International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

Behavior of Steel Frame with and without Horizontally Folded Ferrocement Panel with Window Opening Under In-Plane Lateral Load

G Ravitej[1], Srinivasrao Kulkarni[2], Dr. N Jayaramappa[3]

[1]*PG(M.Tech) Student, Dept. of Civil Engineering, UVCE, Bengaluru*
[2]*Research Scholar, Dept. of Civil Engineering, Sri Siddhartha Academy of Higher Education, Tumkur.*
[3]*Professor, Dept. of Civil Engineering, UVCE, Bengaluru, Karnataka*

Abstract - *Bare steel frames exhibit low lateral stiffness and experience large displacements under lateral loads. This experimental study examines the effectiveness of horizontally folded ferrocement panels with window openings as infills for improving the lateral performance of steel frames. Scaled-down, single-bay two-storey steel frame specimens, including a bare frame and a frame infilled with horizontally folded ferrocement panels, were subjected to in-plane lateral loading. The ferrocement panels were cast using thin cement mortar reinforced with chicken mesh and mild steel skeletal reinforcement, with window openings provided to represent practical conditions. Lateral displacements were measured at each storey level. The results show that frames infilled with horizontally folded ferrocement panels exhibit significantly higher stiffness and load-carrying capacity with reduced storey displacements compared to bare frames. The folded configuration improves load distribution and deformation control, demonstrating that horizontally folded ferrocement panels are an efficient and lightweight infill solution for steel frame structures under lateral loads.*

Keywords*:* Steel frames; Ferrocement infill; horizontally folded panels; Window openings; Lateral loading; Story displacement

1. INTRODUCTION

Ferrocement is a versatile building material which is made up with the blending of cement mortar, wire mesh and steel reinforcement to create thin, strong curved structures like boats, roofs, and tanks. It can be used in various construction like building construction, pipes, irrigation purposes, sanitation. There is no need of high skilled labours. Ferrocement offers high flexibility for complex shapes while using less cement and steel. As its thickness generally range from 25mm to 50mm it is lightweight and offers high tensile strength, flexural capacity, impact resistance and is durable enough to resist cracks and corrosion when compared to standard concrete.

The ACI committee defines ferrocement as "a composite structural material comprising thin sections consisting of cement mortar reinforced by a number of closely spaced layers of steel wire mesh".

Steel frames are widely used in modern construction due to their high strength-to-weight ratio, flexibility in architectural designs and speed of construction. If only bare steel frame is considered it exhibits low lateral stiffness making them vulnerable to lateral loads like seismic loads and wind loads. To overcome this aspect masonry infill walls, concrete infills are used which add more dead load compared to Ferro cement infill wall panels.

In recent years, folded plate structures have gained more attention due to their inherent stiffness and ability to span longer distances with less material consumption. The presence of windows and doors is unavoidable in residential and commercial buildings which influences stress distribution, cracking pattern and overall lateral performance of walls.

This study aims to experimentally investigate the behaviour of steel frames with and without horizontally folded ferrocement panels with window openings when subjected to lateral load.

2. MATERIALS AND MIX PROPORTIONS

2.1 Materials

For this experimental investigation Ordinary Portland Cement (43 Grade), M-sand as fine aggregate, fly ash, GGBS, mild steel reinforcement bars, chicken mesh, super plasticizer, potable water was used. The cementitious materials were selected to ensure adequate strength, workability, and durability of the ferrocement panels.

Mild steel bars od 6mm were used as skeletal reinforcement while chicken mesh of 0.4mm wire diameter were used as primary reinforcement due to its high surface area and effective crack control. To improve workability of mortar superplasticizers were used.

2.2 Mix Proportions

A mortar mix proportion of 1:3.3 (cementitious material to fine aggregate) was adopted. Cement was partially replaced with Fly Ash, and GGBS.

Mix design adopted was:

Cement (70%) + Fly ash (10%) + GGBS (20%) + M Sand + SP 0.5% of cementitious content.

