Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(11) (2021) 1-3
DOI: 10.22060/ceej

Collapse Assessment of Steel Moment Frames Based on Development of Plastic Hinges

V. Saberi*[1] , H. Saberi[2], A. Sadeghi[2]

[1] Assistant Professor, Department of Civil Engineering, University of Eyvanekey, Semnan, Iran
[2] PhD Candidate, Department of Civil Engineering, Mashhad Branch, Islamic Azad University, Mashhad, Iran

ABSTRACT: Building collapse is a level of the structure performance in which the amount of financial and life loss is maximized, so this event could be the worst incident in the construction. In this study, the collapse of low and mid-rise Regular special steel moment frames with 3, 6, and 9 story were designed by ETABS according to code guidelines and then the collapse of mentioned frames has been evaluated by nonlinear static pushover and incremental dynamic (IDA) analyses with SeismoStruct. The nonlinear static pushover analyses with three lateral load patterns were used to determine the likely location of the plastic hinges at the moment of probable failure mechanism for the mentioned frames and the nonlinear incremental dynamic analyses were used to assess the seismic intensities corresponding to form each failure mechanisms. Thus, the intensity of earthquake and the values of drift corresponding to the failure of studied frames were calculated. To perform nonlinear dynamic analyses, 10 far-fault records were used. The results of this study showed that the collapse of studied frames occurs under the far-fault records in different drifts and seismic intensities and the value of relative drift equivalent to the collapse limit varies from 2 to 5 percentage and It was also found that the collapse capacity of 3 and 6-story frames is 3.3 g and 3.4 g respectively in the uniform lateral load method and in 9-story frame, the collapse capacity of the first mode and linear lateral load methods is more and equals to 2.5 g.

Review History:
Received:
Revised:
Accepted:
Available Online:

Keywords:
Collapse
Plastic Hinges
Special Steel Moment Frame
Nonlinear Analyses
Far-Fault Record

1. INTRODUCTION

For many years, the collapse of moment frame structures against seismic loads has been estimated based on the ductility demand and drift response of the stories [1]. Fereshtehnejad et al. [2] presented a novel, robust theoretical approach based on plasticity theory of structures. In this method, the nonlinear pushover static analysis is used to predict the probable mechanism of structural failure and the nonlinear incremental dynamic analysis (IDA) is used to determine the seismic intensity corresponding to the formation of predetermined failure mechanisms. In the mentioned study, by performing numerous numerical analyses and considering the uncertainties in modelling parameters and capacity of structural components, it is concluded that the failure mechanism of structures is mainly a function of structural characteristics and the location of plastic hinges under different seismic loads. The results of static and dynamic analyses have been shown that the both mechanism are similar. But, the process and order of formation the plastic hinges varies under different records. Finally the ultimate mechanisms of collapse under different earthquake records are consistent with the prediction of the nonlinear pushover static analysis. Nazri and Ken [3] investigated the performance of steel moment frames using the nonlinear static and dynamic analyses. In order to investigate the dynamic behavior of 2 dimensional frames with 3, 6 and 9-story, 14 near and far-fault ground motion records have been used. The results show that far-fault records have caused more damage than near-fault records and the performance levels have been determined using nonlinear pushover static analyses. In this study, as a novelty, the damage intensity like peak ground acceleration (PGA) and drift related to collapse limit like Maximum Interstory Drift Ratio (MIDR) have been investigated and compared in order to determine the collapse behavior of steel moment frames with special ductility under the effect of far-fault records based on plastic hinges development according to lateral loading patterns using the nonlinear static and dynamic analyses. In addition, this methodology has been proposed by Fereshtehnejad et al. already, which is based on the method of plasticity theory.

