INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

OPEN ACCESS

Received: 07-07-2022

Accepted: 01-09-2022

Published: 14-10-2022

Citation: Pradeep AR, Rangaraj C, Jayaramappa N (2022) Structural Behavior of steel frame Infilled with Ferrocement Precast Panel S ubjected to Lateral Load. Indian Journal of Science and Technology 15(38): 1941-1948. https://doi.org/10.17485/IJST/v15i38.1266

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Structural Behavior of steel frame Infilled with Ferrocement Precast Panel S ubjected to Lateral Load

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Abstract

Background: When a severe earthquake ground motion hits the structure even if it doesn't collapse it may undergoes inelastic deformations. Steel structure infilled with precast panels becomes less efficient when subjected to large lateral loads like strong wind and earthquake. Hence assessment of actual performance of steel frames provided with infills in the event of earthquake is essential. **Methods**: In the current study, a prototype model of steel frame size 4m x4m bay & 4m height with G+2 story is scaled down and subjected to lateral seismic load by conducting shake table test to assess modal frequencies, the same structure is modelled in Hypermesh and analyzed in Nastran, ETABS software. The results obtained are validated for a 16X16m bay of 4m height commercial complex of G+9 Multi-storeyed structure infilled with Ferrocement Precast panels analysed in ETABS software for base shear, response spectrum and pushover analysis to assess the performance of the structure. **Findings**: The frequency from modal analysis was found to be 45.21 Hz, for G+2 storied model in ETABS, values obtained for frequency, base shear, performance point of the structure are in appreciable. **Novelty**: As per the traditional earthquake design methods, structures are designed for less forces than maximum considered for earthquake. The overall performance of the structure is found to be safe even infilled with Ferrocement precast panels. **Advantages**: Ferrocement panels as infills has benefit as they are slender from structural point of view. Compared with steel bare frame dynamic behavior of bare steel frame which is infilled with Ferrocement precast panel subjected to lateral loads is high that helps in assessing the damage in the event of an earthquake in critical zone V.

Keywords: Infill; Ferrocement precast panels; Pushover Analysis; Performance point; Response spectrum

1 Introduction

In recent days design and structural evaluation of the building systems subjected to lateral loads plays an important role. RCC and steel structures are constructed with various types of infills [1].Precast Infilled panels are more often used for partitioning and covering building areas such as walls [2].Steel frames infilled with precast panels are most widely used forms of multi-story commercial construction the masonry walls are constructed after the basic frame work of beams, columns and slabs have gained sufficient strength. Various types of infills are used in which Ferrocement precast infills play a pivotal role these days in buildings as infilled wall [3]. The internal forces developed depend on the originating forces which depend on the lateral strength and deformability criteria of the constituent member elements [4]. Design forces depend upon the accuracy of the method employed in their analytical determination. Efforts are being made by researchers to develop more efficient structural system strong enough to resist against lateral loads.

In the current work the behavior of steel frame infilled with Ferrocement precast panel is studied on a G+2 story 4X4 m bay with story height 4m is analyses both experimentally and analytically [1].An attempt has been made in this research towards analytical solution. Analysis is carried out using ETABS software for the G+9 storied 16x16m and 4m story height [1].Steel frames with Ferrocement Precast panel infill employed to assess the seismic behavior of the structure [5]. The amount and location of infill panels greatly affect the natural frequency of the structural system the information of plastic hinges, Performance point and response of the structure can be analysed and the pretended results may provide the possibility of damages on the structures [4].

2 Objectives

The basic objective of the study is to analyse the behaviour of steel structure with Ferrocement precast panel infilled all around the four sides of the steel structure under seismic loading and to experimentally compare the results by shake table test and Hypermesh model in Nastran and ETABS software's.

- To assess the suitability of the Beams, columns sections for a G+2 and G+9 storied building.
- To evaluate the performance of Steel bare frame infilled with Ferrocement precast panel under seismic loading for the scaled down prototype.
- To calculate modal frequencies and time periods of the infilled framed steel structure.
- To assess the performance of the infilled structure using pushover analysis and response spectrum method.

