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Research Article

Seismic Performance-Based Evaluation of Cold-Rolled Steel Structures

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Today, lighter buildings with a smaller share of seismic force are needed in the construction industry. Given the attractiveness of this construction method for researchers, it led them to conduct more and more accurate experiments to better understand these structures and, in particular, to study the lateral behavior of these structures. The aim of this study has been to calculate reliability index and probability of failure. In addition to this sources of uncertainty in structural system of cold-formed frames with sharp bracing have been ranked by application of reliability analysis method. To do this, considering sources of seismic and structural uncertainty such as spectral acceleration, live load, cross-sectional dimension, and modulus elasticity of steel has been selected. Then reliability analysis methods, FOSM and FORM, have been utilized to estimate the probability of failure based on limit-state function which is defined as relative displacement of floor to allowed limit. Results show that failure probability following a decreasing trend up to two story-floor frames increased up to five-floor frames. As a result of the analysis, it was found that, in the FOSM method, the reliability index increases with increasing floors in cold-rolled steel structures. In the FORM method, by increasing the floors up to the two-story frame, the reliability index has an ascending trend and up to the five-story frame has a descending trend with a very gentle slope. By increasing the distance, the value of the FOSM method reliability index is different from the value of this index in the FORM method to the extent that, in the Type 5 framework, this difference reaches five units. The probabilities of failure in one-story and three-story frames are the highest and the lowest, respectively. Uncertainty in the load applied to the structure was identified as the most important parameter. The uncertainty in the geometry of the members decreases with the increase of classes.

1. Introduction

Performance-based seismic design of cold rolled steel structures required uncertainities trough reliability methods. The structures performed limited experiments against wind and earthquake loads. On the other hand, the local buckling behavior, distortion and general control, and study of structural performance of various forms of thin-walled profiles have been investigated. In general, the fundamental role of probability theory in the analysis of performance and safety is felt in all branches of engineering. Leading civil engineers in different countries conduct statistical studies on the nature and characteristics of materials. Studies show the existence of uncertainties in the loads and resistances of the structure, which indicates the uncertainty in the performance of the structure, and certainly the analysis of this issue can be done only through probability theory. The use of probability theory in the design of cold-rolled steel structures was developed by examining the design method based on load factor and capacity, and load uncertainties and resistance were introduced by using factors and coefficients, which in turn gained reliability [1].

From a review of studies in the 1930s, the popularity and development of chilled steel production in the United States were hampered by a lack of proper design criteria. The various building codes at the time did not regulate the manufacture of cold steel. It was found that the development of new design criteria for cold-rolled steel buildings is necessary, because not only does the performance of thin members of cold-rolled structures under different loads in many respects differ from hot-rolled steel sections, but also the shapes, sections, joints, and construction methods developed in the chilled steel structure differ in many ways from those of heavy steel structures. As a result, the design criteria for a hot-rolled heavy-duty steel building may not fully cover the design aspects of a cold-rolled steel building [2]. Recent research at Cornell University under the supervision of Professor Teoman Pekoz includes the effect of residual stresses on column strength, maximum column strength, beam distortion buckling, lattice wall force, effects of eccentricity loading on edged gutters, flexural strength of welded roof panels, behavior of compressive components with longitudinal stiffeners, probabilistic test of member strength, direct prediction of member strength using numerical methods of elastic stability, late braced columns with hard-edged wings, and steel members with multiple longitudinal middle stiffeners [2]. In 1990, the Center for Refined Steel Structures was established at the University of Missouri-Rolla, providing a single solution for research, teaching, technical services, and professional activity. Since 1975, the ASCE Special Committee on Conducted Members has reviewed recent research on recruited structures and reviewed articles [2].

After World War II in the United States and the United Kingdom, two committees, ASCE and ICE, began research into the safety of structures considering random variables. Finally, the best way to obtain safe structures is when these parameters are examined by probability theory and statistics from an engineering judgment perspective. Based on the scientific findings, the ASCE and ICE committees submitted two reports on the subject. These reports led to the development of design applications based on reliability [1]. Rahem et al. in 2021 showed that the nonlinear static response indicated that the opening area has an influence on the maximal strength, the ductility, and the initial rigidity of these frames [3]. Given the knowledge that the use of cold-rolled frame structures has flourished in recent decades, research in this area began with tests performed by Tarpy in 1970, the most important of which can be found in experiments performed by McCreless and Tarpy in 1978, after which other researchers based on these experiments performed tests on walls with structural panels [4]. Probability studies on the characteristics of cold-rolled sections were performed in 1998 by Schaffer and Grigoriu in an article entitled "Probability Investigation of the Final Strength Test of Cold-Rolled Steel Members." In this study, three random variables of thickness, residual stress magnitude, and initial defect in the mentioned members under net compressive load and deformability were evaluated by Monte Carlo reliability method. Finally, this study showed that the results of reliability analysis in comparison with AISI regulations, under net bending, are less conservative than net pressure [5].

2. Materials and Methods

Effective parameters in the analysis and design of structures such as mass, damping, material properties, and applied loads can be considered as sources of uncertainty, among which uncertainties can be divided into two separate groups [6]. The first group is inherent uncertainties, which have a definition equivalent to their name, and the second group is cognitive uncertainties, which are due to our insufficient knowledge about them. But this uncertainty decreases with the advancement of science, while inherent uncertainty is irreversible [7]. Due to our inability to predict the loads on the structure during its life and the strengths of materials and idealization of the structure in the formation of mathematical models to predict its behavior and limitations in numerical methods, the existence of this uncertainty makes the absolute safety of the structure impossible. In certain contractual analysis and design methods, it is assumed that not all parameters (loads, material strength, etc.) are subject to probabilistic scattering, and the reliability coefficients provided in existing regulations and standards are based on practice and judgment, and it is an experience and may not be sufficient and economical [12]. Reliability theory is a branch of general probability theory that has gradually found its place in the engineering sciences over the last 30 years. This theory has a logical framework that, by calculating and analyzing the uncertainties caused by the statistical nature of engineering problems using mathematical methods, makes it possible to assess the true safety of a system [13]. Reliability has different meanings that have been interpreted in different ways and contexts. The most commonly accepted definition of reliability is the probability that a system will perform adequately under predetermined operating conditions for a specified period of time. Pinheiro in 2020 revealed that the creation of an ecological skin in architecture accentuates the dilution of the presence of interventions in heritage contexts with an attitude of knowing how to add, involving nature [10]. According to the above definition, reliability is based on the four principles of probability, intended task, time, and operating conditions [12].