3. FRAME AND PANEL CONFIGARATIONS

Ferro cement panels of 30mm thickness were casted in horizontally folded configuration. Dimensions of frame and panels was scaled down to 1:3.3. Considering 3m x 3m wall with window openings 0.9m x 1.8m with sill level at 0.6m. Panels of dimension 1m x 1m with window opening of 0.3m x 0.6m with sill level at 0.2m was casted accounting to 18% of panel area. Panels were submerged in water and cured for 28 days.

ISLC 75 channel sections of Fe250 grade steel was used for frame. Precast ferrocement panels were infilled within the frames to behave as monolithically under loading. Below figure shows the frame infilled with ferrocement panel.

Fig-1: Frame infilled with ferrocement panel

4. TEST SETUP AND INSTRUMENTATION

The experimental investigation on behaviour of steel frames infilled with horizontally folded ferrocement panels with openings under lateral loads.

For loading frame two ISMC 25080 x 10mm channel sections placed 1500mm apart with total height 3700mm were selected for vertical members and two ISLB 12575 x 6mm having length 1500mm placed 100mm apart were selected for horizontal members. Base plate 1500mm length, 300mm wide, 12mm thick connected bottom of these I sections and acted as base to frame specimens.
Apparatus used:

- 50kN capacity Lateral loading frame (with facility to apply to horizontal load) fabricated.
- 2 Hydraulic jacks of 100kN capacity of 0.5 KN least measurable values.
- Three magnetic base dial gauges of least count 0.01 mm to measure lateral sway.

The frame specimen with ferrocement panel with opening was placed in loading frame. Two load points was marked at first and second floor levels.

5. LOADING PROCEDURE

A custom fabricated loading frame of 50 KN capacity was used to apply in-plane-lateral loads. To simulate fixed end conditions steel frame was rigidly fixed at the base. Lateral load was applied at two levels marked at floor levels were applied with the help of hydraulic jacks to replicate seismic type loading.

Magnetic base dial gauges of least count 0.01mm were placed at every storey level to measure lateral displacements. Gradual load increments were applied at two level and jacks were controlled by individual console. For load application hand operated oil pumps were used. The jacks were placed horizontally in line with the centre of beams of the specimen. Frame specimen was painted to ensure visibility of cracks during testing. The static lateral loads simulating earthquake loads in the ratio 1:2 respectively at levels of first and second floor with increment of 2.5 KN.

6. RESULT AND DISCUSSION

6.1 Testing of Bare Frame Specimen

The 2D single bay two storey bare frame specimen was prepared such that it could be easily removed from casting place and lifted. The specimen was transported to loading frame with the help of overhead crane available in laboratory. Two load points were marked at first and second floor and hydraulic jacks were placed at those points. The frame was aligned in loading frame such that it was erect with no tilt about horizontal or vertical plane. Using Arc welding, the column base and plinth beam were med to have fixed end condition. The loading jacks were ready and scale initialized to zero. Magnetic base dial gauge of L.C. 0.01mm were fixed to the loading frame to measure the horizontal displacement (sway) at each storey level and the initial readings were set to zero. The loads were applied at first and second storey in the ratio 1:2 and increment of 2.5KN.

At every increment of load, frame members were closely examined for displacement. The maximum load recorded was 27.5kN. Corresponding displacement of top storey was 62.3mm and of bottom storey was 35.67mm.

Following table gives the readings recorded during the test on steel frame specimen.

Table-1: Storey Displacement of Bare Frame Specimen

SL. NO	Load			Displacement	
	P1 (KN) Top	P2 (KN) Bottom	Total (KN)	D1 (mm) TOP	D2 (mm) BOTTOM
1	0	0	0	0	0
2	2.5	0	2.5	9.31	7.34
3	5	2.5	7.5	24.66	12.46
4	7.5	5	12.5	33.67	18.64
5	10	7.5	17.5	44.41	22.19
6	12.5	10	22.5	56.03	28.7
7	15	12.5	27.5	68.51	36.82

The following graph shows deflection of top and bottom storey of the frame to the total load applied on the frame.

