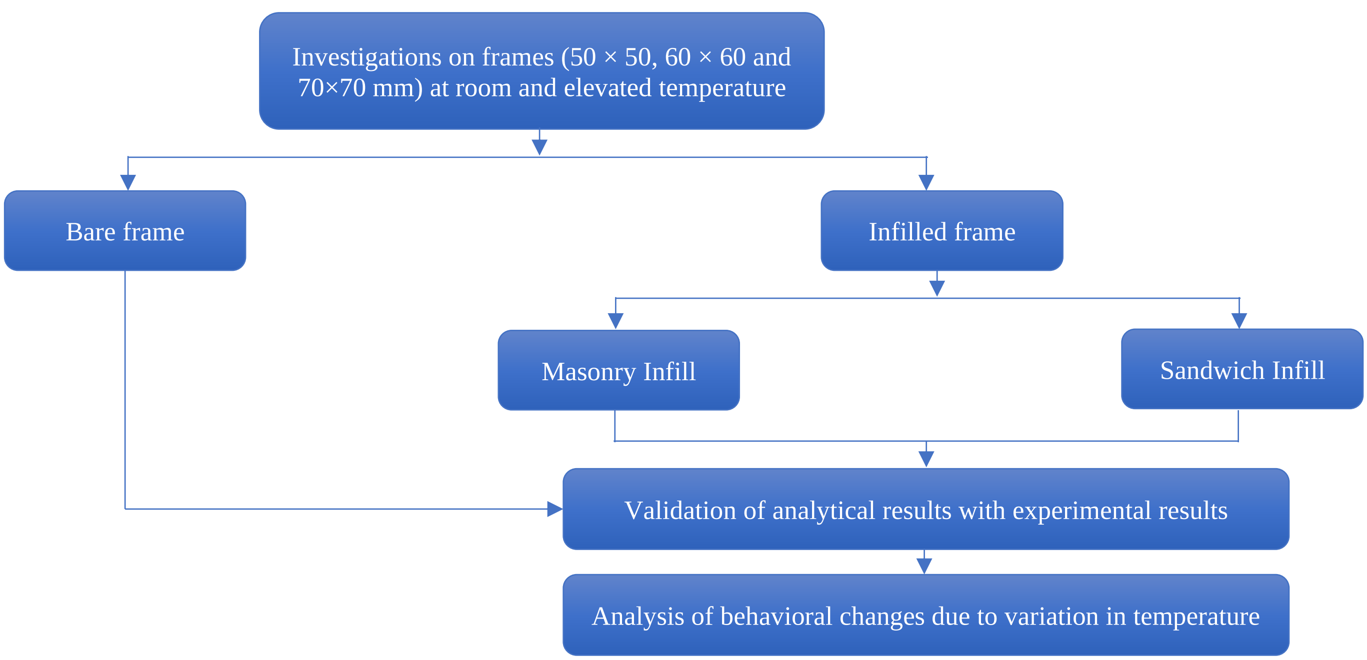


Fig. 4 Methodology

3. Analytical Investigation

3.1. Model Configuration

In this present research, a total of seven frame specimens are prepared, differing in terms of temperature fluctuations and frame detailing. Three different kinds of frame structures, such as bare frames, infilled frames with masonry, and infilled frames using sandwich panels, were constructed with identical geometrical configurations as illustrated in Fig. 5. The specifics of the specimens used in the present research were illustrated in Table 4.

The finite element model created using ABAQUS is shown in Figure 6.

3.2. Interaction and Meshing

Interactions among the different structural elements involved in the structures are the prime criteria for solving the behaviour of the entire structure with accuracy. Two types of interactions were used to achieve the interaction between the connection parts: surface-to-surface contact and tie constraint. A tie constraint was applied for the stiff connection behavior.

Table 4. Specimen configuration

Sl. No.	Specimen	Description of Specimen	Temperature
1	BFWOT70	Bare frame (70 x 70 mm)	Room
2	IFMFWOT70	Masonry infilled frame (70 x 70 mm)	Room
3	IFSWFWOT70	Infilled sandwich wall panel (70 x 70 mm)	Room
4	BFWT70	Bare frame (70 x 70 mm)	Elevated
5	IFMFWT70	Masonry infilled frame (70 x 70 mm)	Elevated
6	IFSWFWT70	Infilled sandwich wall panel (70 x 70 mm)	Elevated
7	GFRPWIFSWFWT70	GFRP wrapping infilled sandwich wall panel frame (70 x 70 mm)	Elevated