The wide variety of methods for idealizing structural reliability models and the different ways in which these ideal models can be combined in a given design problem reveal the need for an appropriate classification that has four floors. In level-one methods, only one characteristic value of each uncertain parameter (usually the mean value) is used and the permissible stress methods are examples of this method [13]. Level-two methods use two characteristic values of uncertain parameters (usually mean and variance) plus the effect of correlation between them (usually covariance). Reliability index methods are examples of these methods [13]. In leveling methods, three methods of reliability theory that use the probability of failure as a scale and require the common distribution of all uncertain parameters are called level-three methods [13]. Finally, the reliability theory examines and analyzes the expectations of the structure with an acceptable scale under probabilistic conditions and according to the principles of engineering economics in terms of cost and usefulness in construction, maintenance, repair, failure consequences, etc. This method is suitable for structures that are of high economic importance and it should be said that this method is still being developed [13]. Although the above classification for reliability methods is not comprehensive, in this study, the level-three method has been used for probabilistic models.

Abedin et al. in 2020 study about the ultimate tensile capacity of the improved connection. Their suggested connection was compared to the typical RHS connection presented in the AISC and the similar double angle sections connected at both legs [11]. Reliability theory of structures in the design process allows the safety and performance considerations of the structure to be quantified into design decisions. If previously in the design of structures the number of members of the structure was considered, now, with the help of this theory, the interaction of members in the system of structures can be considered [13]. Finally, in structural analysis and design, reliability is defined as the probability that a structure will not exceed any specified limit (bending, shear, torsion, or deformation criteria) during the specified base period (structure life). Reliability in terms of failure probability is defined as follows [12]:

$$R_0 = 1 - p_f. \tag{1}$$

In this section, two important criteria of reliability, safety index and failure probability, are examined. However, efficient selection of appropriate approximations at different stages of reliability analysis is a practical tool for many large-scale engineering problems [12]. Reliability science has various methods of probabilistic analysis such as FOSM, FORM, SORM, and sampling. In this section, only explanations about the second-moment methods will be mentioned, because, in the present study, FOSM and FORM methods, which are the same as the second-order first-moment method, have been used. The FORM basis includes the process of linearizing the limit state function described at the design point. The design point is the point on the refractive index that is closest to the origin of the standard-normal space (see (2) and (3)). As a result of the above description, the shortest spatial distance between the safety zone and the failure area is called the reliability index and is undefined. In FORM, the linear limit state function is generated by Taylor's first-order estimation (see (4)). The semester is zero until the limit state function is evaluated at the design point, which is common for gradient normalization and negation. This negative unit vector is attributed to the alpha vector (see (5)). To find the design point, the minimum must be found to continue the path optimization process [13].

$$\beta = \left\| y^* \right\|, \tag{2}$$

$$G(y) \cong G(y^*) + \nabla G y^{*T} \cdot (y - y^*), \tag{3}$$

$$\alpha = -\frac{\nabla G^T (y^*)}{\left\| \nabla G(y^*) \right\|}, \tag{4}$$

$$\alpha_i = -\frac{(\partial G / \partial \theta_i)(y^*)}{\sqrt{\nabla G^T (y^*) \cdot \nabla G(y^*)}}. \tag{5}$$

3. FOSM Method

In the first-order second-moment (FOSM) method, which is a probabilistic method, the limit state function is expressed as a first-order polynomial of the Taylor series expansion in the mean value. If X is assumed to be a random variable, the approximated limit state function in the mean value is expressed as follows [12]. According to the second-order second-moment method, the deviation of the criteria obtained from (6) represents the value of Y sensitivity to each of the random variables. Using these values, the effects of different random variables on the output of the function can be compared. For this purpose, in this study, the derivative in (7) is obtained by using the finite difference method and using equation (8).

$$Y \approx g_0 + \left(\frac{dg}{dx} \right)_0 (X - x_0), \tag{6}$$

$$\frac{\partial g}{\partial x_i} = \frac{g(\mu_i + \Delta x_i) - g(\mu_i - \Delta x_i)}{2 \Delta x_i}, \tag{7}$$

$$\Delta \mathrm{x}_i = \mathrm{a}_p \times \sigma_i. \tag{8}$$

4. FORM Design Point Optimization

The design point is found by continuously solving the following optimization problem. Here is the design point or the closest distance to the failure procedure. The above statement refers to the fact that the design point is at the shortest distance from the line-breaking failure procedure to the point by the tangent line on the surface (see (9) and (10)). For FORM to function, $G(y)$ must be continuously recognizable. The search algorithm to find the FORM design point can be explained as the optimization problem below. An iterative algorithm is formulated to find it. Here is the step size and it is equal to the search direction (see (11)). In the FORM model, there are both fixed step and Armijo sizes. If the steady step fails to converge, Armijo can. Search direction is obtained using the latest method, the iHLRF algorithm. The iHLRF algorithm requires a normalized gradient that is solved analytically (see (12)) [13].

$$\begin{aligned} d_i &= y_{i+1} - y_i \\ &= \left(\frac{G(y_i)}{\left\| \nabla G(y_i) \right\|} + \alpha_i^T \cdot y_i \right) \alpha_i - y_i, \end{aligned} \tag{9}$$

$$y^* = \arg\min \left\{ \frac{1}{2} \| y \|^2 | G(y) \leq 0 \right\}, \tag{10}$$

$$y_{i+1} = y_i + S_i \cdot d_i, \tag{11}$$

$$\begin{aligned} d_i &= y_{i+1} - y_i \\ &= \left(\frac{G(y_i)}{\left\| \nabla G(y_i) \right\|} + \alpha_i^T \cdot y_i \right) \alpha_i - y_i. \end{aligned} \tag{12}$$

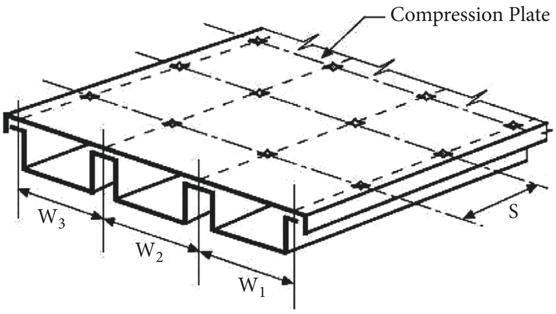


Figure 1: Composite roof cross section.