3 Methodology

Several methods of seismic analysis were adopted the below figure shows the seismic method of analysis and it is analyzed using IS1893 2002 and 2016 IS codes .

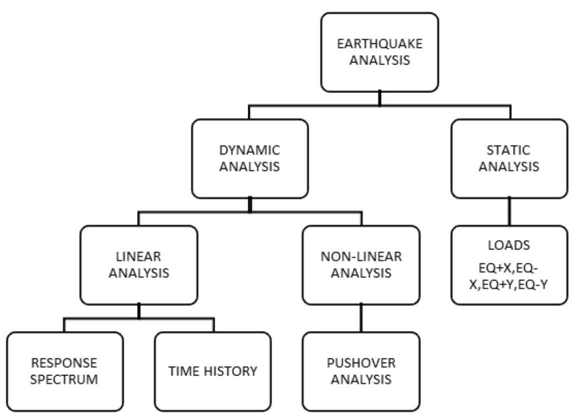

Fig 1. Seismic analysis methods

A detailed literature review is carried out based on the objective of the study. A prototype frame of G+2 story is considered which is of 4x4m bay with a story height of 4m which is modelled in ETABS and a particular frame is scaled down to 1:1 scale to suitably to conduct shake table test to carry seismic analysis. The experimentation gives the modal frequencies for the suitable excitation. The same model is modelled in Hypermesh software and analysed in Nastran, ETABS software's. Results obtained are validated to the G+9 story 16X16m 4x4 bayed model with 4m height commercial building infilled with Ferrocement precast panels for all stories modelled in ETABS which is in earthquake zone V of medium soil [5]. The seismic, response spectrum analysis, steel design check ,Base shear, story drift is carried out using ETABS software and conclusions are drawn on the basis of the behavior After the analysis is completed [1], hinge status, Capacity spectrum curve and performance point is obtained.

Table 1. Structural details of prototype

Particulars	Value	Particulars	Value
Number of stories ISMC400 + 12mm flats columns	G+2	Number of stories ISWB 200 + 12mm flats Beams	G+9
Each Storey height	4m	Density for slab of RC panel	25kN/m^3
Number of bays in x -y direction	4m	Density of steel	78.5kN/m^3
Total height of the building	40m	Density of precast panel infill	24 kg/m^3
Bay length	4m c/c	Thickness of the wall precast panel infill	0.050 m
Importance factor	1	Seismic zone	v
Overall plan	16X16m	Soil profile type	II
For G+2 story scaled down model -2mm flat plate for entire beam and columns as I section fabrication Bricks were suitably scaled down.			

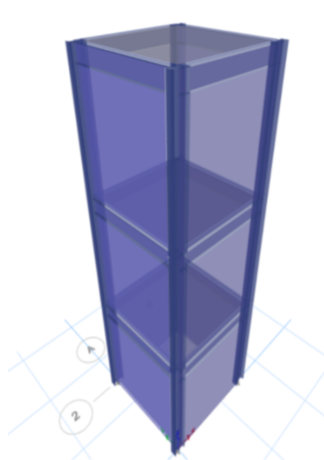

Fig 2. Steel frame with Ferrocement panels as infill in ETABS Software for G+ 2 stories

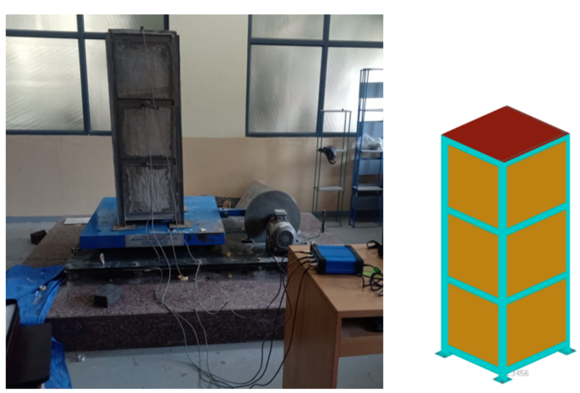

Fig 3. Prototype model of G+2 storied bare frame with Ferrocement Precast Panel all around 4 sides with fixed bases placed on shake table test and Hypermesh model which is analyzed in Nastran software