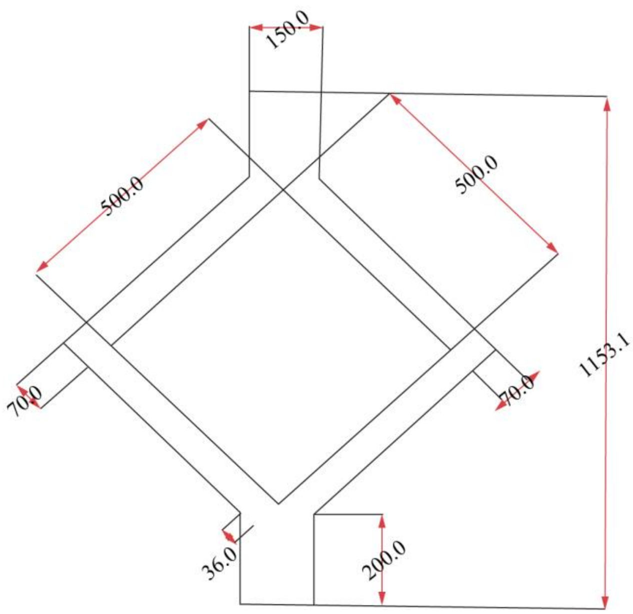


Fig. 5 Cross-section of RC frame

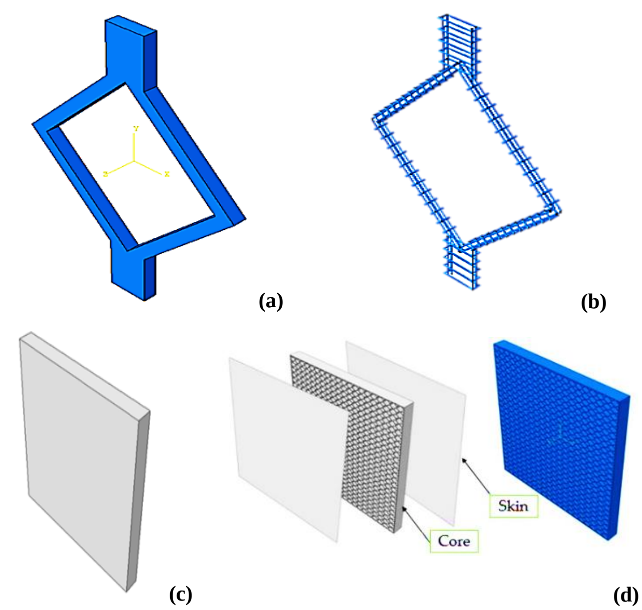


Fig. 6 Finite Element frame model (a) Bare Frame (b) Reinforcement (c) Masonry Model (d) Sandwich Panel

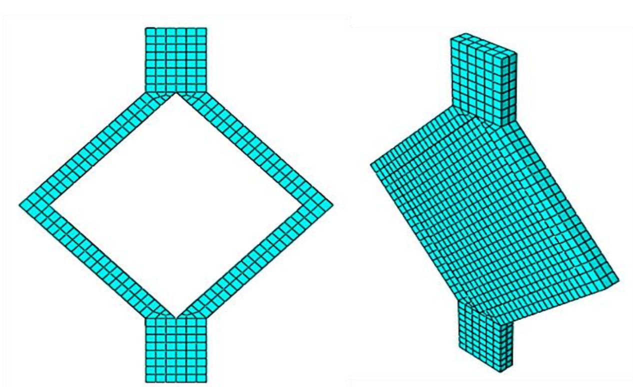


Fig. 7 Mesh pattern of frame components

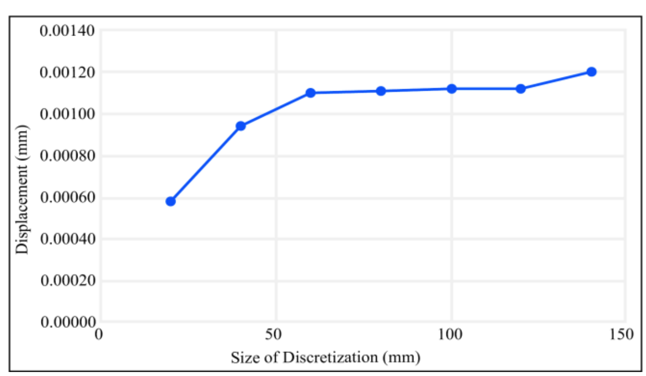


Fig. 8 Mesh convergence

The rectangular meshes were chosen based on the linear geometry of the column and beam, which were represented by the quad 3D element type depicted in Fig. 7. The embedded connection technique was used in the finite element model to connect the reinforcement and concrete. Initially, mesh convergence was studied to determine the reliable element size. The range of mesh sizes was considered from 20 to 140 $mm^{2,}$ as shown in Fig. 8. Based on the observation, a typical mesh size of 70 mm^2 was chosen for the present analysis.

3.3. Boundary Condition and Loading Protocol

Boundary conditions are the necessary parameters in FEA to simulate the structures. All D.O.F. restrains the bottom face of the frames, and the load is applied in the downward directions from the top face of the frame structures shown in Fig. 9. The load-controlled method is used to apply the load and extract the behaviour of the frames.

4. Experimental Investigation

4.1. Fabrications

In this present research, geometrical configurations similar to those used in the analytical investigation were considered. The section of RC beam and columns were considered as 70 mm × 70 mm built with four 6 mm longitudinal bars, and 40 mm c/c of 6 mm diameter bars were used for shear reinforcement. The detailing of reinforcement is shown in Fig. 10. The dimensions of the infill panels were considered 500 x 500 mm for both the masonry and sandwich panels, with a thickness of 50 mm. The frames were tested and subjected to an in-plane compressive load to find their stiffness behaviour. The sandwich panel core (PU) thickness was considered 49.1 mm, with a skin thickness of 0.45 mm. The panels and frames were exposed to high temperatures. The impact of temperature was investigated and compared with that of RC frames infilled with masonry. High temperatures were applied to the panels and frames. The phases of fabrication are discussed in detail as follows, and the preparation of specimens is demonstrated in Fig. 11.

