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Reliability-based Evaluation of Beams Designed in Accordance with Iranian Design Code

E. Jahani*

Assistant Professor, Faculty of Engineering and Technology, University of Mazandaran

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ABSTRACT

Iranian design code like any other design code increases the reliability of a structure by means of multiplying the partial safety factors by load and resistant. The reliability index can be evaluated in order to survey the reliability of structures. In this paper, the reliability index of a beam as an important member of a structure is considered and the effect of the values and coefficient of variation of design parameters on the reliability index is surveyed. Finally, the partial safety factors for different states are proposed. In this paper, a new method based on genetic algorithm (GA) is used to calculate the reliability index. This new method has more efficiency in comparison with the classic methods and the simulation methods such as Monte Carlo. This method does not require the mathematical form of the limit state function and on the other hand, this method takes less computational time in comparison with simulation methods. In structural construction, there are many different design parameters which are random variables. Probability distribution can be considered for each of these random variables. For different statistical data of design parameters, different partial safety factors are needed to optimum design of a beam. However, Iranian design code considers the constant partial safety factors for all different conditions. In case that the exact and specific statistical data of design parameters are available, the structural reliability analysis can be applied for reaching an optimum design. The statistical data of design parameters can be obtained by gathering the statistical data in any country and after that a reliable design code can be obtained based on these statistical data. Because of lack of statistical data of design parameters in Iran, five usual conditions were considered for data and then partial safety factors are calculated.

KEYWORDS:

Reliability Theory, Genetic Algorithm, Reliability Index, Limit State Function

* Corresponding Author, Email: e.jahani@umz.ac.ir

1- Introduction

In construction of any structural member, there are many design parameters which these parameters are random variables. Therefore, probability distribution functions can be considered for each of these design parameters. Some of these design parameters have negligible coefficient of variation so those can be considered as certain parameters. But some of them have significant coefficient of variation which must be considered. These random design variables are called basic variables. Due to the random behavior of the design parameters, the probability of structural failure or structural damage cannot be stated definitively. The reliability theory is used to calculate the failure probability of a structure. There are several ways to determine the reliability index. In this approach, the limit state function is approximated by the first sentence of Taylor series in the average point and thus the limit state function becomes a linear function. By calculating the mean and standard deviation of the limit state function, reliability index is obtained by Eq. (1):

$$\beta = \frac{\mu_m}{S_m} \tag{1}$$

where μ_m and S_m are the mean and standard deviation of the limit state function. The failure probability P_f can be approximately calculated by Eq. (2):

$$P_f = \Phi\left(-\beta\right) \tag{2}$$

In which, Φ is a standard normal cumulative distribution function. But this method obtains an exact response only for linear limit state function. If the limit state function is not a linear function, this approach cannot represent an exact response. But the more sentences of the Taylor series expansion for the limit states can be considered to solve this problem. Another disadvantage of the Cornell method is that for different mathematical forms of the specified limit state function, different values for reliability index is obtained. To solve this problem Hasofer and Lind [3] in 1974, with normalization of random variables, transformed the problem space into a normalized space. In this approach, the form of the limit state does not affect the value of reliability index. All of these methods that require mathematical form of the limit state function are called analytical approaches and this requirement is the biggest disadvantage of these analytical approaches. Monte Carlo analysis has been proposed to solve this problem [4]. But in the Monte Carlo analysis the design point which is an important part of the reliability based design cannot be obtained. The genetic algorithm that has not any of these constraints can be considered as a viable solution. In this paper, a brief introduction to the genetic algorithms and reliability theory using genetic algorithms is expressed. To learn more about the theory of reliability see [5-7].

2- Genetic algorithm

Genetic algorithms as a powerful tool in the search and optimization for the first time presented in John Holland's doctoral thesis in 1974. In this algorithm, at first a set of solutions is considered randomly and then using three operations selection, crossover and mutation from a generation to next generation the better solution is obtained.

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3- Assessment of the reliability index of the beam

The reliability index of each structural member designed based on Iranian design codes depends on the statistical parameters of the design parameters of structural members. In this paper, the reliability index of the beam is evaluated in different situations.

4- Results and discussion

In this paper, partial safety factors are calculated for different statistical parameters of design variables. Table 1 shows these partial safety factors for five different situation of statistical parameters.

Table 1. Partial safety factors

Basic variables	1	2	3	4	5
f_s	0.66	0.68	0.72	0.7	0.74
f_c	0.93	0.93	0.65	0.93	0.68
DL	1.05	1.05	1.05	1.05	1.05
LL	1.06	1.22	1.2	1.68	1.65

5- Conclusions

As can be observed for designing a beam, for different statistical data of design parameters, different partial safety factors are achieved. Iranian design codes like other design codes represents the same partial safety factors in all different statistical situations. Thus, if there is detailed statistic information of design parameters, the reliability analysis can be used to achieve optimum design with a specified reliability index. However, by collecting statistical data in each country, the statistical parameters of the design parameters can be obtained in that country and then based on this information, the design code can be prepared based on reliability theory.

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