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Progressive Collapse Study on Spaced Frame Steel Structure by Nonlinear Static Analysis

PYLA DHARANII[1] and G VENKATA LAKSHMAI[2]

M.Tech Student in Civil Engineering, Pydah College of Engineering, Visakhapatnam[1]

Assistant Professor, Dept. of Civil Engineering, Pydah College of Engineering, Visakhapatnam[2]

Abstract: The present study describes the comparison between the irregular steel space frameworks with and without having considerable progressive collapse cases using nonlinear static analysis. Pushover analyses using various invariant lateral load patterns and modal pushover analysis were performed on steel moment resisting frames. The results revealed that the steel space frameworks with progressive collapse cases showed a large decrement in the maximum base share and maximum displacement capacity compared to their irregular steel space frameworks without progressive collapse cases. The results of the pushover analysis also confirmed that the irregular steel space frames works with progressive collapse cases have significantly improved stability in seismic zones over their counterparts without progressive collapse cases.

Key words: Progressive collapse, displacement, seismic zones and steel space frames.

I INTRODUCTION

In last decades steel structure plays an important role in the construction industry. It is necessary to design a structure to perform well under push-over analysis. Design of such structure should have good ductility property to perform well under push-over analysis(1&2).

A simple computer-based push-over analysis is a technique for performance-based design of building frameworks is Push-over analysis attains much importance in the past decades due to its simplicity and the effectiveness of the results. The present study develops a push-over analysis for steel frame designed according to IS-800 (2007) and ductility behavior of each frame.

To provide a detailed review of the literature related to modeling of structures in its entirety would be difficult to address in this chapter. A brief review of previous studies on the application of the pushover analysis of steel frames is presented is this section. This literature review focuses on recent contributions related to pushover analysis of steel frames and past efforts most closely related to the needs of the present work (3).

Scope of the study

The scope of the study involves

1. Design of (G+5) irregular steel space frames using STAAD.PRO as per IS: 800-2007
2. Analyzing the base shear performance of steel moment resisting frame by progressive collapse condition at different positions of weak columns (i.e., Exterior & Interior Columns) (IRFC-1,IRFC-2,IRFC-3,IRFC-4,IRFC-5,IRFC-6) using STAAD.PRO(3).

Pushover Analysis:

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces(4&5). A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity.

Limitations of existing study

Many experimental and analytical works has been done by many researchers in the area of the pushover analysis of the steel frames. The concept of pushover analysis is rapidly growing nowadays.

This research is concerned with the pushover analysis of the steel frames. The uses of pushover analysis of the steel frames have been studied extensively in previous studies. However, many researchers performed experimentally and analytically on the pushover analysis but limited work is done on the study of pushover analysis (2).

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II THEORY AND METHODOLOGY

Structural modelling

1. The study in this thesis is based on nonlinear analysis of steel frames on different configurations of frames are selected such as **case-(1)**: Irregular G+5 frame ,**case-(2)**: progressive collapse load case by removing a column (C1) at assumed first corner joint, **case-(3)**: progressive collapse load case by removing a column (C2) at assumed second corner joint in Z direction, **case-(4)**: progressive collapse load case by removing a third corner column (C3), **case-(5)**:: progressive collapse load case by removing assumed edge column (C4), **case-(6)**: progressive collapse load case by removing middle column (C5) at assumed interior joint. **case-(7)** : progressive collapse load case by removing second middle column (C5) at assumed interior joint This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the steel frame geometry considered for this study.

Geometrical Configuration

The details of considered steel space frame are shown in the fig. 3.1. The building is assumed to be unsymmetrical in plan. Plan dimensions of the considered steel space frame are 18m x 16m.

Pushover analysis was performed for the following different cases to study the nonlinear behavior of the structure with removal of key columns of a considered space frame.

CASE: I Irregular G+5 framed structure (Regular space frame (IRF)).

CASE: II IrregularG+5 framed structure by considering 1st corner column (C1) removed in X direction. (IRFC-1)

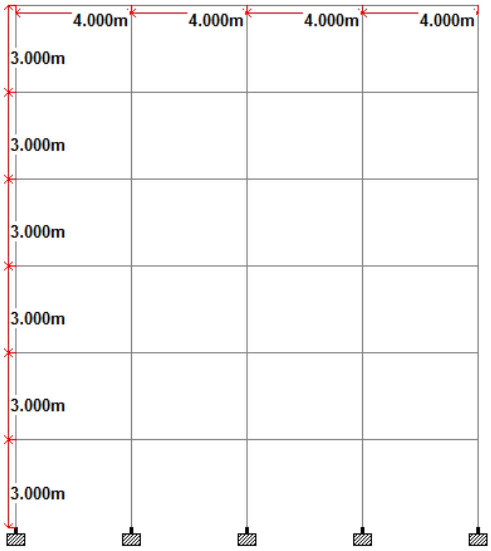
CASE: III Irregular G+5 framed structure by considering 2nd corner column (C2) removed in X-direction. (IRFC-2)