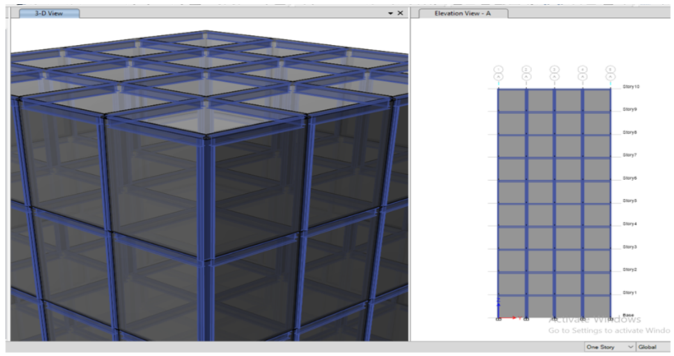

Fig 4. Elevation of G+9 storied Steel bare frame infilled with Ferrocement precast panels on all sides.

4 Results and discussion

For experimental purpose a 3 floors 3D model is considered from the prototype structure and modelled separately in ETABS software and is scaled down to prepare the experimental model. The prototype is scaled down for a scale factor of 11 and steel sections are used for the model. And conducted for shake table test to assess the dynamic behavior of the structure when infilled with precast panels by placing accelerometers at respective floors as shown in the experimental setup.

The following table shows the results obtained in ETABS, Nastran and experimentation for G+2 storied model infilled by Ferrocement infilled panels.

Table 2. Modal Frequency details for Steel bare frame with Ferrocement precast infill panel

Mode no.	ETABS	Nastran	Experiment
1	45.21	47.47	42.09
2	100.22	112.25	93.26
3	238.88	257.99	220.99
4	522.39	481.30	500.81
5	534.78	543.29	508.30
6	656.93	729.19	628.62
7	865.54	995.37	804.95
8	893.20	937.86	858.00
9	914.19	868.48	885.03
10	1158.18	1250.83	1119.82

From the above Table 2 we can observe the first natural frequency as 42.09Hz for prototype and 47.47 from Nastran and 45.21 from ETABS analysis.

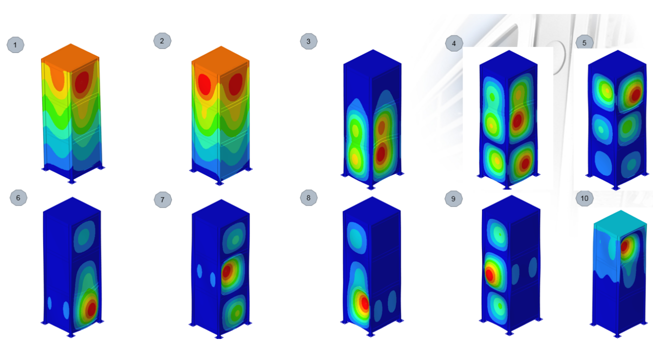

Fig 5. Model shape for the natural frequency –displacement plot for modal frequencies of steel bare frame infilled with Ferrocement precast panels contour plot in Nastran software

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Analysis is carried out in ETABS on a 16x16m bay 4m height G+9 storied commercial building to assess the base shear, Pushover analysis, and Response spectrum analysis and performance point of the structure.

The following are the results obtained after analysing in ETABS software for G+9 storied infilled with Ferrocement precast panels framed model.

Table 3. Storey shear and base shear values for G+9 storied Ferrocement precast panel infilled framed steel frame

Floor level	W_i (kN)	h_i (m)	Wi hi2	Story force(Q_i)	Base force (kN)
Story 9	1699.27	40	2718832.00	329.9	329.9
Story 8	2851.27	36	3695245.92	448.4	778.3
Story 7	2851.27	32	2919700.48	354.3	1132.6
Story 6	2851.27	28	2235395.68	271.3	1403.8
Story 5	2851.27	24	1642331.52	199.3	1603.1
Story 4	2851.27	20	1140508.00	138.4	1741.5
Story 3	2851.27	16	729925.12	88.6	1830.1
Story 2	2851.27	12	410582.88	49.8	1879.9
Story1	2851.27	8	182481.28	22.1	1902.1
Base	2851.27	4	45620.32	5.5	1907.6
			15720623.2	1907.6	

The base shear on the structure by seismic coefficient method is found to be 1916.77kN and by response spectrum method is found to be 1916.77 kN along both X and Y directions by ETABS and manual calculations is 1907.6kN which are approximately nearer.

