Evaluation of the seismic sensitivity of steel frame with converging bracing to random variables

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ABSTRACT

Structural response to seismic load is one of the tasks of structural and earthquake engineers. Many factors affect the response of structures to seismic load. Seismic load, structural system, geometric characteristics and materials are examples that affect the response of structures to seismic load. The effect of each of these cases can be determined by sensitivity analysis. The purpose of this study was to evaluate the sensitivity of steel frame with converging braid compared to random variables under a seismic load. 10-story frame types with convergent bracing system (four types) are analyzed after design and modeling using Monte Carlo and FOSM methods. Then the sensitivity of their response to random variables is evaluated. In this study, two-dimensional frames for sensitivity analysis were used. Also, the sensitivity analysis of the FOSM method is compared to the Monte Carlo analysis. The steel yield stress, the steel elastic modulus, the dead load, the live load, the damping coefficient and the length of the span are considered as random variables and their impact on the period of the structures, the maximum displacement of the roof and the maximum base shear have been investigated. The results show that the effect of random variables on the maximum Roof displacement is higher. The maximum sensitivity of the base shear to the random variables in the X convergent brace is more than the other structural systems, and the FOSM method has the least error in estimating the periodicity of the structures with the lowest error compared to the maximum roof displacement and the maximum base shear. The general results of the analysis show that steel yield stress, dead load, and damping ratio have the most effect on the response of steel bracing frames, so they should be carefully considered in structural calculations. This sensitivity is lower in live load, span length, and elasticity modulus of steel.

Keywords:

Sensitivity analysis, bracing steel frame, random variables, structural response

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Introduction

Reducing damage to structures at different loads has always been one of the tasks of structural and earthquake engineers. Different structures have different functions against these loads [1]. Assessing the effectiveness of seismic performance of structures has always been one of the key methods for estimating damage and damage caused by earthquake loads [2]. Uncertainties are the most important parameter in probabilistic evaluation [3]. In seismic loads, uncertainty is divided into two degrees of uncertainty due to seismic load and structural uncertainties [4]. Changes in any of these uncertainties or random variables can affect the seismic response of structures. Geometric specifications, loading, and materials can be considered as a structural uncertainty or random variable. The aim of this study was to evaluate the seismic sensitivity of steel frames with a double moment frame system with convergent bracing relative to random variables. In this study, a large number of structural models, random variables and two methods of sensitivity analysis have been considered. The Monte Carlo method is a very time consuming method that requires a lot of time and energy. On the other hand, in many studies, when the goal is to compare the sensitivity method or to compare the sensitivity of different structures, they generally use an earthquake record. Therefore, in this study, an earthquake record has been used to evaluate seismic sensitivity.

Methodology

There are several ways to assess the sensitivity of a structure to the desired parameters of engineering. Three methods: Monte Carlo (MCS), FOSM, and the Tornado diagram are the most widely used of these methods in assessing the sensitivity of structures. MCS is one of the deepest methods in solving problems related to uncertainty analysis and probabilistic analysis. In this method, the random variable is defined as a set of deterministic values. This set of input data results in a set of deterministic outputs. Finally, the probabilistic form of the outputs is calculated and presented. Due to its high accuracy, the MCS method is commonly used to validate other probabilistic methods. Using the MCS method is very time consuming. There are several ways to assess the sensitivity of a structure to the desired engineering parameters. One of these methods is the first order analysis of the second time (FOSM). In the FOSM method, only the mean and standard deviation (SD) of the random variables are assumed to be based on their distribution. And the mean and SD responses are measured. The standard deviation of this method can be considered as a criterion for sensitization. The main advantage of the FOSM method is that despite the fact that the analysis process is simpler than other methods, the probabilistic characteristics of the structural responses can be obtained.

Specifications and numerical model

To evaluate the sensitivity of restraint structural systems to random variables, a two-dimensional double steel frame with convergent restraints was used. Convergent bracing systems include cross-braces, diagonal, weekly, and porcelain braces. All models use a double bending frame system with braces, and all beam and column connections are considered rigid. Structural systems are modeled and designed in the form of steel bending frames with braces in accordance with the design regulations of steel structures and based on the LRFD method. Seismic loading is based on the design regulations for earthquake-resistant structures (Fourth Edition of Standard 2800). The structural plan was selected as a square plan with five openings measuring 5 meters. The structures are analyzed and designed on 10 floors with a story height of 3.2 meters.

After the initial design, one of the enclosed perimeter frames was considered as a two-dimensional model for nonlinear and sensitivity analysis. Figure 1 shows the two-dimensional models of the study. For beams, I-shaped sections are used, and for columns and braces, box-sections are used.