5. Modeling and Numerical Analysis

Based on the design frameworks of the constructed structures, 10 types of two-dimensional frame models of this type of structure were analyzed and designed according to the existing regulations, which are further explained about the structural system and the behavior of its members. Several probabilistic methods are used to estimate the uncertainty of engineering demand. Among these methods, we can mention Monte Carlo and moment-second-order methods. The Monte Carlo simulation method is a relatively accurate method for estimating uncertainties. However, in modeling with a large number of parameters, using this method will not be economical either temporally or computationally, because one of the challenges of probabilistic evaluations of the performance of structural systems is their high computational cost compared to dogmatic methods of systems analysis. On the other hand, the application of the second-order first-moment approximation method, due to its simplicity and efficiency, seems to be very effective in estimating the average and standard deviation of engineering demand and sensitivity analyzes instead of Monte Carlo simulation, which is a method with high computational cost.

6. Analysis and Design of Cold-Rolled Steel Structures

The use of these buildings as an independent structural system is often in low-rise mass construction. This structural system can be combined with other structural systems. All components of the system are composed of chilled steel sections. The sections used in this system are C, U, and Z, which are usually connected by cold connections. Each wall consists of a number of general C-shaped components (masters) at intervals of 40 to 60 cm, which are connected at the top and bottom to the horizontal components of U-shaped or C-shaped studs (track or runner). The structural roof of these buildings consists of metal beams in which the distances of the beams are determined according to the bearing capacity of the member and the dimensions of the roof covering parts, which can be gypsum-wooden boards or reinforced concrete slabs. The beams mainly have sections with studs or Z-shape. The vertical components of this system act as compressive load members under gravity loads, as the compression members are located in the braced openings and, in addition to gravity loads, they withstand the forces caused by lateral wind and earthquake loads. These vertical members in this system are called master structures. The connection of the compression members (masters) to the transverse coils (trucks) is done by an intermediate member with gutter sections (runner). The compression members are not continuous at the height of the building and are limited to each floor and under the roof of the upper floor structure. Figures 1 and 2 show all the members of this type of structure.

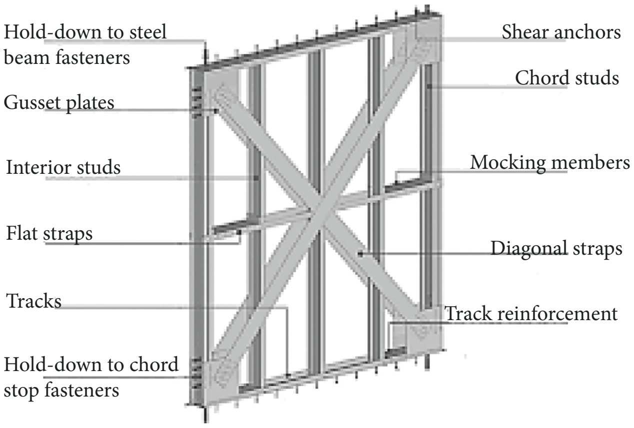


Figure 2: Cold-rolled steel frame components.

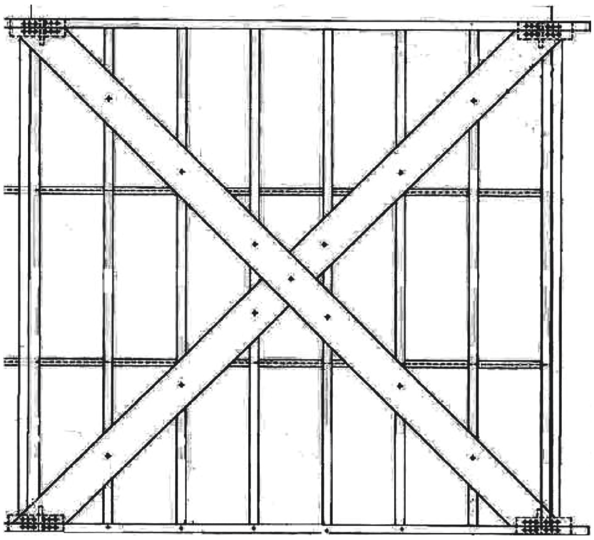
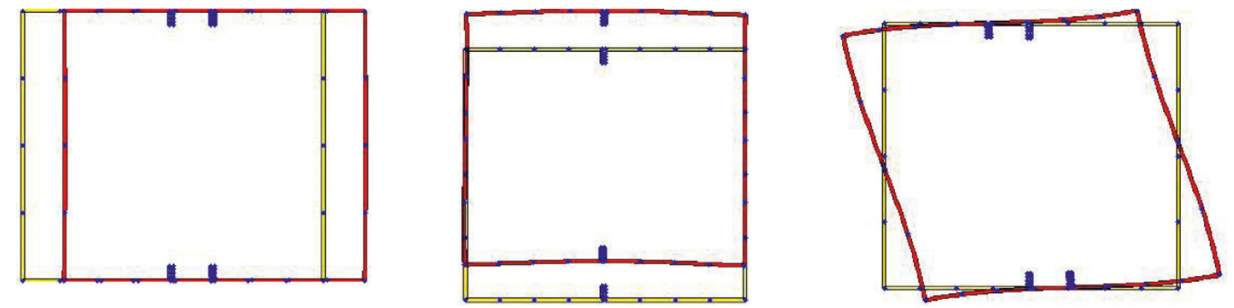


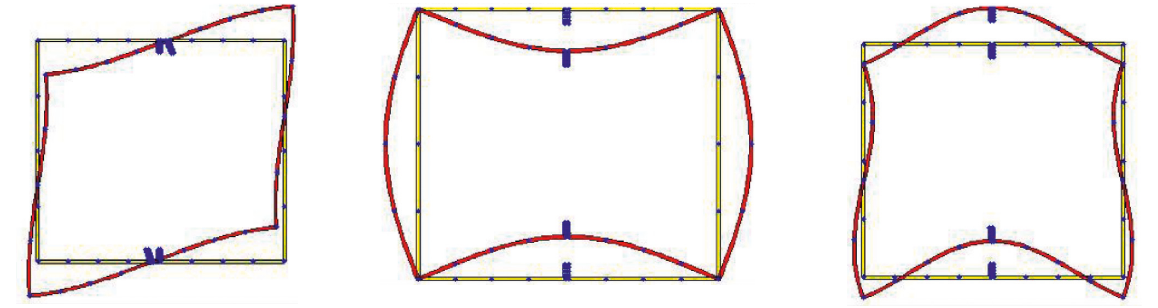
Figure 3: Details of connecting the bracing of diagonal straps to the middle part in the braced opening.