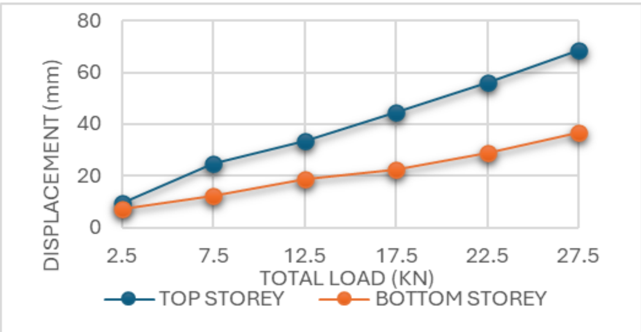

Chart-1 Graph Showing Deflection of Bare Frame

6.2 Testing of Frame Specimen Infilled with Ferrocement Panels with Window Opening

The 2D single bay two storey frames infilled with horizontally folded ferrocement panel with window opening was prepared such that it could be easily removed from casting place and lifted. The specimen was transported to loading frame with the help of overhead crane available in laboratory. Two load points were marked at first and second floor and hydraulic jacks were placed at those points. The frame was aligned in loading frame such that it was erect with no tilt about horizontal or vertical plane. Using Arc welding, the column base and plinth beam were med to have fixed end condition. The loading jacks were ready and scale initialized to zero. Magnetic base dial gauge of L.C. 0.01mm were fixed to the loading frame to measure the horizontal displacement (sway) at each storey level and the initial readings were set to zero. The loads were applied at first and second storey in the ratio 1:2 and increment of 2.5KN.

At every increment of load, frame members were closely examined for displacement. The maximum load recorded was 52.5KN. Corresponding displacement of top storey was 82.9mm and of bottom storey was 41.62mm

.

Following table gives the readings recorded during the test on steel frame specimen infilled with ferrocement panel.

Table-2 Storey Displacement of Infilled Frame Specimen

Sl No	Load			Displacement	
	P1 (KN) TOP	P2 (KN) BOTTOM	Total (KN)	D1 (mm) TOP	D2 (mm) BOTTOM
1	0	0	0	0	0
2	2.5	0	2.5	2.795	1.565
3	5	2.5	7.5	5.24	3.005
4	7.5	5	12.5	8.795	4.88
5	10	7.5	17.5	11.105	6.74
6	12.5	10	22.5	15.995	9.485
7	15	12.5	27.5	20.705	10.76
8	17.5	15	32.5	28.265	14.24
9	20	17.5	37.5	31.715	17.795
10	22.5	20	42.5	37.01	20.165
11	25	22.5	47.5	50.885	26.345
12	27.5	25	52.5	61.925	32.84

The following graph shows total load and its corresponding deflection of top storey and bottom storey.

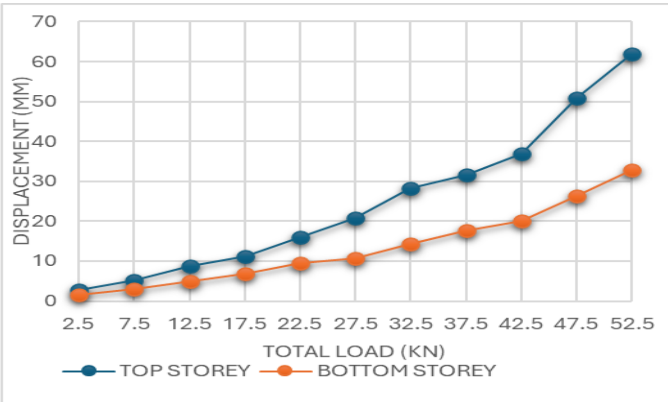

Chart-2: Graph Showing Deflection of Infilled Frame

The following graphs represent load and deflection of top storey of a bare frame specimen and frame infilled with ferrocement panel specimen.

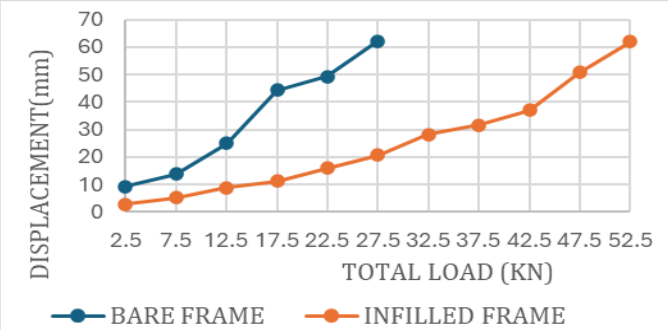

Chart-3: Graph Showing Displacement of Top Storey

The following graphs represent load and deflection of bottom storey of a bare frame specimen and frame infilled with ferrocement panel specimen

