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

Experimental Investigation on Steel Frames Infilled with Flat Ferrocement Panels with and without Openings Subjected to In-Plane Lateral Loads

Ajith G O[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–*This paper presents an experimental investigation on the behavior of a 2D single bay two story steel frame with flat ferrocement infill with and without openings. Steel frame with flat ferrocement infill with and without openings is casted in the laboratory to a scale down of 1:3.3; the dimension of frame is 2.3 m height and 1m width. Channel Section ISLC 75 is used as beams and columns for the frame. The proposed model is subjected to lateral load at each storey level and their performance was assessed based on load carrying capacity and deflection. Experimental results are tabulated, compared with each other and conclusions are drawn.*

Keywords: Lateral Loading Frame, 2D Steel Bare Frame, Behavior of Bare Frame

1. INTRODUCTION

Ferrocement is not an unknown material now a days, ferrocement is multifaceted material made up of wire mesh, sand, water and cement which is different from reinforced cement concrete. Ferrocement has different quality of strength and unique serviceability. In this type of construction not required skilled labor. Ferrocement is not only used in building construction, even it can be used in water supply section like pipe, irrigation purposes, sanitation etc. various studies shows that ferrocement has good seismic resistant. Ferrocement is a very thin layer of mortar, covering reinforcement material such as steel bar, steel wire mesh. The thickness of ferrocement generally ranges to 25 mm to 50 mm. Ferrocement is an environment friendly sound technology and possesses excellent unique properties such as good tensile strength, improved toughness, water tightness, lightness, fire resistance, resistance to cracking and cost, time and material effective construction technology. The following definition was adopted by the ACI Committee "Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials"
This study aims to experimentally investigate the behaviour of steel frames with and without flat ferrocement panels with window openings when subjected to lateral load.

2. Literature Review

H. A. Moghaddam 2004, this paper focuses on the structural performance of masonry infilled steel frames, particularly under lateral loads and also to investigate the effects of masonry infills on the strength and stiffness of steel frames and to explore various repair and retrofit techniques that can enhance their performance during seismic events. The conclusion driven is frames are significantly affected by the presence of infills, which enhance their lateral load capacity. Proper design and reinforcement strategies are essential to mitigate the risk of failure, particularly in the compressive corners of infill panels. And, it has been shown that the modulus of elasticity of the brick work material Ein obtained from the couplet tests grossly underestimates the overall stiffness of an infilled frame. An analytical approach for evaluation of a more accurate value for Ein has been put forward. The repair techniques, such as the application of concrete covers, are effective in restoring and enhancing the strength of damaged infill panels.

N.Jayaramappa 2016, this study is aimed at determining the behaviour of ferrocement panel elements under lateral load. Sample size used were 1000 mm X 2000 mm X 30 mm size FERROCEMENT elements for lateral load test containing single, two, three and four layers of hexagonal chicken mesh and skeletal reinforcement were cast using cement mortar 1:3 (w/c= 0.5) and cured for 28 days. The elements fixed at base were progressively tested under in- plane lateral load applied at top up to failure and their behaviors are compared. The results obtained were,

The load-deformation behavior of Ferrocement panel acting as cantilever can be idealized to consist of three zones, Elastic zone, elastoplastic zone and plastic zone. The ultimate load, ultimate lateral displacement, modulus of elasticity and ductility of ferrocement panels subjected to Inplane lateral load increases with increase in volume fraction. As Vf increases by 1.52 times, the ultimate load and ultimate displacement increase by 1.23 and 1.64 times respectively. The modulus of elasticity of ferrocement panels acting as cantilever increase 1.32 times with increase in volume fraction of 1.52 times. The ductility of FERROCEMENT panels

subjected to lateral loads increase 1.52 times with an increase in volume fraction of 1.52 times.