The mould is prepared using a wooden board with the specific dimensions of the frame. To prevent mortar from sticking to the mould, grease has been applied in the interior part of the mould. The wooden mould is strengthened with battens to prevent the cement slurry from leaking out of the mould during vibration and to prevent it from bending under the weight of the concrete. A spirit level is used to level the mould on the ground. After inserting the reinforcement cage into the mould, adjustments are made to ensure the cage is properly aligned within the mould. The cage is positioned to offer the appropriate side and bottom coverings. Fig. 11a shows the configuration of the reinforcing cage inside the formwork. Specific quantities of the specimen's components are stored on a different platform. Before adding the required amount of water, the cement, F. A., and C. A is thoroughly mixed while dry. The mixture is thoroughly blended using a concrete mixer machine with a capacity of 0.25 m3 until it has a uniform appearance. Immediately after mixing, the concrete is quickly poured into three layers into the mould and manually compacted with a tamping rod, as shown in Fig. 11b. After casting, specimens are kept in the mould for a day.

After 24 hours, the specimens are taken out from the mould, as shown in Fig. 11c. For ease of identification, and the designations are marked on the frame. Curing concrete keeps the ideal moisture content stable, which is essential for cement hydration and resists shrinkage fractures as well as early straining and disturbance in the concrete. Wet jute bags are used for curing, as seen in Fig. 11d, which takes place over 28 days.

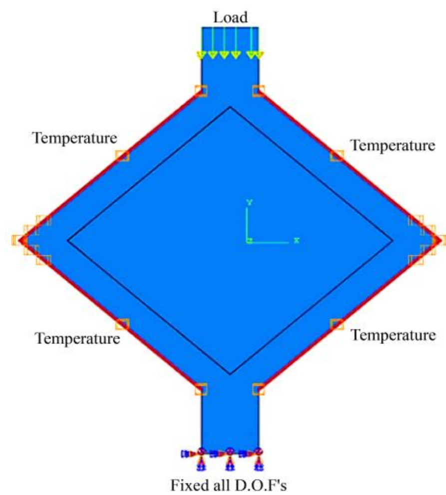


Fig. 9 Boundary condition with application of load

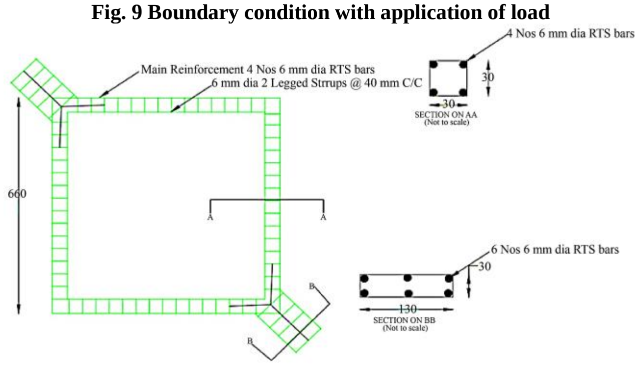


Fig. 10 Detailing of reinforcement

Fig. 11 Preparation of RC frames (a) Mould with reinforcement (b) Casting of frames (c) Demoulding (d) Curing (e) Masonry infilled frame (f) Sandwich infilled frame

4.2. Preload Arrangements

The temperature and loadings were simultaneously achieved at a rate of 55 minutes in the analytical investigations that used the transient state. Due to practical limitations in the experimental studies, the configuration demonstrated in Fig. 12 was utilized to simulate this loading concept. It is made up of four 20 mm diameter rods fastened by bolt connections between two 10 mm plates. A load cell was positioned over the specimen to measure the loading intensity as the bolts rotated. The bolt was rotated 180 degrees to apply a load of 3.73 tons. During the experiment, this was used to preload the frame.

The gunny bags were taken off after the frames had cured, and the specimens were cleaned. The specimen which was tested under elevated temperature was placed in an oven (setup is shown in Fig. 12b) at 225°C for approximately 2 hours. Five thermocouples were used for the temperature measurements: two in the panel, two in the beams, and two in the columns.

4.3. Test Setup and Loading Protocol

To obtain the load-displacement behaviour as the response, RC bare frames, infilled masonry frames, and sandwich wall panels were fixed in the self-straining frame of capacity 400 kN for experimental investigation. Using plumb bob and spirit levels, the specimen was levelled and centred after it had been placed over the testing frame. The isometric view of the schematic diagram and realistic test setup in the laboratory are shown in Fig. 13a and Fig. 13b, respectively.

The application of an axial load was accomplished by fixing a 100 kN loading jack, a 150 kN load cell, and a hydraulic pumping unit at the top. Loads were applied gradually at a rate of 1kN, and the corresponding deformations at different points were recorded for every loading increment.

(a) **(b)**

Fig. 12 Preload arrangements and temperature setup

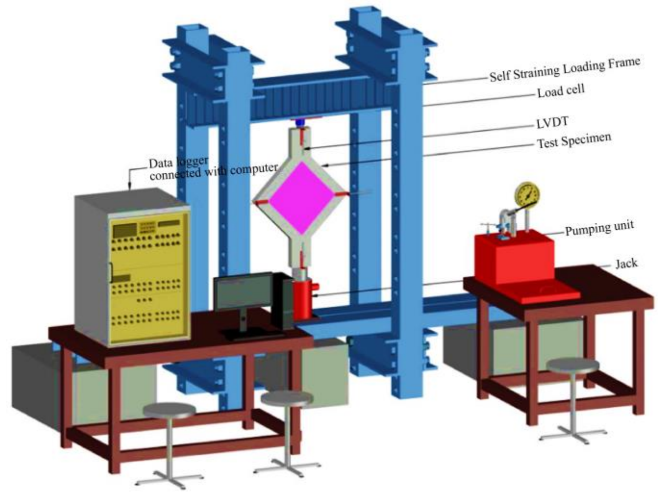


Fig. 13 (a) Schematic diagram for test setup for RC frame

Fig. 13 (b) Experimental setup for RC frame

As the impact gradually increased, careful inspection was performed to locate the fractures. For increased precision, a 32-channel recording system was linked to every LVDT, load cell, and loading jack. The condition in which the frame continues to deflect beyond the ultimate loading point with no increase in load is defined as the failure stage. The frame was arranged in a vertical position by erecting the loading frame and was adjusted such that the applied load passed axially. The LVDT was placed at the top, bottom, left, and right corner positions where deformation needs to be evaluated.