7. Cold-Rolled Steel Frame Structural System

The structural system used in this method shows that, due to the connections between the compressive members and the flexural members, under the effect of gravity loads, the main bending members act as universal beams and the compressive members also transfer the loads under pressure and to the lower floor. Beams with a specific load-bearing surface transfer gravity loads to the main bending beams [14]. First, the diagonal bracing of the mounted frames is explained. In



CUFSM results half-wavelength = 1500 load factor = 273.4787 mode = 1 CUFSM results half-wavelength = 1500 load factor = 1150.7763 mode = 2 CUFSM results half-wavelength = 1500 load factor = 1843.7072 mode = 3



CUFSM results half-wavelength = 1500 load factor = 3097.4678 mode = 4 CUFSM results half-wavelength = 1500 load factor = 6582.7402 mode = 5 CUFSM results half-wavelength = 1500 load factor = 23282.1232 mode = 6

Figure 4: A number of section buckling modes in CUFSM software.

Table 1: Sources of structural uncertainty.

Sources of uncertainty	Random variable	Distribution function
Earthquake spectral acceleration	S_a	Log-normal
Modulus of elasticity of steel	Ey	Log-normal
Live load	L.L	Normal
Primary defect	G	Normal
Dimensions	A	Log-normal

this system, the compression members are distributed along the opening and the diagonal members are connected to them (Figure 3); as a result, in addition to gravity bearing, the compression members also participate in withstanding the lateral forces of wind and earthquake [14].

The cold-formed steel frames were modeled in SAP2000 program and since it is not possible to design double cooled sections in this software, all these sections were modeled in CUFSM finite element software and their loading was controlled. This software calculates and draws a half-wavelength diagram for thin-walled sections. This tool is a vital tool in the latest method of designing thin-walled sections. Due to the fact that this method considers more realistic buckling behavior, the sections designed by it are much more efficient and lighter than conventional methods. In addition, the speed of calculations using the finite strip method is much higher than conventional methods such as finite elements, so the design of sections is done in less time (Figure 4).

The main purpose of this study is to consider the uncertainties of structural analysis and risk analysis in estimating the response of the structure and to calculate the effect of these uncertainties on the response. Before introducing the sources of uncertainty used in analyses, Table 1 summarizes the data related to the uncertainties and the distributions that govern them.

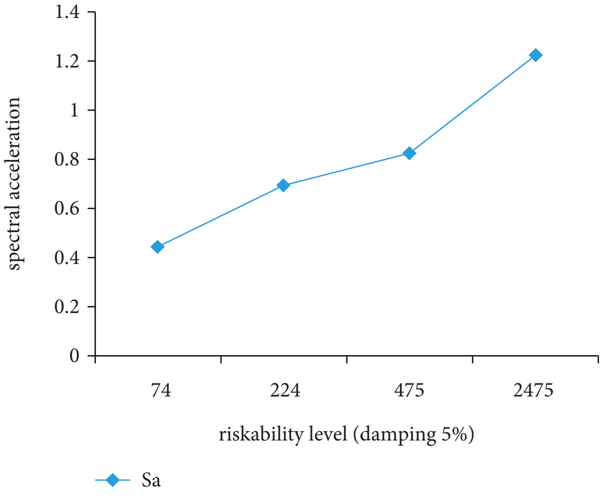


Figure 5: Seismic hazard curve of single-story cold-rolled steel structure with a period of 0.325 seconds.

8. Seismic Hazard Curve

In this research, the city of Kerman is considered as a target area in the process of selecting and scaling earthquakes. According to studies, Kerman is a region with very high seismic risk and the probability of occurrence of high-intensity and shallow earthquakes in this region is very high.

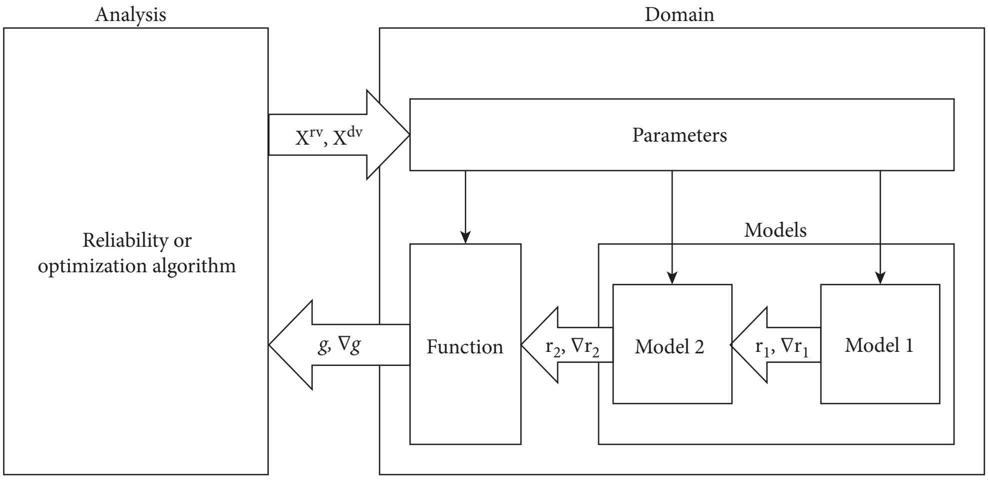


Figure 6: Overview of the analysis method in RT.