Somasekhar 2020, this researcher has explained the performance of plain and folded ferrocement panels under axial stress and to assess their load bearing capacity. Both the panels were cast and tested using the same dimensions and materials, with a length of around 3000 mm, a depth of 2700 mm, and a thickness of 30 mm. For both panels, a 1: 3 cement mortar with a water cement ratio of 0.45 is employed, double layered chicken mesh and HYSD 8mm bars are positioned at 200mm c/c. Two-point loads were gradually applied throughout the span of the panels, and the resulting deflection was measured for each load increment. The following are the conclusions drawn from this study, the load taken by folded ferrocement plates is approximately 5 times that of plain ferrocement plates, according to the results of the experimental test on ferrocement plates. When compared to plain plates, the deflection recorded in the experimental test for folded plates is approximately 55% lower. When these experimental data are compared to analytical results, it is found that the load bearing capacity of plain and folded ferrocement plates is improved by 50% and 25%, respectively.

Siddhesh Nivate 2023, this paper investigates the durability characteristics of Ferrocement, a composite material made from a thin layer of cement mortar reinforced with multiple layers of wire mesh. It also investigates how well Ferrocement can withstand various environmental conditions, particularly focusing on water penetration, sorptivity (the ability to absorb water), and resistance to sulphate attacks. The materials casted were Cubes and cylinders using a mortar mix with a ratio of 1:3 and a water-cement ratio of 0.40. The specimens were cured for different periods (28, 56, and 90 days). The results found that proper curing significantly enhances the durability of Ferrocement. The study suggests that the use of additives (like fly ash or silica fume) could further improve the performance of Ferrocement against environmental challenges. They recommend further research into long-term anti-corrosion methods to protect the reinforcing mesh from water and salt penetration.

3. MATERIALS AND MIX PROPORTIONS

The following materials were used for the experimental investigation and were tested in the laboratory as per relevant IS codes.

- Cement
- Fine aggregate
- Fly Ash
- GGBS (Ground Granulated Blast Furnace Slag)
- Water
- Chicken Wire Mesh
- Reinforcement Bars (6mm diameter)
- Chemical Admixture

A mortar mix proportion of 1:3 (cementitious material to fine aggregate) was adopted. Cement was partially replaced with Fly Ash, and GGBS.

Table -1: Parameters of Steel Frame with Infills

Parameter	Frame
Type of Frame	2D
No. of Bays	1
No. of Storey	2
Bay Length	1m
Storey Height	1m
Structural Material	Steel
Beam	ISLC 75
Column	ISLC 75
Wall Panel	Flat Ferrocement (30mm thick)
Mortar Mix for Ferrocement	Cement (70%) + GGBS (20%) + Fly Ash (10%) + M-Sand (3 Parts) + SP (0.5% of Cementitious Content)
Steel Reinforcement	6mm Dia Bars
Chicken Mesh	0.4 mm Dia (Hexagonal)

4. EXPERIMENTAL INVESTIGATION ON INFILLED FRAME WITH FERROCEMENT ELEMENTS AS INFILL

The present chapter deals with the details of the experimental investigation taken up to understand the behavior of Steel Sections infilled frames having Ferrocement infills in comparison to Steel infilled frame having Horizontally Folded Ferrocement infill and Steel bare frame, all subjected to progressive lateral load equivalent to seismic load. The details of casting and testing of the model frames, results obtained and their discussions are presented.

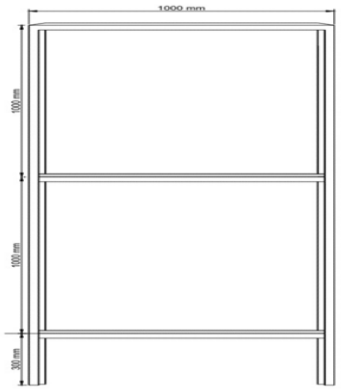

Fig-1: AutoCAD Drawing of Steel Bare Frame (ISLC 75)

Fig-2: Bar Bending of Panels.

Fig-3: Casting of ferrocement panels.

5. TEST SETUP AND INSTRUMENTATION

The experimental investigation on behaviour of steel frames infilled with flat ferrocement panels with and without 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 panels were placed in loading frame. Two load points was marked at first and second floor levels.