5. Result and Discussion

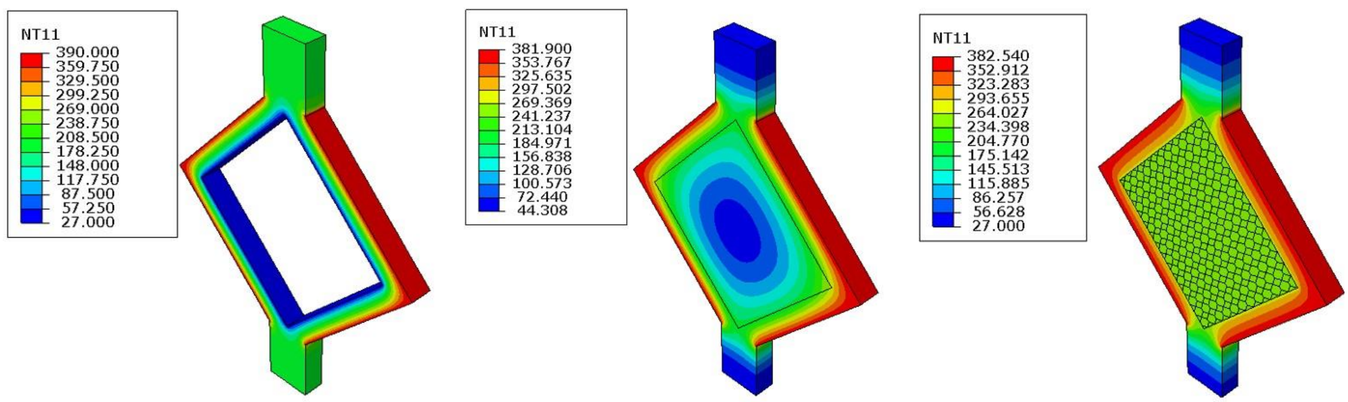
5.1. Analytical Investigation

Temperature variations had a significant impact on the strength of the masonry as well as that of the surrounding components, including the roof, beam, and column. The structure is harmed by the temperature swings that cause thermal stress. RC frames filled with sandwich wall panels and masonry were examined in this investigation and compared with the behavior of bare frames. A transient temperature was applied. The temperature was kept constant at 23°C, which was considered as standard room temperature.

The stress variation against temperature was examined once every five minutes. RC frame structures were exposed to temperature until the heat caused the structure to fail. The critical temperature capacity was observed from the analytical simulation and demonstrated in Fig. 14. The bare frame depicts 2.12 and 1.95% higher temperature capacity compared to infilled frames with masonry and sandwich panels, respectively. In addition to this, infilled frames using sandwich panels show 0.16% higher temperature capacity compared to masonry infilled frames, which was very minimal.

The maximum principal stress recorded at the critical temperature for infilled frames with masonry and sandwich panels is shown in Fig. 15 and Fig. 16, respectively. The analytical results were compared and tabulated in Table 5.

The ultimate load-carrying capacity of infilled frames was reduced by about 16.99 and 30.96% in the case of masonry and sandwich panels, respectively, with the changes of temperature from room to elevated conditions. Besides this, frames undergo larger deformation with the increase of temperature from room to elevated conditions. In the case of deflection characteristics, bare frames undergo more than infilled frames. The maximum deflection of infilled frames was increased by about 14.93 and 12.09% in the case of masonry and sandwich panels, respectively, with the changes of temperature from room to elevated conditions.



(a) **(b)** **(c)**

Fig. 14 Temperature capacity of RC frames (a) Bare frames (b) Infilled masonry frames (c) Infilled frames using sandwich panel