Table 2: Results of reliability analysis of the frame of a cold-rolled steel frame by RT program.

FORM		FOSM	Type
Probability of failure	Reliability index	Reliability index	
0.09	1.28	1.27	I

Table 3: Results of the significance of uncertainties scale in FOSM analysis of type I headed frames.

Uncertainty					Type I
Dimensions	Geometry	Live load	E	Spectral acceleration	
-0.22	0.22	0.89	−0.22	0.22	FOSM

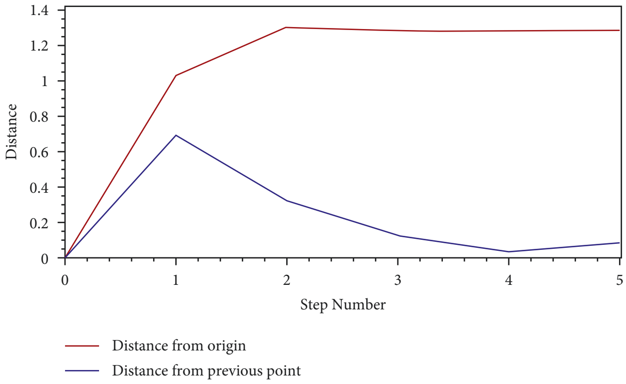


Figure 7: FORM analysis convergence diagram for type I frame in RT program.

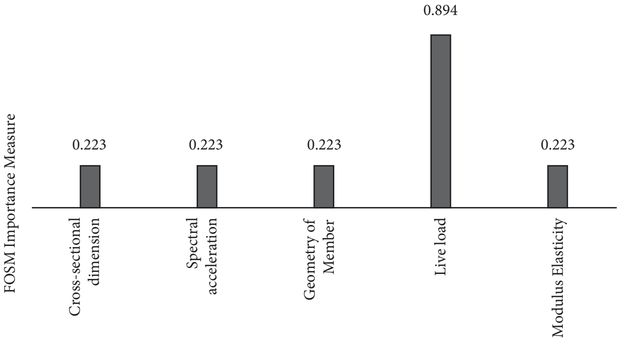


Figure 8: Scale diagram of the significance of type I frame uncertainties in the FOSM method.

Therefore, studies have been conducted in relation to the risk and estimation of the probability of occurrence of different earthquakes with multiple return periods in this region. Based on what was stated and the research conducted in the area, the seismic hazard curve of Kerman for a single-story steel structure with a belt brace and a period of 0.32 seconds has been obtained as follows. As a result of statistical calculations performed for a single-story steel structure, the earthquake acceleration as a random variable follows the normal log probability distribution function with an average of 0.79 g and a standard deviation of 0.11 g. This process has been performed for all structures used in this study and the mean values and standard deviation related to the distribution of earthquake acceleration probability for each structure have been estimated (Figure 5).

The first step in analyzing the reliability and design of structures is to study the distribution of resistance of building members in bending, shear, pressure, torsion, and so forth. The strength of a structural member may differ

Table 4: Results of reliability analysis of cold-rolled two-story steel frame by RT program.

FORM Reliability index	Reliability index	FOSM Reliability index	Type
0.08	1.39	1.41	II

Table 5: Results of the significance of uncertainties scale in FOSM analysis of type II headed frames.

Uncertainty Dimensions	Geometry	Live load	E	Spectral acceleration	Type II
−0.11	0.23	0.93	0.23	0.11	FOSM

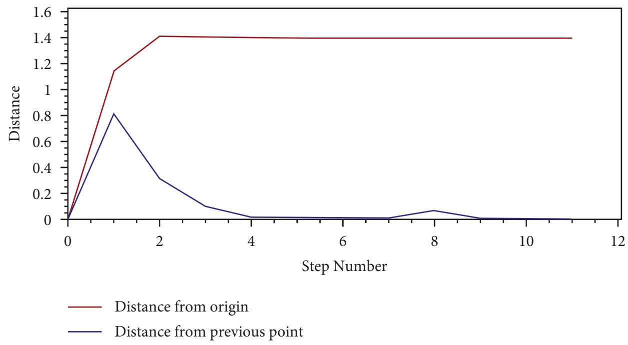


Figure 9: Convergence diagram of FORM analysis for type II frame in RT program.

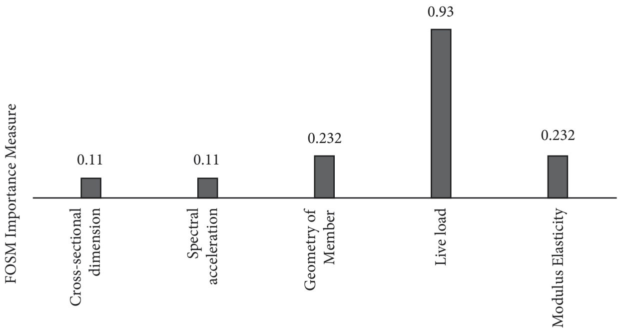


Figure 10: Scale diagram of the significance of type II frame uncertainties in the FOSM method.

from the calculated value or the nominal strength for the member resistances. The main need in reliability studies is to collect information about the strength of physical properties of building materials and their statistical analysis [12]. Structural designers determine the specifications of materials, and manufacturers try to produce materials close to the specified specifications. But if quality control is poor, the strength of the building members will be less than the assumed values. This may endanger the safety of the building. Therefore, in order to provide a design with a reliable level of reliability, systematic characterization of uncertainties in material specifications and statistical analysis of data becomes an important need [12]. Efforts have been made to investigate the probability modulus of elasticity of steel used in structural members of chilled steel structures. According to these studies, which were performed in order to develop the LRFD method for cold-rolled structures, the mean and variance for the modulus of elasticity of cold-rolled steel for log-normal distribution are as follows [1] and the mass curve probability and the cumulative probability function is given as random variable [15].