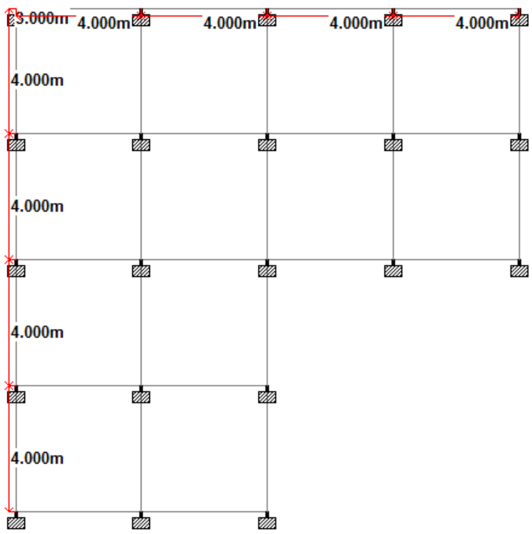
CASE: IV IrregularG+5 framed structure by considering 3rd corner column (C3) removed in Z-direction (IRFC-3)

CASE: V Irregular G+5 framed structure by considering 4th edge column (C4) removed(IRFC-4)

CASE: VI rregularG+5 framed structure by considering 5th middle column (C5) removed. (IRFC-5)

CASE: VII IrregularG+5 framed structure by considering 6th middle column (C6) removed. (IRFC-6)





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Pushover Analysis Methodology

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. For regular buildings, it can also give a rough idea about the global stiffness of the building, shows the pushover methodology for both the frames. This chart describes the pushover steps and details over the pushover analysis(5).

Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modeled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It givesan idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. The roof displacement is plotted with the base shear to get the global capacity (pushover) curve of the structure(4).

III RESULTS

Pushover analysis on IRF at Seismic zone II

The following are the load steps and capacity curve obtained from pushover analysis at seismic zone II.

Load steps:

Table 1: Load steps for IRF at Seismic zone- II

Load Step	Displacement mm	Base Shear kN
1	0	0
2	0.030	1.300
3	0.680	29.398
4	50.274	2134.086

Capacity curve:

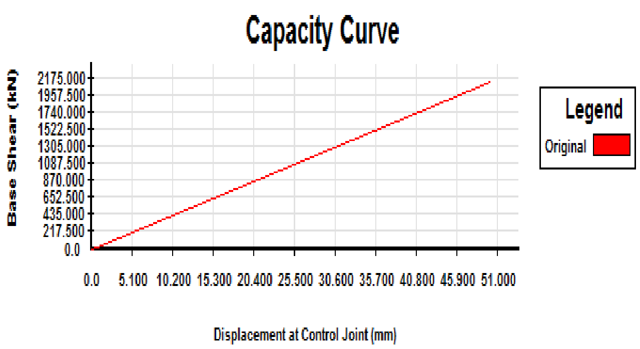

Fig 1 Capacity curve for IRF at Seismic zone II

The following are the load steps and capacity curve obtained from pushover analysis at seismic zone III

Load steps:

Table 2: Load steps for IRF at Seismic zone- III

Load Step	Displacement mm	Base Shear kN
1	0	0
2	0.033	1.300
3	0.737	29.405
4	54.411	2141.703

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Capacity curve:

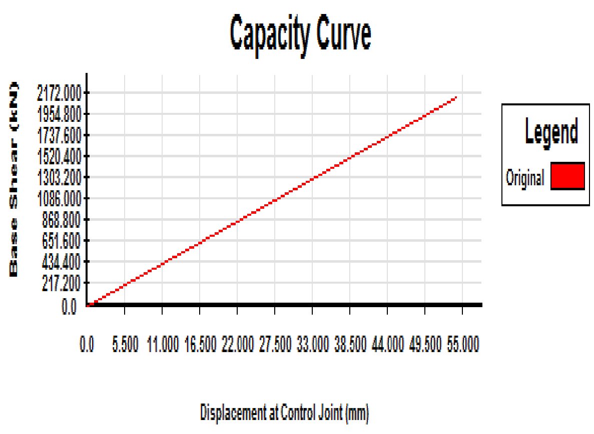

Fig 2 Capacity curve for IRF at Seismic zone III

The following are the load steps and capacity curve obtained from pushover analysis at seismic zone IV

Load steps:

Table 3: Load steps for IRF at Seismic zone -IV

Load Step	Displacement mm	Base Shear kN
1	0	0
2	0.029	1.300
3	0.657	29.405
4	52.468	2346.673

Capacity curve:

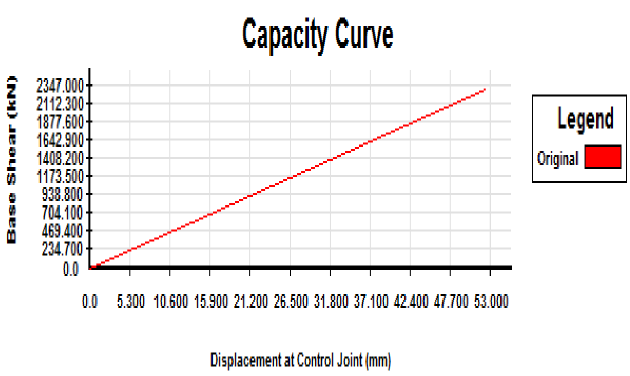

Fig 3 Capacity curve for IRF at seismic zone IV

The following are the load steps and capacity curve obtained from pushover analysis at seismic zone V

Load steps:

Table 4: Load steps for IRF at Seismic zone V

Load Step	Displacement mm	Base Shear kN
1	0	0

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2	0.033	1.300
3	0.737	29.405
4	58.795	2346.782

Capacity curve:

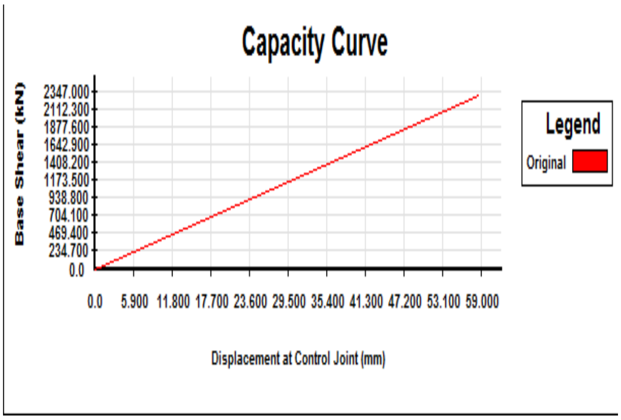

Fig 4 Capacity curve for IRF at Seismic zone V

IV DISCUSSIONS ON RESULTS

Comparison of base shears and displacements for steel space framed structure with different progressive collapse conditions:

Comparison between base shears and displacements from the capacity curves obtained from the pushover analysis at Seismic zone II is observed that the displacements of the Space framesIRFC-1, IRFC-2, IRFC-3, IRFC-4, IRFC-5, IRFC-6 is reduced by 89.8%, 90.003%, 89.1%, 89.8% , 89.9%, 89.6 % when compared to Irregular space frame IRF.

Comparison between base shears and displacements from the capacity curves obtained from the pushover analysis at Seismic zone III is observed that the base shear capacity of the Space framesIRFC-1, IRFC-2, IRFC-3, IRFC-4, IRFC-5, IRFC-6 is reduced by 91.9%, 92.2%, 92.2%, 92.3% , 92.2%, 92.2 % when compared to Irregular space frame IRF.

Comparison between base shears and displacements from the capacity curves obtained from the pushover analysis at Seismic zone IV is observed that the base shear capacity of the Space framesIRFC-1,IRFC-2, IRFC-3, IRFC-4,IRFC-5, IRFC-6 is reduced by 92.2%, 92.12%, 92.12%, 91.6% , 92.1%, 92.1 % when compared to Irregular space frame IRF.

Comparison between base shears and displacements from the capacity curves obtained from the pushover analysis at Seismic zone V is observed that the base shear capacity of the Space framesIRFC-1, IRFC-2, IRFC-3,IRFC-4, IRFC-5, IRFC-6 is reduced by 91.5%, 91.8%, 91.8%, 91.9% , 91.7%, 91.8 % when compared to Irregular space frame IRF.

IV CONCLUSIONS

Performed pushover analysis on braced steel space frames for various progressive collapse cases (i.e., IRF, IRFC-1, IRFC-2, IRFC-3, IRFC-4,IRFC-5 &IRFC-6). Following were the conclusions drawn from the study.

1. The maximum base shear and maximum displacement capacity of the Space frame with considering progressive collapse case is reduced by92.4% and 90.093% when compared to Irregular space frame in Seismic zone II
2. The maximum base shear and maximum displacement capacity of the Space frame with considering progressive collapse case is reduced by 92.3% and 89.9% when compared to Irregular space frame in Seismic zone III

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3. The maximum base shear and maximum displacement capacity of the Space frame with considering progressive collapse case is reduced by 92.2% and 89.8% when compared to Irregular space frame in Seismic zone IV
4. The maximum base shear and maximum displacement capacity of the Space frame with considering progressive collapse case is reduced by 91.9% and 89.27% when compared to Irregular space frame in Seismic zone V
5. Out of all the seismic zones compared the percentage change in reduction of both base shear and displacements is very minute in all progressive collapse load cases of same zones.

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