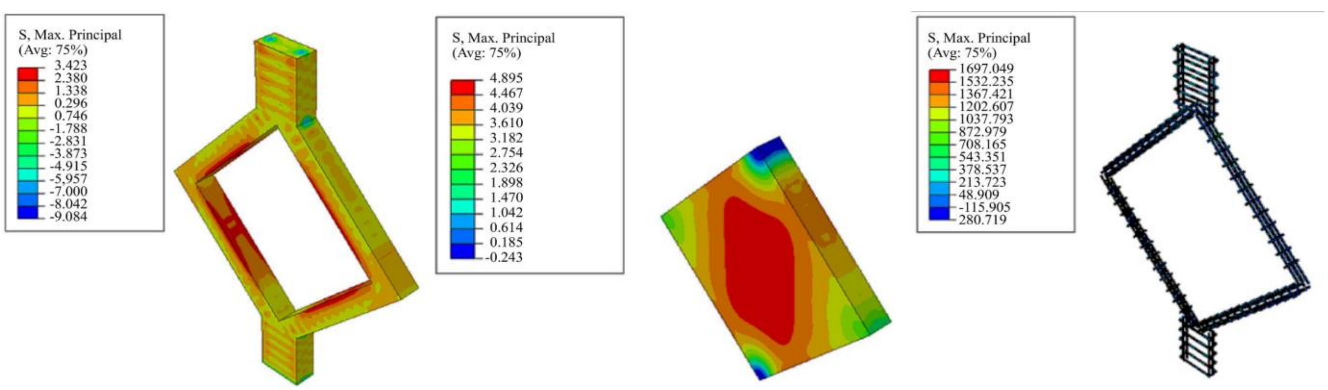


Fig. 15 Maximum principal stress of infilled masonry RC frame

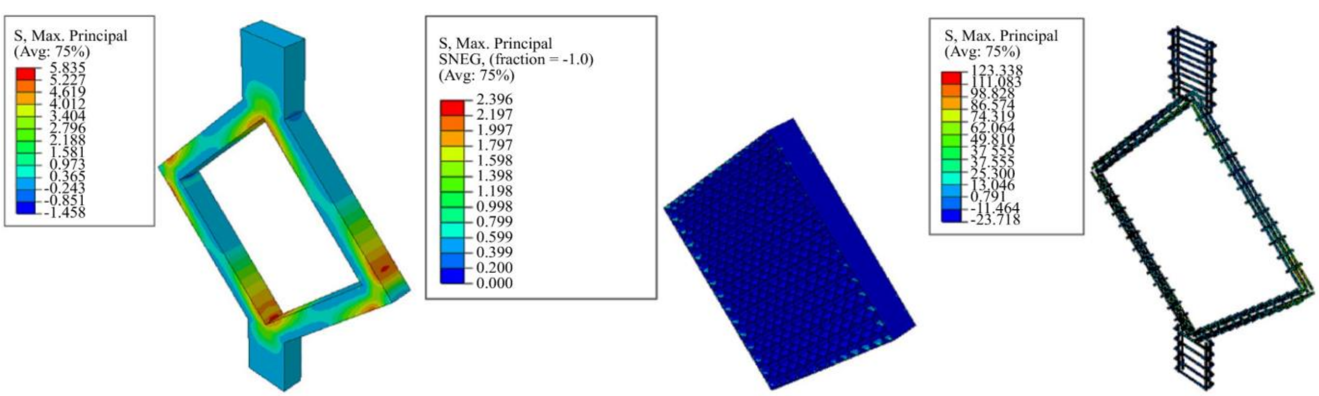


Fig. 16 Maximum principal stress of infilled RC frame using sandwich panel

5.2. Experimental Investigation

The observations obtained from experimental investigations were noted and illustrated as follows.

5.2.1. Effects of Temperature

The temperature has shown its impact on the performance of RC frames in terms of ultimate load-carrying capacity, displacement characteristics, and initial stiffness. The displacement was measured against its corresponding load capacity, shown in Fig. 17. In the case of a bare frame, an identical curve pattern was observed between the test and analytical results.

However, experimental models depict more load-carrying capacity than finite element analysis. The ultimate load capacity was increased by 4.20% for the bare frame structure in case of changes in temperature from high to room conditions.

Similarly, in the case of infilled frames using masonry and sandwich panels, the load-carrying capacity was increased by about 21.73 and 24.76%, respectively, with the changes in temperature from elevated to room conditions. However, in the case of deflection characteristics, elevated temperature depicts positive impacts on the behavior of RC infilled frames. Infilled frames using masonry and sandwich panels show 7.99 and 13.88%, respectively, larger deformation with the changes of temperature from room to elevated condition. The stiffness degradation behavior for bare and infilled frames under temperature fluctuations from room to elevated were shown in Fig. 18. The initial stiffness was reduced by 25.53% for bare frames structure in case of changes of temperature from room to elevated. Similarly, in the case of infilled frames using masonry and sandwich panels, the initial stiffness was reduced by about 39.19 and 52.81%, respectively, with the changes in temperature from room to elevated conditions.