The RT is a new computer program that is developed to analyze the reliability by combining probabilities. This program can be downloaded online for free. The purpose of the program is to perform reliability and optimization analyzes by overlapping several probabilistic models [16]. RT easily calculates reliability methods such as FOSM, FORM, and sampling as acceptable. This program can be used in any field and is a tool to simulate and predict the actual performance of the structure. Figure 6 shows the reliability analysis algorithm in RT [16]. One of the attractive features of RT software is its linking to other software programs such as Matlab, OpenSees, ANSYS, Abaqus, and SAP2000. In the present study, using this feature, the models made in SAP2000 software are introduced to the RT program and the reliability analysis is performed based on the outputs obtained from it. Also Ullah in 2021 discussed joint shear deformation and beam rotation for RC beam-column eccentric connections [13].

9. Reliability Analysis in Cold-Rolled Steel Frame Models

9.1. Cold-Rolled Steel Frame (Type I). The frame of a cold-rolled steel floor with a belt brace was subjected to reliability analyses by FOSM and FORM methods. In this regard, the results of the analysis are presented in the form of Tables 2 and 3 and Figures 7 and 8.

9.2. Cold-Rolled Two-Story Steel Frame (Type II). The cold-rolled two-story steel frame with belt buckle was subjected to reliability analyses by FOSM and FORM methods. In this regard, the results of the analysis are presented in Tables 4 and 5 and Figures 9 and 10.

Table 6: Results of reliability analysis of three-story steel frame with RT program.

FORM Reliability index	Reliability index	FOSM Reliability index	Type
0.001	3.17	3.62	III

Table 7: Results of the significance scale for uncertainties in FOSM analysis of type III headed frames.

Uncertainty Dimensions	Geometry	Live load	E	Spectral acceleration	Type III
0.00	0.21	0.94	−0.21	0.11	FOSM

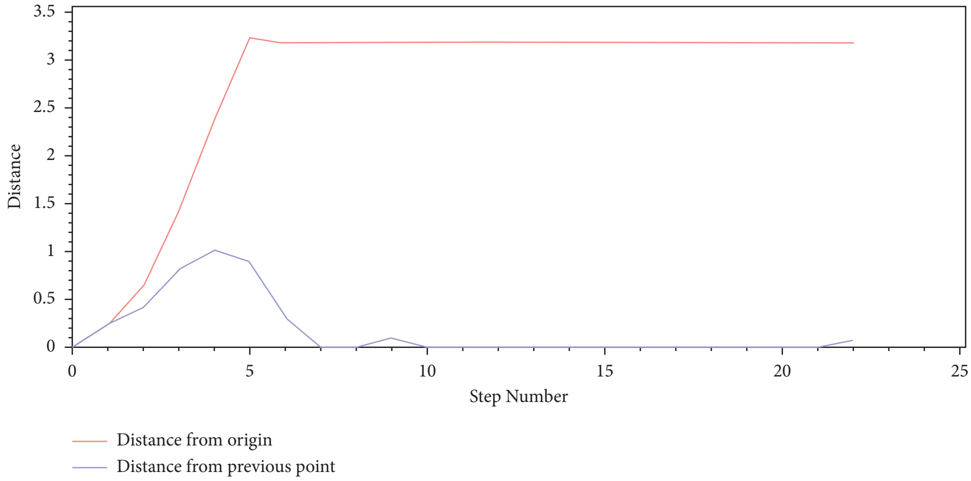


Figure 11: FORM analysis convergence diagram for type III frame in RT program.

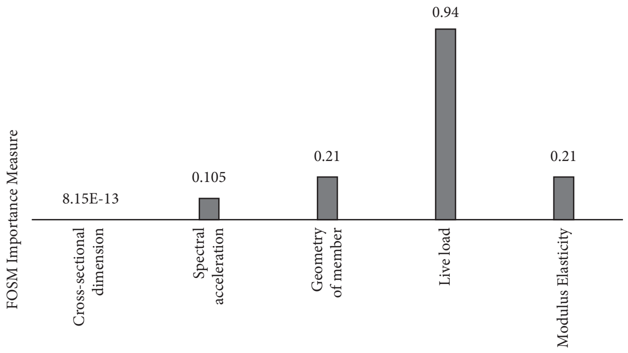


Figure 12: Scale diagram of the significance of type III frame uncertainties in the FOSM method.

9.3. Cold-Rolled Three-Story Steel Frame (Type III). The cold-rolled three-story steel frame with belt buckle was subjected to reliability analyses by FOSM and FORM methods. In this regard, the results of the analysis are presented in Tables 6 and 7 and Figures 11 and 12.

9.4. Cold-Rolled Four-Story Steel Frame (Type IV). The four-tiered steel frame with belt buckle was subjected to reliability analyses by FOSM and FORM methods. In this regard, the results of the analysis are presented in Tables 8 and 9 and Figures 13 and 14.

9.5. Cold-Rolled Five-Story Steel Frame (Type V). The five-layer rolled steel frame with belt bracing was subjected to reliability analyses by FOSM and FORM methods. In this

Table 8: Results of reliability analysis of four-story steel frame with RT program.

FORM	FOSM		Type
Reliability index	Reliability index	Reliability index	
0.002	2.90	6.74	IV

Table 9: Results of the scale of significance of uncertainties in FOSM analysis of type IV headed frames.

Uncertainty Dimensions	Geometry	Live load	E	Spectral acceleration	Type IV
0	0.12	0.96	−0.24	0	FOSM

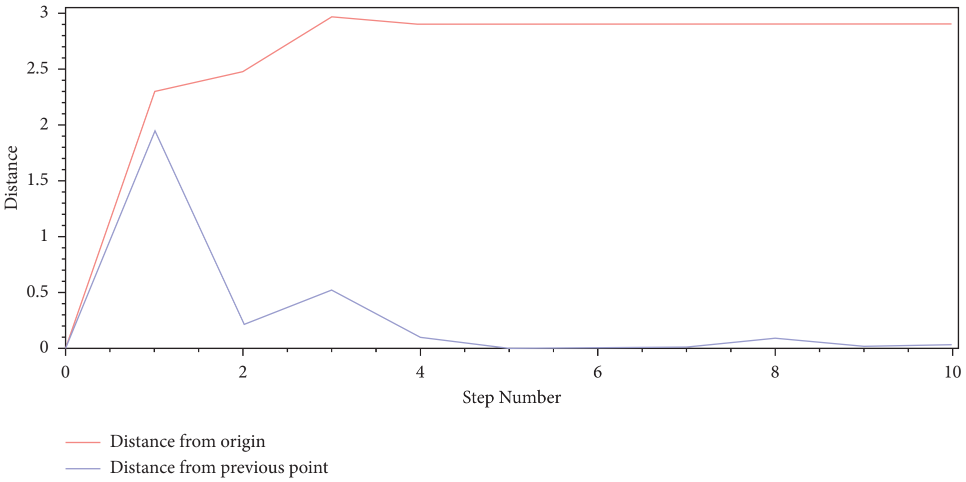


Figure 13: Convergence diagram of FORM analysis for type IV frame in RT program.