6. LOADING PROCEDURE

A custom fabricated loading frame of 50KN 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.

7. RESULT AND DISCUSSION

7.1 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 –2: 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.

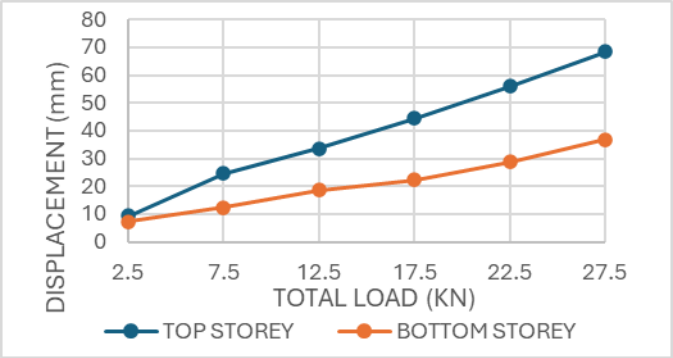

Chart-1: Graph Showing Deflection of Bare Frame

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

The 2D single bay two storey frames in filled with flat Ferro cement 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 –3: Storey Displacement of Infilled Frame Specimen with opening.

Sl No	Load			Displacement	
	P1 (kN) Top	P2 (kN) Bottom	Total (kN)	D1 (mm)	D2 (mm)
1	0	0	0	0	0
2	2.5	0	2.5	10.13	5.69
3	5	2.5	7.5	16.80	8.01
4	7.5	5	12.5	26.35	12.84
5	10	7.5	17.5	34.12	15.05
6	12.5	10	22.5	48.65	24.60
7	15	12.5	27.5	54.38	29.27
8	17.5	15	32.5	69.23	41.19
9	20	17.5	37.5	76.56	46.90
10	22.5	20	42.5	81.34	49.57
11	25	22.5	47.5	91.23	58.31
12	27.5	25	52.5	98.56	64.01

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

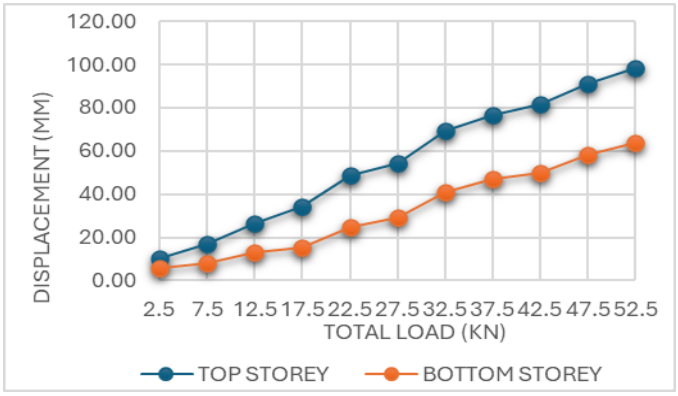

Chart-.2: Graph Showing Deflection of Infilled Frame with opening

7.3 Testing of Frame Specimen Infilled with Ferrocement Panels without Window Opening

Table -4: Storey Displacement of Infilled Frame Specimen without opening

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	6.36	3.82
3	5	2.5	7.5	10.17	5.17

4	7.5	5	12.5	15.63	7.91
5	10	7.5	17.5	20.07	9.17
6	12.5	10	22.5	28.37	14.63
7	15	12.5	27.5	34.51	19.21
8	17.5	15	32.5	40.13	24.11
9	20	17.5	37.5	44.32	27.37

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

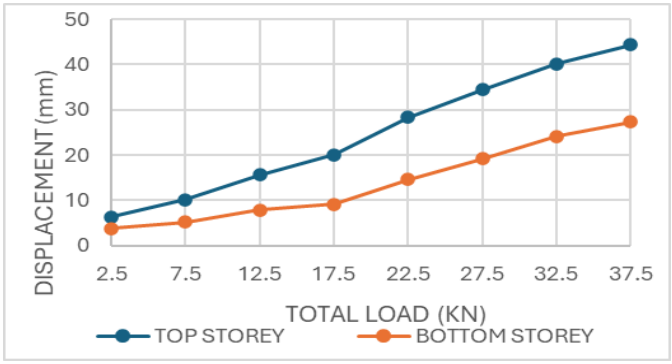

Chart -3: Graph Showing Deflection of infilled Frame without opening

The following graphs represent load and deflection of top storey of a bare frame specimen, flat ferrocement panel with and without opening specimens.