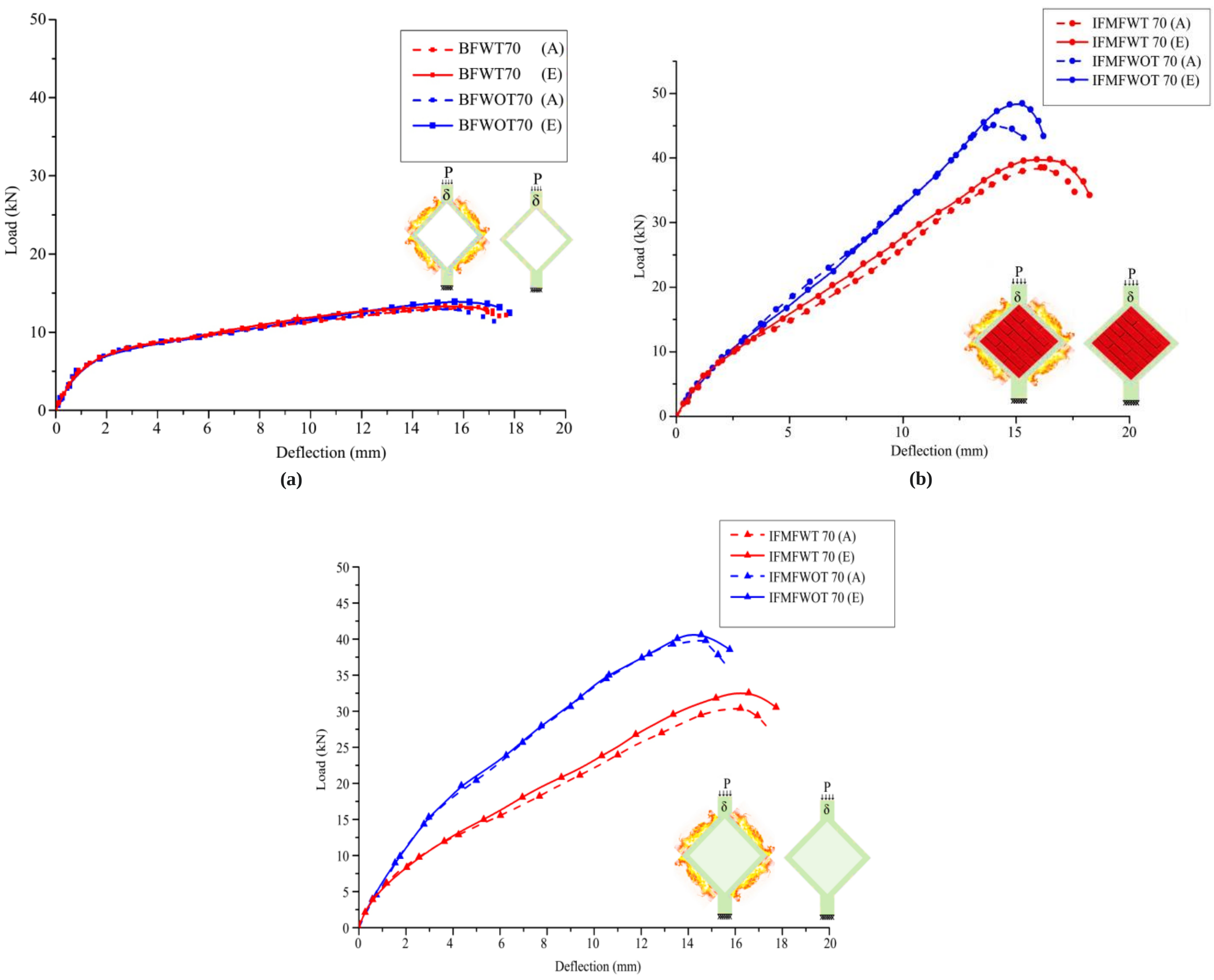


Fig. 17 Load-displacement behavior (a) Bare frame (b) Infilled masonry frame (c) Infilled frame using sandwich panel

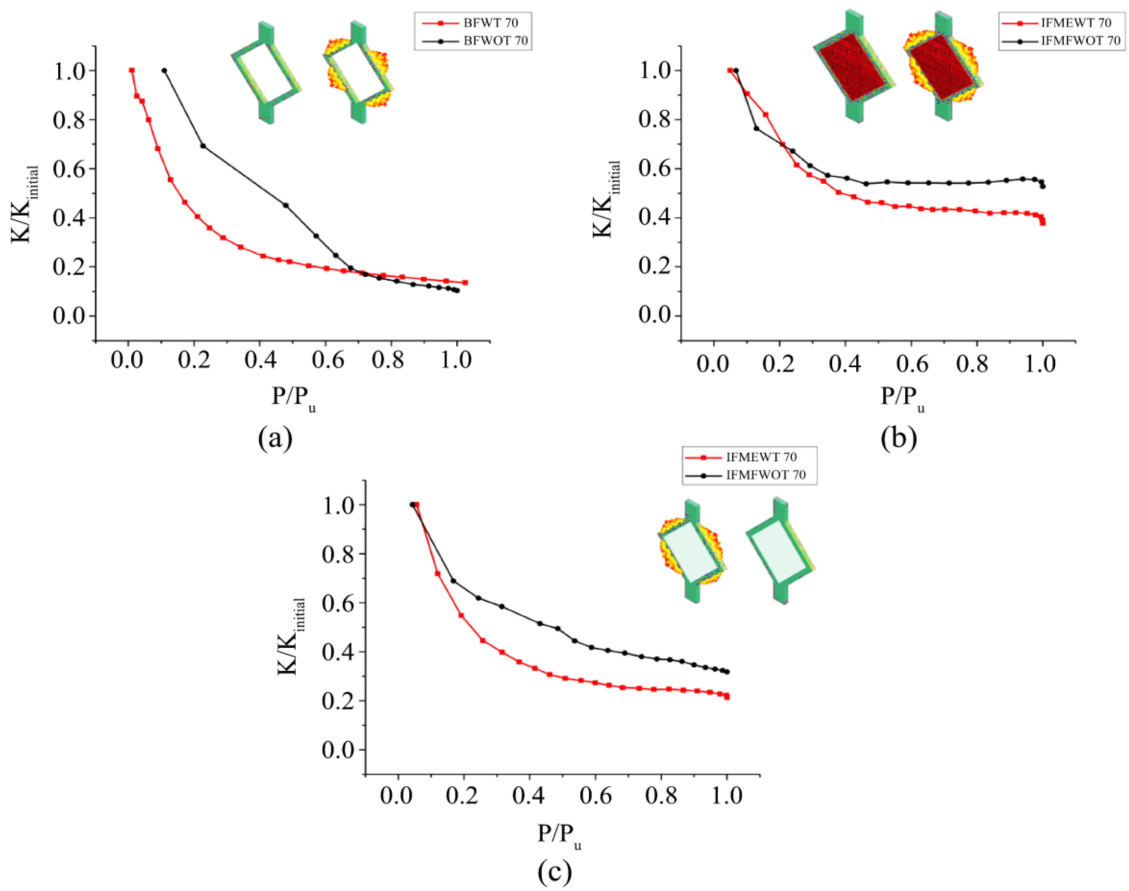


Fig. 18 Stiffness degradation (a) Bare frame (b) Infilled masonry frame (c) Infilled frame using sandwich panel