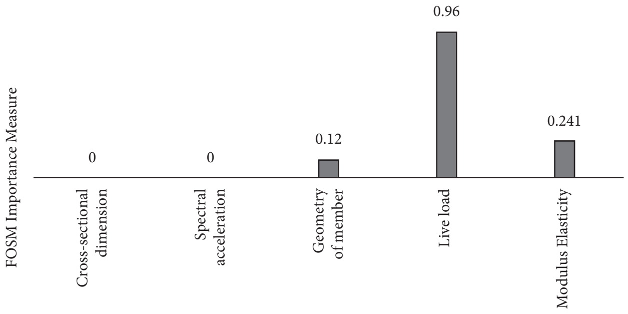


Figure 14: Scale diagram of the significance of type IV frame uncertainties in the FOSM method.

Table 10: Results of reliability analysis of five-layer chilled steel frame by RT program.

FORM		FOSM	Type
Reliability index	Reliability index	Reliability index	
0.001	3.15	8.83	V

Table 11: Results of the significance scale for uncertainties in FOSM analysis of type V header frames.

Uncertainty					Type V
Dimensions	Geometry	Live load	E	Spectral acceleration	
-0.12	0	0.81	−0.35	0.46	FOSM

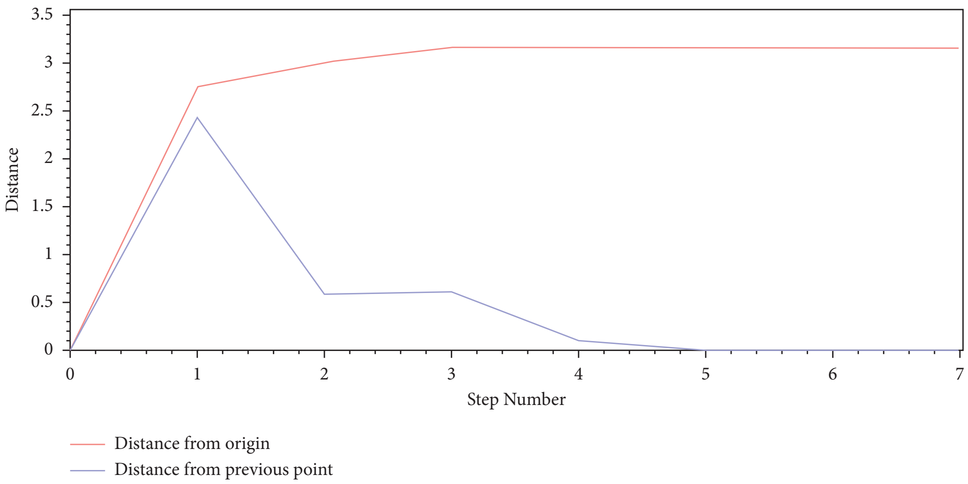


Figure 15: Convergence diagram of FORM analysis for type V frame in RT program.

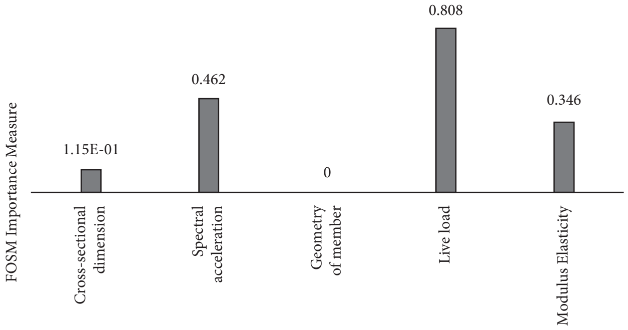


Figure 16: Scale diagram of the significance of type V frame uncertainties in the FOSM method.

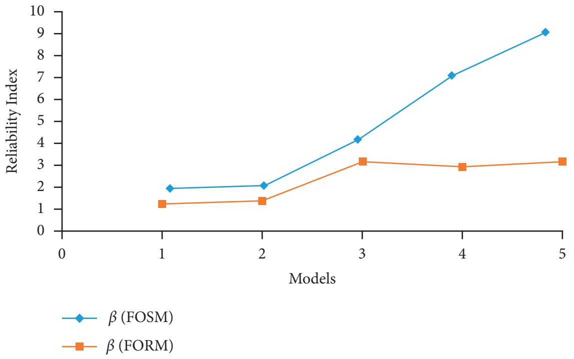


Figure 17: Comparison of reliability indices of FOSM and FORM methods in models.

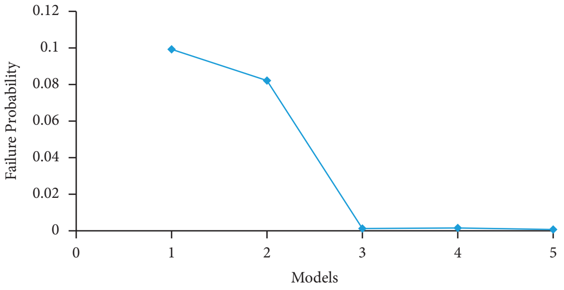


Figure 18: Possibility of failure in models.