2. METHODOLOGY

In this study, steel moment frames 3, 6 and 9-story with regular configuration and special ductility are designed in two dimensional. The application of these structures is residential in accordance with the fourth edition of seismic Iranian standard 2800 [4] and soil type is III. Design acceleration is due to very high relative hazard area (PGA = 0.35) for all prototypes. dead and live loads of stories are considered 1750 kg/m and 1000 kg/m respectively and live load of roof is 750 kg/m. Frames are designed according to code guidelines [4, 5, 6] by ETABS software [7] and then nonlinear static and

*Corresponding author's email: saberi.vahid@gmail.com

Table 1. The ratio of plastic hinges in columns to total plastic hinges subjected to 3 lateral loading pattern

Pattern	3-story	6-story	9-story
Mode 1	% 47.8	% 40.5	% 36.4
Linear	% 47.8	% 39	% 37.3
Uniform	% 40	% 40	% 37.5

Table 2. The average of PGA related to collapse limit of the studied frames

Frames	Average of PGA (g)		
	Pattern		
	Mode 1	Linear	Uniform
3-story	0.93	0.93	1.02
6-story	1.01	1.02	1.44
9-story	1.6	1.6	1.64

Table 3. The average of MIDR related to collapse of limit the studied frames

Frames	Average of MIDR (%)		
	Pattern		
	Mode 1	Linear	Uniform
3-story	3.35	3.35	3.47
6-story	4.12	4.13	5.39
9-story	5.33	5.31	6.41

dynamic analyses were performed under 10 far-fault ground motion records based on FEMA P695 [8] by SeismoStruct software [9].

3. RESULTS AND DISCUSSION

The nonlinear pushover static analyses for three steel moment frames with special ductility are performed with 3 types of lateral loading patterns such as the first vibration mode "Mode 1", linear and uniform patterns. The ratio of the number of plastic hinges in the columns to the total number of plastic hinges is formed at the moment of structural failure is shown in Table 1. The results show that the average 40% of the plastic hinges are formed in the columns and 60% in the beams due to the strong column-weak beam principle in the design of the studied frames.

In this study, we combine the results of nonlinear pushover static analysis and incremental dynamic analysis (IDA) by using plasticity theory in order to determine the point of structural collapse and the corresponding PGA and MIDR values. The collapse limit of the studied frames is presented in Tables 2 and 3 under 10 far-fault ground motion records.