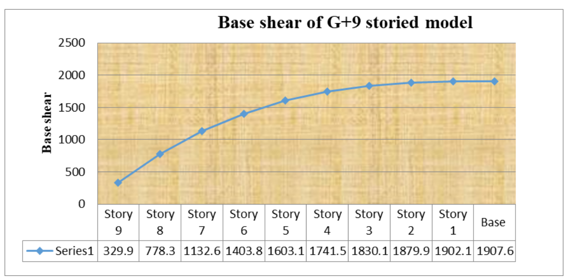

Fig 6. Base reaction of bare frame infilled with Ferrocement precast panels manual calculation for Ferrocement precast panel infilled G+9 storied structure

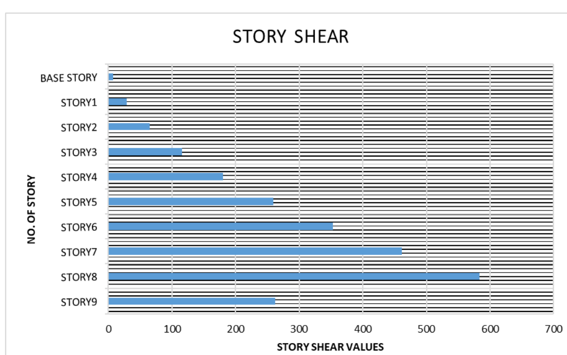

Fig 7. Story shear reaction of bare frame infilled with Ferrocement precast panels by manual calculation of G+9 storied structure from the above graph we can observe that there is gradual rise in base shear values as the stories rise [6]

4.1 Pushover curves

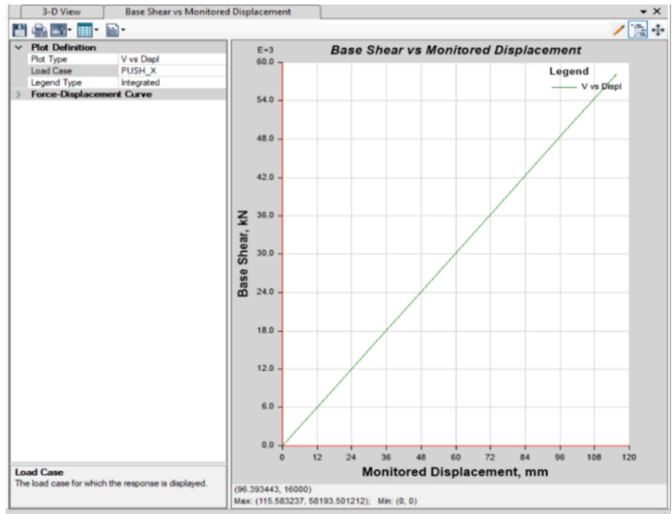

Fig 8. Pushover Curve of Ferrocement precast panel infilled G+9 storied structure.

