Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 997-1001

AENSI Journals

Journal of Applied Science and Agriculture

Journal home page: www.aensiweb.com/jasa/index.html

Application of FOSM method to evaluate the reliability of the RCS frame Detection

[1]Hosseinnezhad A., [1]Heidarpour B., [1]Panjalizadeh Marseh B., [3]Ekramirad A.

[1]*Department of Civil Engineering, Young Researcher Club, Roudsar and Amlash Branch, Islamic Azad University, Roudsar, Iran.*
[3]*Department of Civil Engineering, Langroud Branch, Islamic Azad University, Langroud, Iran.*

ARTICLE INFO

Article history:
Received 19 October 2013
Received in revised form 16 January 2014
Accepted 22 January 2014
Available online 3 February 2014

Keywords:
RCS frame,Nonlinear analysis, Reliability

ABSTRACT

Background: The RCS composite system consisting of reinforced concrete columns and steel beams. The optimal use of compressive and flexural properties of concrete and steel causes the structure become lighter than the normal moment bearing reinforced concrete frames. **Objective**: Also compared to the moment bearing steel frames with large spans, the RCS frames show better behavior during earthquakes. **Results:** In this research the reliability of the RCS frames (frame with steel beams and reinforced concrete columns) is studied. The parameters, (special strength of concrete), (yield stress of steel bars and sections), (sectional area of compressive steel bars), d (effective depth of steel bars), DL (dead load), LL (live load) and the length of spans are considered as random variables. First order second moment method is used to calculate the reliability of the RCS frame. **Conclusion:** The frame is modeled by using the finite element software and the analysis is done in probabilistic method. Finally the effect of height of floor and span length on the reliability of the structure is studied.

To Cite This Article: Hosseinnezhad A., Heidarpour B., Panjalizadeh Marseh B., Ekramirad A., Application of FOSM method to evaluate the reliability of the RCS frame Detection. ***J. Appl. Sci. & Agric.***, *8(6): 997-1001, 2013*

INTRODUCTION

The RCS frame is one of the new structural systems which is used in frames with large spans and normal height. In common reinforced concrete moment frames with large spans, the beams dimensions occupy the space of roof and defect the interior architectural view of building. The RCS structural system solves the problem by using steel beams. Moreover, the moment bearing steel frames with large spans in many cases show nonlinear behavior due to earthquake loading that the recent problem is solved by using suitable materials in the RCS frames. Many research centers in the world are probing the behavior of the RCS structural system and in this paper the reliability of the system is studied.

MATERIALS AND METHODS

Characteristics RCS frame:

The RCS structural system is a combination of steel beams and reinforced concrete columns. The beams are attached to the columns by a special connection which is shown in Figure 1. The columns below and top of any connection restrain the beams and provide desired stiffness . However, the lack of top reinforced concrete column in the last floor causes the considered stiffness does not provide. So, the mentioned floor design and constructed by steel beams and columns. In Figure 1, a 4 span and 10 floor RCS frame with a connection joint is illustrated. The analysis and design are accomplished based on the AISC-ASD 89 and ACI 318-99 codes.

Reliability theory:

In fact, reliability theory is a technique to relate the rate of the structure safety versus received loads. In this method, unlike the usual methods, is tried that as much as possible, the available parameters in the procedure of structure analysis and design get closer to reality. In other words, in this method the status of analysis and design change from deterministic to probabilistic. In deterministic case, the parameters which are involved in designing process usually have specific quantities, but in probabilistic case each available parameter is considered as a random variable and is recognized by a general characteristic which is called "probability density function". According to these probability density distribution functions, variables are defined by two other detailed characters which are named mean value and standard deviation. Mean value and standard deviation are used in structure probabilistic analysis procedure. To analyze each structure, first the failure criteria are defined and according to those, several restrictive conditions that are name the boundary conditions are considered. Finally,

Corresponding Author: Hosseinnezhad A., Department of Civil Engineering, Roudsar and Amlash Branch, Islamic Azad University, Roudsar, Iran.