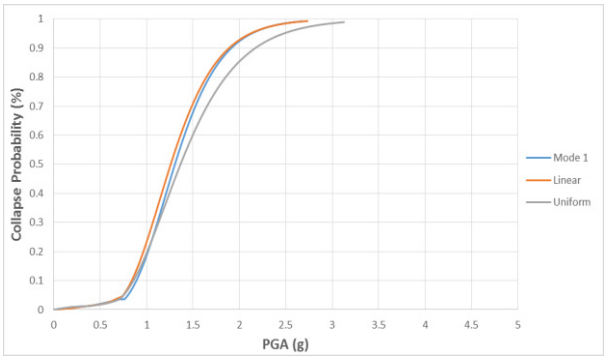

Fig. 1. The fragility curves of 3-story frame

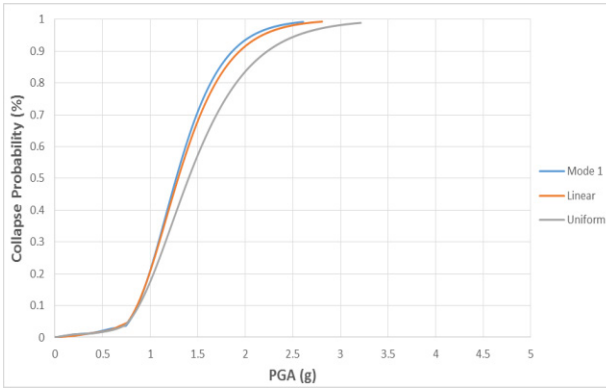

Fig. 2. The fragility curves of 6-story frame

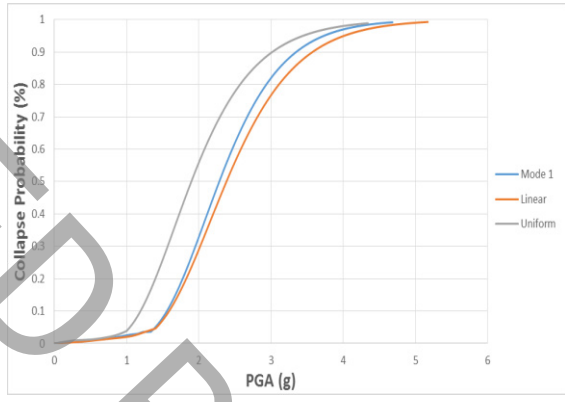

Fig. 3. The fragility curves of 9-story frame

In this study, the fragility curves of different lateral loading patterns (the first mode, linear, and uniform) of 3, 6 and 9-story frames are presented in Fig.s 1 to 3 based on PGA.

4. CONCLUSIONS

In this study, using the plasticity theory to evaluate the collapse point of 3, 6 and 9-story steel moment frames with special ductility and regular configuration based on the results of nonlinear pushover static and nonlinear incremental dynamic analyses (IDA) are discussed. The results of the analyses are presented below:

- The nonlinear pushover static analyses performed under 3 lateral loading patterns (the first mode, linear and uniform). The first mode and linear lateral loading patterns have similar

results for 3 and 6-story frames. However, under the uniform lateral loading pattern, the failure mechanism estimation is not suiTable only under 3-story steel moment frame and the damage intensity corresponding to the collapse limit for this pattern is higher than other lateral loading patterns. But with higher height and higher modal effects, the accuracy of the uniform loading pattern has been increased and suiTable results have been achieved for 9-story frame.

- The average collapse (MIDR) values for the studied frames presented in the range of 3.35 to 5.33%. Since the fourth edition of Iranian Standard 2800 restricted the maximum interstory drift to 2 or 2.5%, it can be expected that the sample frames will not collapse under the effects of the earthquake. It is also proposed the threshold 5% adopted by FEMA-356 for the collapse limit, which appears to be non-conservative for low-rise frames.

- Based on the fragility curves, it is found that the uniform lateral loading pattern showed a higher collapse capacity than the other patterns in 3 and 6-story frames, but in 9-story frame, the linear and first mode lateral loading patterns presented more collapse capacity than uniform loading pattern.

REFERENCES

[1] H. Krawinkler, R. Medina, B. Alavi, Seismic drift and ductility demands and their dependence on ground motions, Engineering Structures, 25(5) (2003) 637-653.

[2] E. Fereshtehnejad, M. Banazadeh and A. Shafieezadeh, System reliability-based seismic collapse assessment of steel moment frames using incremental dynamic analysis and Bayesian probability network, Engineering Structures, 118 (2016) 274-286.

[3] F.M. Nazri, P.Y. Ken, Seismic performance of moment resisting steel frame subjected to earthquake excitations. Front. Struct. Civ. Eng. 8, (2014) 19-25.

[4] BHRC. Iranian code of practice for seismic resistant design of buildings. Tehran: Building and Housing Research Centre, Standard No. 2800, (2014). (In Persian).

[5] INBC. Design and Construction of Steel Structures. Tehran: Ministry of Housing and Urban Development, Iranian National Building Code, Part 10, (2013). (In Persian).

[6] INBC. Design Loads for Buildings. Tehran: Ministry of Housing and Urban Development, Iranian National Building Code, Part 6, (2013). (In Persian).

[7] Habibullah, A. SAP-Three Dimensional Analysis of Building Systems. Manual. Computers and Structures Inc., Berkeley, California, (2018). https://www.csiamerica.com/

[8] FEMA P 695. Quantification of Building Seismic Performance Factors. Washington, D.C. Federal Emergency Management Agency, USA, (2009).

[9] SeismoStruct, A computer program for static and dynamic nonlinear analysis of framed structures, SeismoSoft's Ltd, (2018). https://www.seismosoft.com/

HOW TO CITE THIS ARTICLE

Saberi V., Saberi H., Sadeghi A. (2021). Collapse Assessment of Steel Moment Frames Based on Development of Plastic Hinges. Amirkabir J. Civil Eng., 52(11): 1-3.

DOI: 10.22060/ceej***