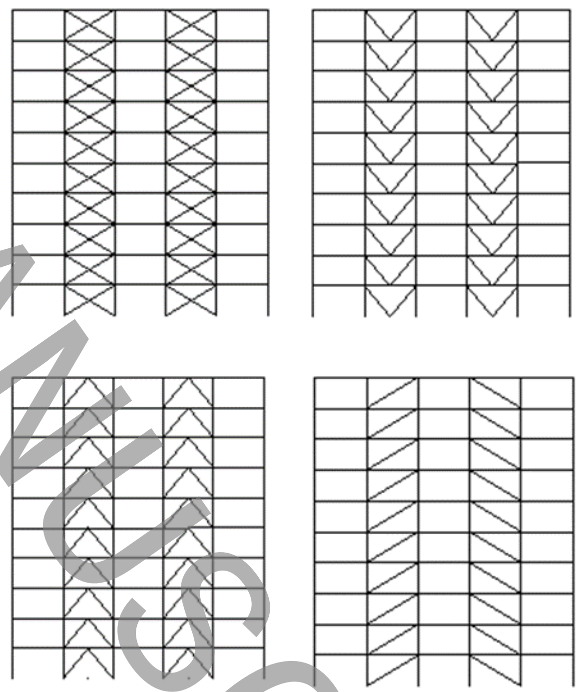
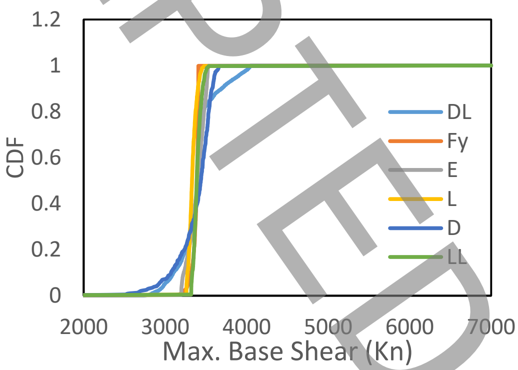


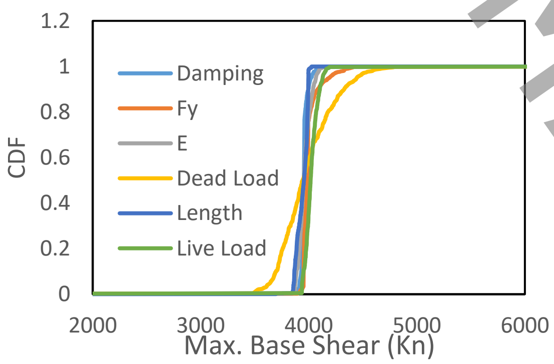
Figure 1. Structural Model

Conclusions

Figure 2 examines the effect of random variables on the maximum base shear frame of this study. The results of the Monte Carlo analysis are presented first. The results of the Monte Carlo analysis are presented in the form of CDF curves based on the maximum base cut in Figure 10. CDF curves of each frame show that different structural systems are affected differently by random variables. For example, the width of the CDF curve in the frame with the brace is different from the frame with the weekly brace. In addition, the width of the CDF curves for the maximum base cut is different from the width of the CDF diagrams for the maximum displacement of the roof. The results show each of the structural features (maximum base shear and maximum roof displacement) has different sensitivity to random variables. Therefore, each of the responses or capacities of structural systems is more sensitive to a specific random variable.



a)



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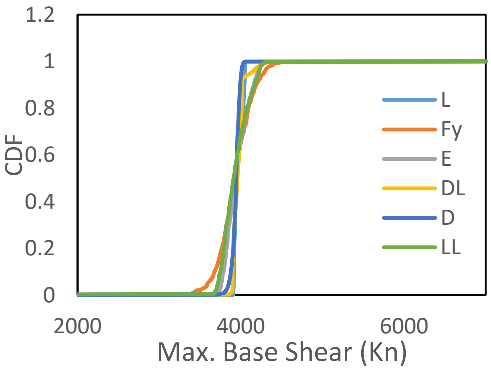

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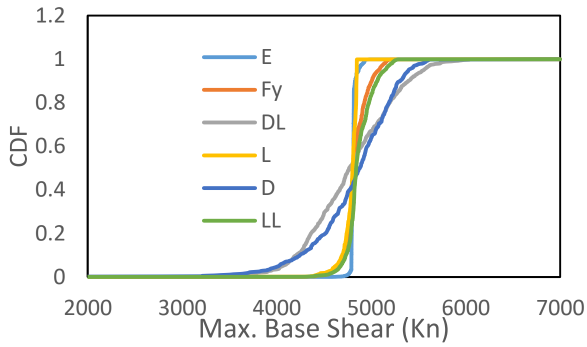

d)

Figure 2 Curves of maximum base shear changes in Monte Carlo method sensitivity analysis, a) diagonal, b) In-V c) V d) X brace

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