5.2.2. Effects of Infills

Types of infill materials were a crucial factor in making the structure stiffer and reducing the self-weight. It was observed from the research that the ultimate load-carrying capacity of infilled frames was depicted more compared to bare frame structure. In the case of room temperature, infilled frames using masonry and sandwich panels show 248.95 and 192.29%, respectively, more load-bearing capacity compared to bare frames.

However, in the case of elevated temperature, infilled frames using masonry and sandwich panels show 198.72 and 144.11%, respectively, more load-bearing capacity compared to bare frames. But compared to masonry infilled frames, infilled frames using sandwich panels depict 19.38 and 22.37%, respectively, more ultimate load capacity in case of room and elevated temperature conditions. In addition to this, in the case of stiffness characteristics, sandwich wall panels show better results compared to bare and masonry-infilled frames. The initial stiffness of the sandwich wall panel was increased by about 314.41 and 18.69%, respectively, compared to bare and masonry-infilled frames under room temperature. Similarly, in the case of elevated temperature, the sandwich wall panel depicts 240.43 and 8.11% higher stiffness compared to bare and masonry-infilled frames, respectively.

However, infilled frames using a sandwich panel with GFRP laminates depict 4.49% higher load-carrying capacity compared to an infilled frame using the sandwich panel.

5.3. Ultimate Strength and Failure Modes

The behavior of RC frames' structural element was illustrated in this section in terms of the loads corresponding to the formation of the initial crack, failure mode, and the ultimate load capacity. The obtained results from the test are listed in Table 5 and compared with the analytical values. The corresponding relative stiffness for masonry infilled frames was calculated using the relation proposed by researcher Stafford Smith, 1968 [25] illustrated in Equation.1

$$\lambda h = h \sqrt[4]{\frac{E_{it} \sin 2\theta}{4 E_C I_C h'}} \quad (1)$$

λh = Relative stiffness factor
λ = characteristic of infilled frame
Ei = Modulus of elasticity of infill
Ec = Modulus of elasticity of frame (material of column)
h = Height of storey, c/c of beams
h' = Height of infill
t = Thickness of infill
Ic = Second moment of area of column section
θ = slope of infill diagonal to horizontal angle of inclination of strut in radians

Table 5. Results of RC frames

Sl. No.	Specimen	Ultimate load (kN)		Displacement (mm)		Initial Stiffness (kN/mm)	Relative stiffness factor (λh)
		Test	FEA	Test	FEA		
1	BFWOT70	13.89	13.06	15.64	15.32	1.18	-
2	IFMFWOT70	48.47	45.10	15.26	13.99	4.12	3.23
3	IFSWFWOT70	40.60	39.84	14.55	14.47	4.89	-
4	BFWT70	13.33	13.04	15.29	16.31	0.94	-
5	IFMFWT70	39.82	38.55	16.48	16.08	2.96	-
6	IFSWFWT70	32.54	30.42	16.57	16.22	3.20	-
7	GFRPWIFSWFWT70	34	-	13.28	-	2.74	-