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 997-1001

according to the defined boundary conditions, the safety margin equation is defined. Then by doing a random analysis a parameter that is named the reliability index obtains which states the real available rate of safety in the structure for the defined boundary conditions (Ranganathan, R.1992)

In a general look, structures reliability analysis methods are classified in to three levels. The first level consists of method based on load and resistance factor design which is known as LRFD method and is called 1^{st} level reliability method. The second level comprises a method based on mean value (first order) and standard deviation (second moment) of random variables which is called 2^{nd} level reliability method (FOSM). The third level includes a method based on probabilistic distribution functions that are defined for all variables. Surely, this last method is the best way to relate structure reliability. But because of integral probabilistic distribution functions for variables are not available practically, thus to implement of this method at the present time is actually impossible. The last method is called 3^{rd} level reliability analysis method. In this research reliability analysis has been done by the second method that is 2^{nd} level reliability analysis method (Ranganathan, R.1992)

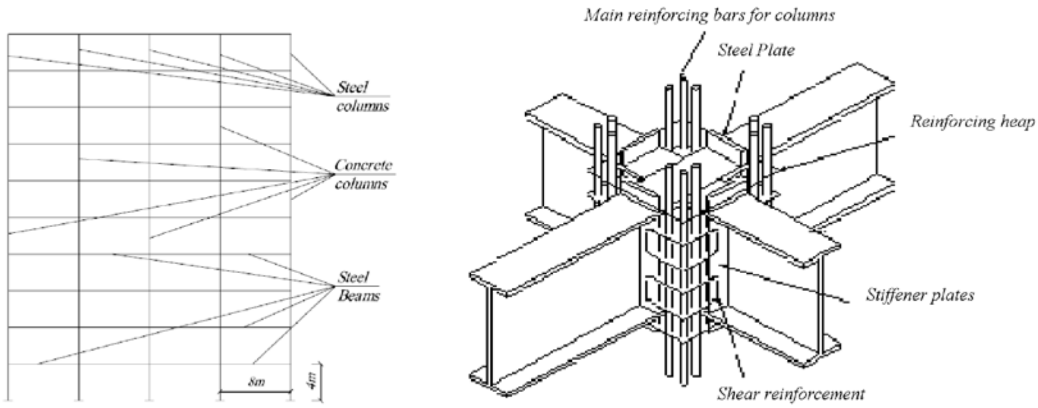

Fig. 1: RCS frame and a connection joint

Failure criteria:

The failure criteria which are defined in usual design methods do not give a correct view of the safety rate and the failure state of the structure. For example, in the serviceability limit state, the maximum depth of cracks or deflections of structure are considered as failure criteria, whereas even if these criteria don't happen, complete failure of structure may be far. In the reliability analysis method, formation of a mechanism is a failure criterion. In other words, in this method the structure is considered to be damaged when it is involved in partial (3 joint in one direction mechanism or rotational mechanism) or thorough (number of plastic hinges equal to degree of indeterminacy +1) mechanism. Thus boundary conditions are defined by considering these failure criteria. According to the defined boundary conditions, the safety margin equation is defined. This equation is obtained from subtracting the effect of received loads (S) out of resistance of the structure (R). For this equation, mean values and standard deviations are computed by available statistical methods and according to them; structure safety rate for considered boundary conditions is computed.

In this research, structure safety rate has been computed for bending moments caused by loading. In this method, failure criterion for steel members is the formation of plastic hinge and for the reinforced concrete members is the maximum possible compressive strain (Ranganathan, R.1992).

Limit states and safety margin equation:

According to the defined failure criteria in the research related to reinforced concrete structures, the boundary conditions are defined as below (Biondini *et al*,2004).

$$\varepsilon_{cu} \leq 0.003 \tag{1}$$

In which, ε_{cu} is the maximum compressive strain of concrete. Also, the equation of safety margin has been given like [2] :

$$g = R - S \tag{2}$$

In which, R is resistance of structure and S is the effect of received load on structure and the equation of failure probability is defined as: [2, 4]

$$P_f = P(R < S) = P(R - S < 0) = P\left(\frac{R}{S} < 1\right) \tag{3}$$

In which p_f is the failure probability of structure. Now, if R and S to be considered as random variables, Eq. (4), by using probabilistic equations, is stated as (Ranganathan, R.1992).

$$P_f = 1 - R_0 = 1 - \int_{-\infty}^{+\infty} f_S(S) \times [1 - F_R(S)]\, ds \tag{4}$$

In which, R_o is reliability of structure, f_s is probability density function of S and $F_R(S)$ is the cumulative distribution function of R. Results of the integrals obtain a value for failure probability of the structure and also the reliability. These formulas are very complicated, so to solve them in many cases, numerical methods are used (Ranganathan, R.1992).