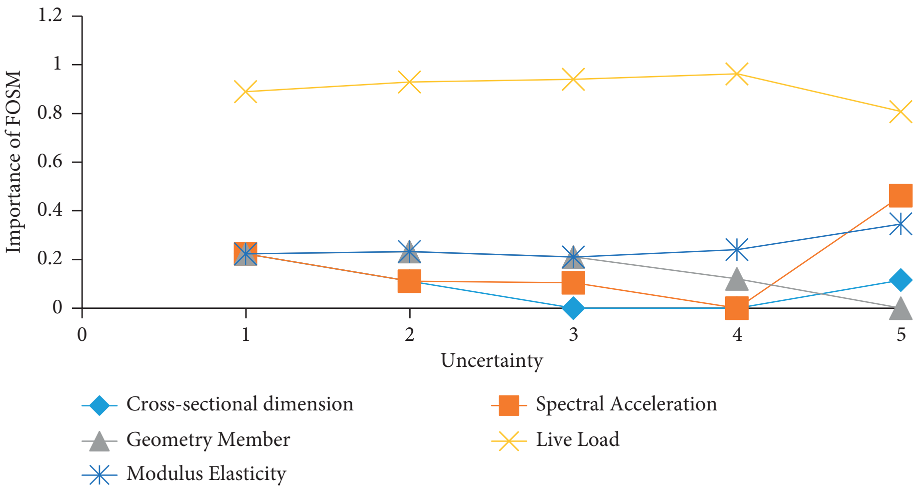


FIGURE 19: Measure the importance of uncertainties in models.

regard, the results of the analysis are presented in Tables 10 and 11 and Figures 15 and 16.

Figure 17 shows that the confidence index has an upward trend with increasing index classes. In Figure 18, the probability of failure as the classes increase increases the downward trend. Figure 19 shows the participation of uncertainties in the FOSM method in different types of cold-rolled steel frames, the most effective of which is the live load.

10. Conclusion

A more detailed study of the behavior of light steel cold-rolled frames requires the use of new methods such as structural reliability analysis and performance-based design and, as mentioned in the previous sections, the use of these methods in considering uncertainties in the analysis process, as well as finding and classifying these sources of uncertainty in terms of their impact on the response of the structure, which is obtained through the analysis of the FOSM significance index; another requirement is probability-based analysis. In this research, using the probability-based method (second-moment), which includes two methods of reliability analysis of FOSM and FORM, the effect of structural and seismic parameters on the structural response has been investigated. Reliability analysis methods have been examined and, among these, two methods of FOSM and FORM analysis have been considered. In order to calculate the parameters in the form of FOSM and FORM probabilistic methods, the probabilistic distributions governing the structural parameters have been obtained by reviewing the research works. The five types are modeled in SAP2000 and CUFSM software and, after introducing these models to RT software, defining uncertainties in it, and performing long-term analyses, two reliability indicators, FOSM and FORM methods, were calculated. The modulus of elasticity after the live load is the most important among the assumed uncertainties and the share of this uncertainty is almost the same in all frames. Uncertainty in the spectral acceleration of an earthquake in a five-story frame has the greatest contribution. The largest contribution to spectral acceleration occurs in the five-story frame. The contribution of uncertainty in cross-sectional dimensions has a decreasing trend with the increase of frame classes.

Data Availability

Requests for access to these data should be made to the corresponding author (e-mail address: s.zekri@student.kgut.ac.ir).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

[1] L.-E. Hsiao, W.-w. Yu, and T. V. Galambos, *Load and Resistance Factor Design of Cold Formed Steel Reliability Based Criteria for Cold Formed Steel Members*, pp. 114–119, Missouri University of Science and Technology, Rolla, Missouri, 1990.

[2] W.-W. Yu and R. A. LaBoube, *Cold Formed Steel Design*, John Wiley & Sons, NY, USA, 2010.

[3] S. M. Seyed Kolbadi, N. Hassani, S. M. Seyed-Kolbadi, and M. Mirtaheri, “Analyzing parametric sensitivity on the cyclic behavior of steel shear walls,” *Shock and Vibration*, vol. 2021, Article ID 3976793, 10 pages, 2021.

[4] A. Grummel, *Development of Fragility Curves for Cold Formed Steel Light-Framed Structural Systems: A Two-Pronged Approach*, pp. 9–11, Washington State University, Washington, USA, 2010.

[5] B. W. Schafer, M. Grigoriu, and T. Peköz, “A probabilistic examination of the ultimate strength of cold formed steel elements,” *Thin-Walled Structures*, vol. 31, pp. 1–18, 1998.

[6] S. M. S. Kolbadi, H. Piri, A. Keyhani, S. M. S. Kolbadi, and M. Mirtaheri, “Seismic performance evaluation of slotted-web and bolt-flange plate moment connection,” *Earthquakes and Structures*, vol. 20, no. 6, pp. 655–667, 2021.

[7] E. Nikolaidis, D. M. Ghiocel, and S. Singhal, *Engineering Design Reliability Handbook*, pp. 22–50, CRC Press, Boca Raton, Florida, 2004.

[8] R. Ranganathan, *Reliability Analysis and Design of Structures*, pp. 34–75, Tata McGraw-Hill, NY, USA, 1990.

[9] R. Ullah, M. Fahim, and M. Nouman, “Joint shear deformation and beam rotation in RC beam-column eccentric connections,” *Civil Engineering Journal*, vol. 7, no. 2, pp. 236–252, 2021.

[10] H. T. Pinheiro, G. Eyal, B. Shepherd, and L. A. Rocha, “Ecological insights from environmental disturbances in mesophotic coral ecosystems,” *Ecosphere*, vol. 10, no. 4, p. e02666, 2019.

[11] M. Abedin, E. Shahrokhinasab, and S. Mokhtari, “Net section fracture assessment of welded rectangular hollow structural sections,” *Civil Engineering Journal*, vol. 6, no. 7, pp. 1243–1254, 2020.

[12] S.-K. Choi, R. V. Grandhi, and R. A. Canfield, *Reliability-based Structural Design*, pp. 13–32, Springer Science & Business Media, Heidelberg, Germany, 2006.

[13] S. Gavrilovic, *Reliability-based Design Optimization Using DDM Enabled Finite Elements*, pp. 20–22, University of British Columbia, Canada, 2015.

[14] S. E. Institute, *Bracing Cold Formed Steel Structures: A Design Guide*, American Society of Civil Engineers/ASCE, USA, 2005.

[15] J. Kim, J.-H. Park, and T.-H. Lee, “Sensitivity analysis of steel buildings subjected to column loss,” *Engineering Structures*, vol. 33, no. 2, pp. 421–432, 2011.

[16] M. Mahsuli, *Probabilistic Models, Methods, and Software for Evaluating Risk to Civil Infrastructure*, University of British Columbia, Canada, 2012.