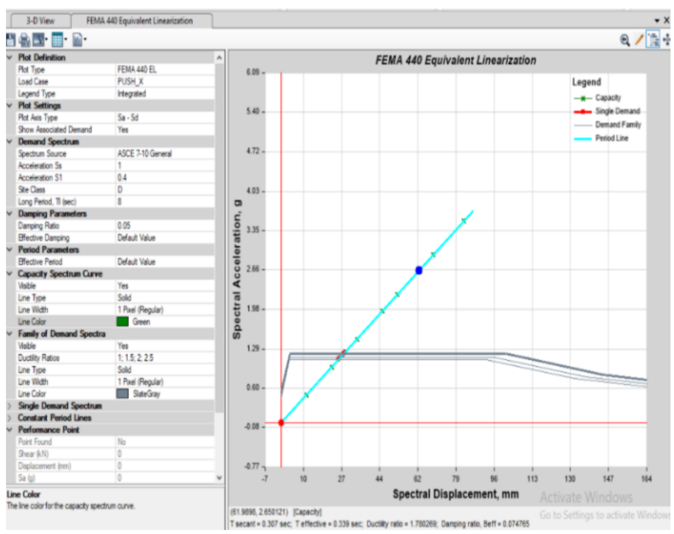

Fig 9. Performance Point by ETABS of Ferrocement precast panel infilled G+9 storied structure

From the above graph Performance point of the structure is calculated by ASCE 41-13 NSP method and FEMA 440 EL method the performance point for Spectrum Curve in X and Y directions respectively X-Direction = Performance point by ETABS is 19761.77 kN , 44.81 mm Y-Direction = 21275.39 kN , 42.469 mm [7].

4.2 Hinge result at performance point

Figure 10 shows hinge status at the performance point in X and Y direction respectively.

Hinges formed in the structure are under the immediate occupancy state hence the structure is safe. Formation of plastic hinges at elements ends, Ferrocement precast panels are analysed for collapse that simulates the possibility of failure of connection between panels and steel frames.

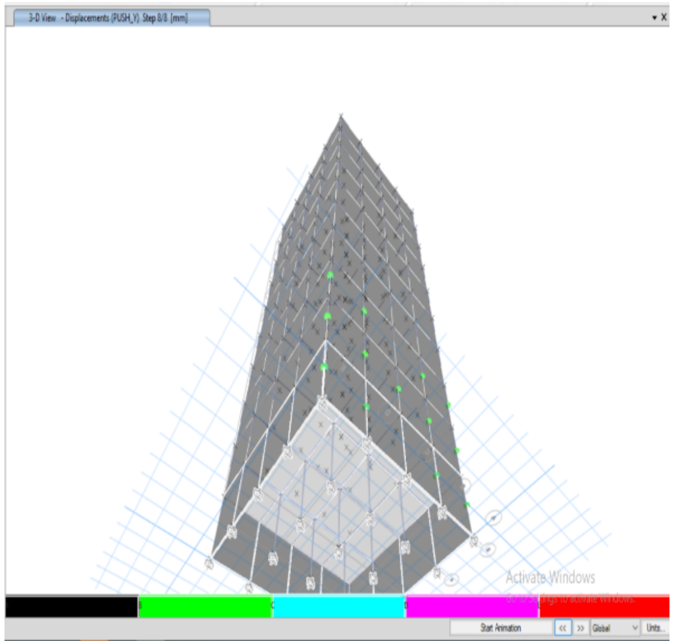

Fig 10. Hinge status at performance point

5 Conclusion

The structure is analyzed and designed for seismic zone V, the obtained values of experimentation are within the requirements of IS1893-2016 and IS 800 2007.

- Shake table test gives the behavior of infilled framed structure under vibration and the effect of resonance.
- The frequency form modal analysis was found to be 45.21 Hz in ETABS, 47.47Hz in Nastran and 42.09 Hz by experimentation where all the values are approximately nearer for G+2 scaled down model by shake table test.
- Base shear on the structure by seismic coefficient method by ETABS is 1916.77 kN which is approximately same from manual calculation for G+9 storied model which are in permissible limits.
- Performance point of the structure in X and Y directions respectively are 19761.77 kN, 44.81 mm Y-Direction = 21275.39 kN, 42.469 mm.
- Performance point by capacity spectrum method is found to in safer limits G+9 story model in ETABS according to IS 1893:2016.
- Analytical and experimental results show similar behavior with a difference of 10-12% in values of modal frequencies due to manual errors during experimentation which are in permissible limits as per the previous researchers this difference may be acceptable.

6 Acknowledgement

We thank for the anonymous reviewers for their useful suggestions and comments on this study. The authors greatly acknowledge with gratitude to SSAHE University, Tumakuru for providing the required inputs to accomplish this work.

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