Failure modes:

In a RCS frame, failure modes can be seen in 3 kinds. 2 modes appear in the form of partial failure (beam failure or rotational failure) and one of them appears in the form of complete failure (collapse). To form a complete failure in a structure (collapse), the number of the plastic hinges must be equal with the degree of indeterminacy plus one. But for a partial failure in a fixed-end beam, the accessibility of only 3 plastic hinges in a straight direction is enough. Excessive rotation of a reinforced concrete joint leads to form a rotational partial failure mode. Therefore, it is necessary that in each phase of analysis the amount of rotation of reinforced concrete joints be controlled in order to check this partial failure mode. The required equations to compute the maximum plastic rotation are given as follows (Ranganathan, R.1992).

$$\theta_y = \frac{Z\,F_{ye}\,L_b}{6\,E\,I_b} \qquad \text{Beams (5)}$$

$$\theta_y = \frac{Z\,F_{ye}\,L_c}{6\,E\,I_c}\left(1 - \frac{P}{P_{ye}}\right) \qquad \text{Columns (6)}$$

In which θ_y is yield rotation, E is modulus of elasticity, L_B is beam length, L_C is column length, P is axial force in element, $P_{ye} = A_g \times F_{ye}$ is axial yield force of the member and Z is plastic modulus of the section.

RESULTS AND DISCUSSION

Numerical studies:

In order to study the reliability of RCS frames, 4-span frames with 6 and 8 meter length and 2 to 10 floors (the height of each floor = 4 meters) are analyzed. Finally, the effect of increasing the number of floors for each span length, on reliability of frame is studied.

Random variables and their distribution functions:

Many variables exist in the matter that can be considered as random variables. Table 1 shows the specified random variables with their specifications (Biondini *et al*,2004).

Table 1: Random variables and their specifications

Random variable	Mean value	Standard deviation	Distribution function
f_c' (characteristic strength of concrete)	40 $\frac{N}{mm^2}$	5 $\frac{N}{mm^2}$	LN
f_y (yield strength of steel bars)	410 $\frac{N}{mm^2}$	100 $\frac{N}{mm^2}$	LN
d(effective depth of steel bars)	Nominal value	5 mm	N
DL (dead load)	6000 $\frac{N}{mm^2}$	600 $\frac{N}{mm^2}$	N
LL (live load)	2500 $\frac{N}{mm^2}$	250 $\frac{N}{mm^2}$	N
A_s' *(sectional area of compressive steel bars)*	Nominal value	0.025 A_s'	N

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 997-1001

LN is logarithmic normal distribution function and N is normal distribution function.

Equation of safety margin, according to the defined boundary conditions is obtained as follows:

$$g = M_u - M_s \tag{7}$$

In which M_u is ultimate moment of section and M_s is the moment caused by loading. By using probability formulas, mean value and standard deviation of safety margin equation are stated as follows:

$$\mu_g = \mu_{Mu} - \mu_{Ms} \tag{8}$$

In which μ_{Mu} is the mean value of ultimate moment of section and μ_{Ms} is mean value of the moment caused by loading. The quantity of standard deviation of safety margin equation is given like the following:

$$\sigma_g = \left(\sigma_{Mu}^2 + \sigma_{Ms}^2\right)^{\frac{1}{2}} \tag{9}$$

By using equations 8 and 9, reliability index is stated as given.

$$\beta = \left(\frac{\mu_{Mu} - \mu_{Ms}}{\sqrt{\sigma_{Mu}^2 + \sigma_{Ms}^2}}\right) \tag{10}$$

In this equation β is reliability index and from that, failure probability of the structure is stated as the following:

$$P_f = \Phi(-\beta) \tag{11}$$

In which equation Φ is standard normal distribution function with zero mean value and standard deviation equal to one. According to the defined boundary conditions, the resisting force for reinforced concrete section is defined as follows (Tahooni Sh,2000).

$$M_u = C_c \times \left(d - \frac{a}{2}\right) + C_s \times (d - d') \tag{12}$$

In which, C_c is the compression force in the compressive region of concrete, *d* is depth of tensile bars, *a* is the height of equivalent rectangular block for compressive stress prism of concrete, C_s is the force in compressive bars and d' is effective depth of compressive bars. Mean value and standard deviation of M_u according to mean value and standard deviation of Eq. (13) variables are stated as follows (Ranganathan, R.1992):

$$\mu_{Mu} = \mu_{C_C} \times \left(\mu_d - \frac{\mu_a}{2}\right) + \mu_{C_S} \times \left(\mu_d - \mu_{d'}\right) \tag{13}$$

$$\sigma_{M_u} = \left\{\left(d - \frac{a}{2}\right)^2 \sigma_{C_C}^2 + (d - d')_\mu^2 \sigma_{C_S}^2 + (C_C + C_S)_\mu^2 \sigma_d^2 + (C_S)_\mu^2 \sigma_{d'}^2 + \left(\frac{C_C}{2}\right)_\mu^2 \sigma_a^2\right\}^{\frac{1}{2}} \tag{14}$$

Computing reliability

By using equations 7 to 14, reliability of frames is computed. The results are presented in table below.