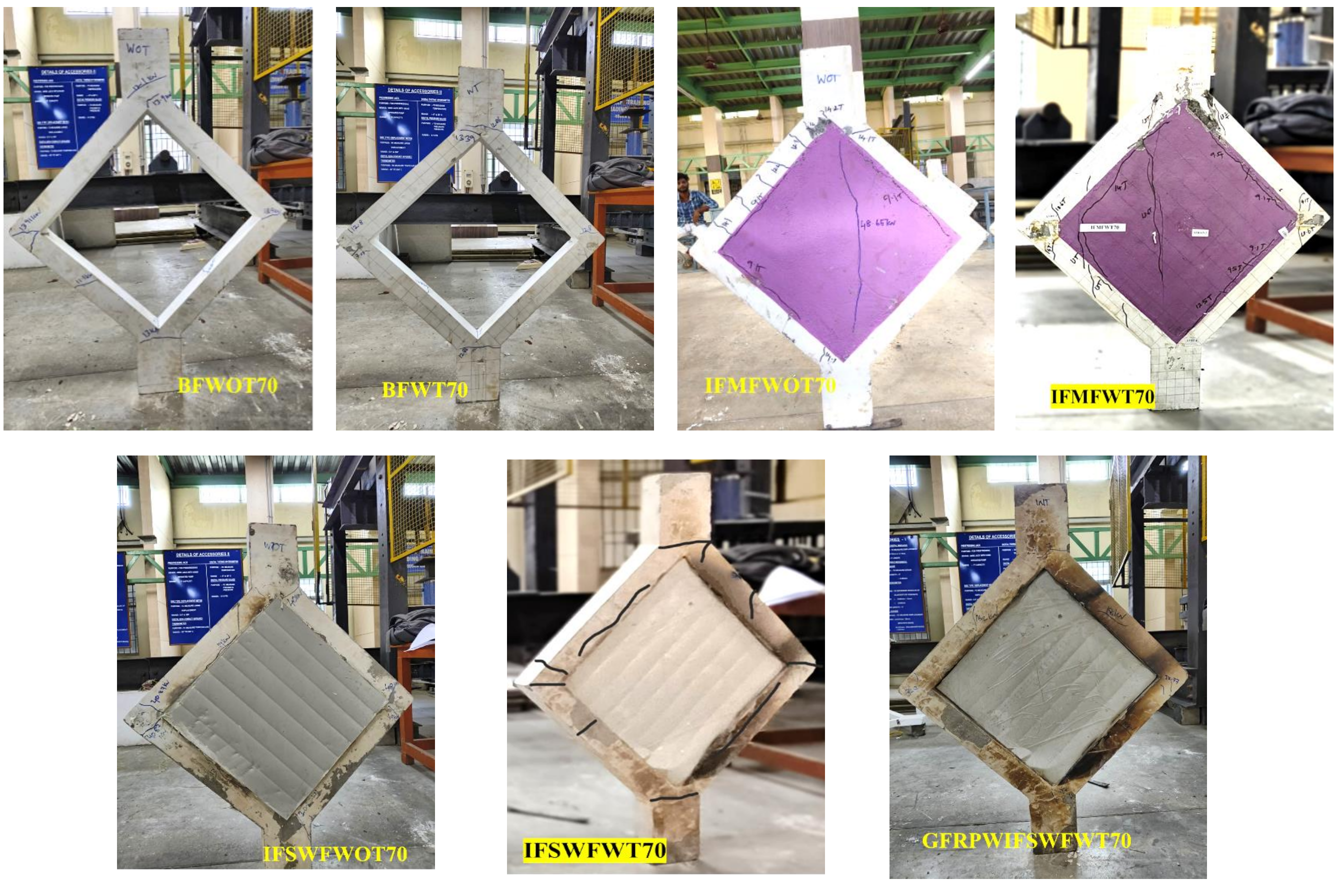


Fig. 19 Failure pattern of RC frames

During the load application, the initial crack on the surface of the frame was visually observed, and the corresponding displacement with the load was observed. Furthermore, the propagation of the cracks and the formation of new cracks were observed with the enhancement of loads. Two kinds of failure patterns, such as brittle and ductile, were identified. The brittle and ductile failure was classified depending on the distance of two consecutive cracks. The failure of masonry frames was in brittle mode, whereas the bare frames were failed ductile in nature. In addition to this, delamination was observed in the case of infilled frames using sandwich panels. Hence, GFRP lamination techniques were used to prevent the failure. The crack patterns of bare frames, infilled masonry frames, infilled frames using sandwich wall panels, and sandwich wall panels laminated using GFRP under temperature variations
were illustrated in Fig. 19.

6. Conclusion

Analytical simulation predicts the critical temperature was 380°C. The bare frame depicts 2.12 and 1.95% higher temperature capacity compared to infilled frames with masonry and sandwich panels, respectively. In addition to this, infilled frames using sandwich panels show 0.16% higher temperature capacity compared to masonry infilled frames, which was very minimal.

- The ultimate load-carrying capacity of infilled frames was reduced by about 16.99 and 30.96% in the case of masonry and sandwich panels, respectively, with the changes of temperature from room to elevated conditions. The maximum deflection of infilled frames was increased by about 14.93 and 12.09% in the case of masonry and sandwich panels, respectively, with the changes of temperature from room to elevated conditions.
- The experimental results show that ultimate load capacity was increased by 4.20% for bare frame structures in case of temperature changes from high to room conditions. Similarly, in the case of infilled frames using masonry and sandwich panels, the load-carrying capacity was increased by about 21.73 and 24.76%, respectively, with the changes in temperature from elevated to room conditions.
- In the case of deflection characteristics, elevated temperature depicts positive impacts on the behavior of RC infilled frames. Infilled frames using masonry and sandwich panels show 7.99 and 13.88%, respectively, larger deformation with the changes of temperature from room to elevated condition.
- The initial stiffness was reduced by 25.53% for the bare frame structure in case of changes in temperature from room to elevated. Similarly, in the case of infilled frames using masonry and sandwich panels, the initial stiffness was reduced by about 39.19 and 52.81%, respectively, with the changes in temperature from room to elevated conditions.
- Infilled frames using masonry and sandwich panels show 248.95 and 192.29%, respectively, more load-bearing capacity compared to bare frames under room temperature. But in the case of elevated temperature, infilled frames using masonry and sandwich panels show 198.72 and 144.11%, respectively, more load-bearing capacity compared to bare frames.
- Compared to masonry infilled frames, infilled frames using sandwich panels depict 19.38 and 22.37%, respectively, more ultimate load capacity under room and elevated temperatures.
- In the case of stiffness characteristics, sandwich wall panels show better results compared to bare and masonry-infilled frames. The initial stiffness of the sandwich wall panel was increased by about 314.41 and 18.69%, respectively, compared to bare and masonry-infilled frames under room temperature. Sandwich wall panel depicts 240.43 and 8.11% higher stiffness compared to bare and masonry infilled frames, respectively, under elevated temperatures.
- Infilled frames using sandwich panels with GFRP laminates depict 4.49% higher load-carrying capacity compared to infilled frames using sandwich panels.

Author Contributions

SAR: conceptualization, methodology, Software, investigation, Validation, Formal analysis, writing, and editing the draft.

KSS: conceptualization, Supervision, investigation, validation, editing, and review of the draft.

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