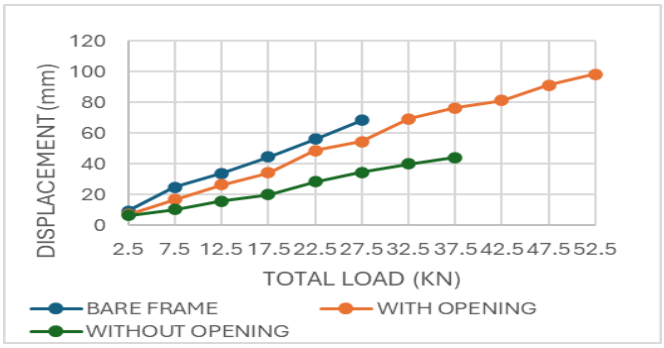

Chart -4: Graph Showing Deflection of Top Storey

The following graphs represents load and deflection of Bottom storey of a bare frame specimen, flat ferrocement panel with and without opening specimens

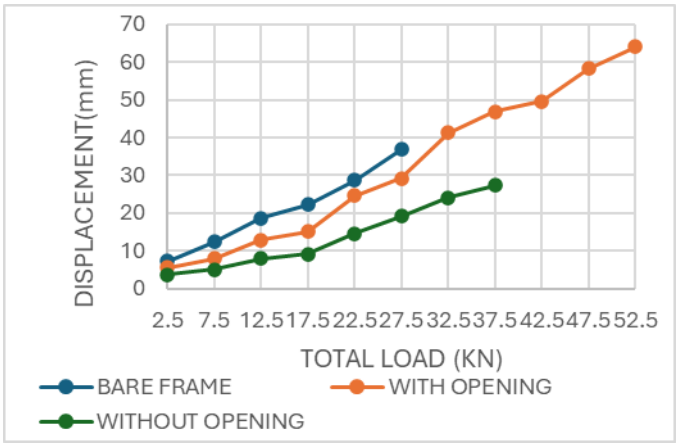

Chart -5: Graph Showing Deflection of Bottom Storey of Specimen

7. CONCLUSIONS

- Since Steel frames are ductile in nature no cracks or failure occurred when In-plane lateral load was applied.
- Since walls in a building are casted with and without openings and are unavoidable, both are considered for this project.
- Adding infills with window openings significantly increases overall stiffness of the frame by gradual decrease in displacement compared to bare frame
- 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 Flat Ferrocement panel with Window Openings as infill, top storey deflection was 98.56 mm, where the load was 52.5KN.
- In flat ferrocement panel with Window Openings as infill, bottom storey deflection was 64.01 mm, where the load was 52.5KN.
- In Flat Ferrocement panel without Window Openings as infill, top storey deflection was 44.32 mm, where the load was 52.5KN
- In flat ferrocement panel without Window Openings as infill, bottom storey deflection was 27.37 mm, where the load was 52.5KN
- Though we have tested for higher loads on infilled frames which have more stiffness when compared to bare frames.
- The Infilled frame specimens considered are stiffer and withstand higher load than bare frame specimen. Frame with Flat Ferrocement panel without opening as infill specimen has higher stiffness, strength and deformation capacity than frame with flat ferrocement panel with opening as infill specimen as per the experimental study.
- From the above, it can be seen that the performance of infilled frame with flat ferrocement panel without window opening is much better than that of both bare

frame and frame with flat ferrocement panel with opening.

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.