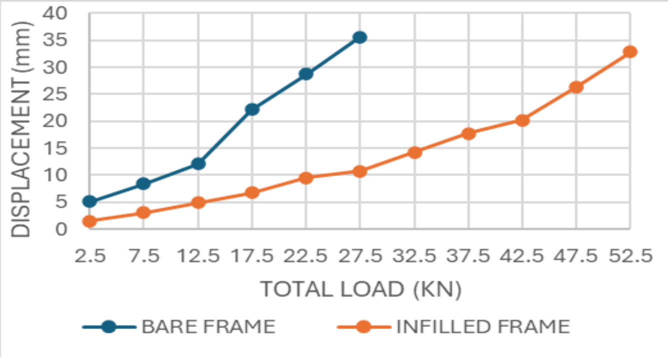

Chart-4 Graph Showing Deflection of Bottom Storey

7. CONCLUSIONS

- Since Steel frames are ductile in nature no cracks or failure occurred when In-plane lateral load was applied.
- Studying precast horizontally folded ferrocement panels with window openings helps in understanding its behavior when lateral loads are applied.
- Adding infills with window openings significantly increases overall stiffness of the frame by gradual decrease in displacement.
- In Bare frame, the stiffness is very least, there was a deflection of 62.3 mm (Top storey) when the load is 27.5KN.
- In Horizontally Folded Ferrocement with Window Openings as infill, top storey deflection was 61.9 mm, where the load was 52.5KN.
- Horizontally folded ferrocement with Window Openings as infill, bottom storey deflection was 32.84 mm, where the load was 52.5KN.
- Though we have tested for higher loads on infilled frames which has more stiffness when compared to bare frames.
- The Infilled frame specimens considered are stiffer and can withstand higher load than bare frame specimen. Frame with Horizontally folded Ferrocement infill specimen has higher stiffness, strength and deformation capacity.
- From the above, it can be seen that the performance of infilled frame with horizontally folded ferrocement panel with window opening is much better than that of bare frame.
- Infilled frame with horizontally folded ferrocement infill can be said to be good option in constructions.

REFERENCES

[1] IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi.

[2] IS 10262:2019, Concrete Mix Proportioning – Guidelines, Bureau of Indian Standards, New Delhi.

[3] N. Jayaramappa Dr. H. Sharada Bai "Behaviour of Ferrocement Panels Subjected to Inplane Lateral Load" Volume: 6 Issue: 6 June 2016 ISSN - 2249-555X IF: 3.919 IC Value: 74.50

[4] Somasekhar, N. Jayaramappa, C. Venkata Sai Nagendra "Comparative Study on Folded Ferrocement and Plain Ferrocement Panels Subjected to Axial Loading" 57(6) December 2021

[5] Mohamad N. Mahmood & Sura A. Majeed (2009) "Flexural Behavior of Flat and Folded Ferrocement Panels" Al-Rafidain Engineering Volume: 17.

[6] Mariam Farouk Ghazy, Metwally Abd Allah. Abd Elaty, and Ahmed Abo Elkhair "Flexural behaviour of geopolymer ferrocement plates and folded panels." ICASGE'23 6-9 March 2023, Hurghada, Egypt.

[7] S. Kaliraj.S, P. Madasamy, and S. Dharmar, "Impact behaviourof geopolymer Ferro cement trough panel," SSRG International Journal of Civil Engineering, pp. 496-500,2017

[8] Malathy Ramlingam, Poornima Mohan, Parthiban Kathirvel and Gunasekaran Murali "Flexural Performance and Microstructural Studies of Trough-Shaped Geopolymer Ferro cement Panels", Published by MDPI.

[9] Sirajul Muneer. M & Dr.M. Neelamegam (2016), "Structural Behavior of Ferro cement Composite Wall Panels", International Journal of Innovative Research in Science, Engineering and Technology Vol 5, Issue 6, pg. No-10442-10447.