Table 2: Effect of floor no. vs. reliability index

NF / L	2	3	4	5	6	7	8	9	10
6 m	3.83	3.54	3.34	3.18	3.06	2.95	2.58	2.77	2.69
8 m	3.12	2.78	2.54	2.35	2.20	2.07	1.95	1.86	1.77

NF: number of floors and L: length of span

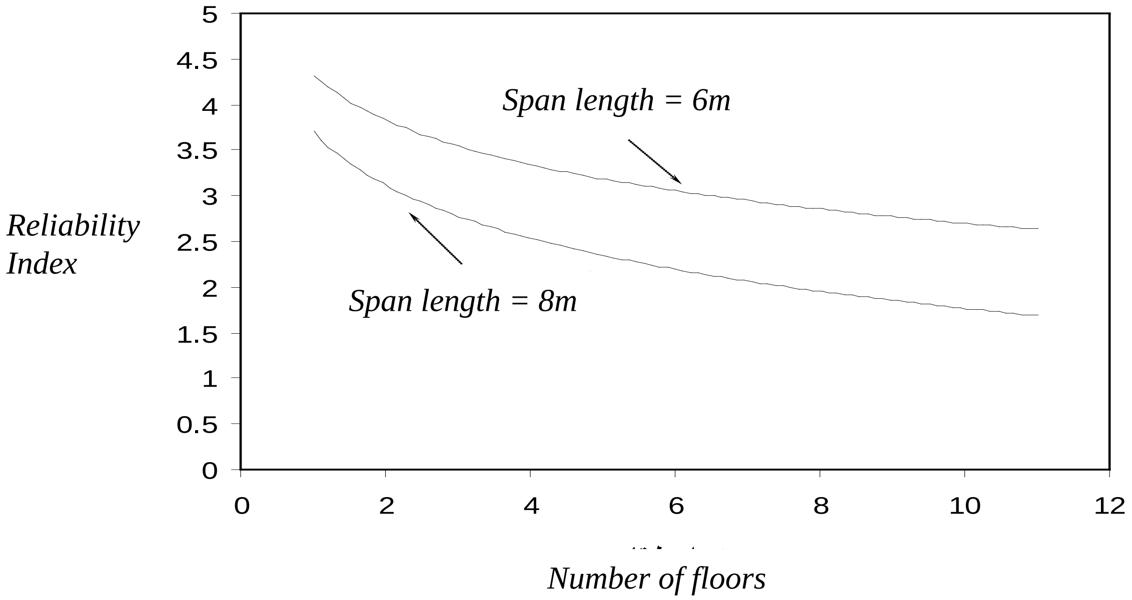

Fig. 2: Reliability index vs. number of floors

Conclusions:

The reliability of RCS frames by FOSM method was studied. Characteristic strength of concrete $\left(f_c'\right)$, yield stress of bars $\left(f_y\right)$, effective depth of bars $\left(d\right)$, A_s' (sectional area of compressive steel bars), dead load (DL) and live load (LL) were considered as random variables. According to these considerations, the results are presented.

The results represent that unlike conventional structural frames the reliability reduced sharply by increasing the degree of indeterminacy. This may be due to the special connection between the steel beams and the reinforced concrete columns. In the RCS frame the provided stiffness in a connection joint is approximately 80% of a similar connection in a steel or reinforced concrete moment bearing structural system. Moreover, it is clear that the reliability index reduces significantly by increasing the span length and story height. So, the application of the RCS frame is limited by the length of spans and story height. To sum up, implementation of the RCS frame instead of normal moment bearing steel and reinforced concrete systems is not a suitable alternative in frames with large spans and long height. In other words, the use of this structural system over large span is not suitable for high altitude.

REFERENCES

Biondini, F. *et al*. 2004. “Reliability of material and geometrically non-linear reinforced and prestressed concrete structures”, Computers & Structures.

Castillo, E. *et al*,2002. “Computing failure probabilities. Applications to reliability analysis”, Reliability Engineering & System Safety, 77: 131-141.

Ranganathan, R., 1992. “Reliability analysis and design of structures”, Tata McGraw-Hill Publishing.

Tahooni Sh, 2000. Design of Reinforced Concrete Structures Based on ACI. University of Tehran Publishing.

The ASCE, 1985. Task Committee on Design Criteria for Composite Structure in Steel and Concrete “Guidelines for Design of Joint between Steel Beams and Reinforced Concrete Columns.