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Using new methods to assess the safety of civil engineering systems

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Abstract
This article examines the use of new methods to assess the safety of civil engineering systems. Currently, safety is very important in the design and construction of civil structures and systems and should be evaluated with appropriate methods. The new methods discussed in this article include the error and risk factor analysis method, code coverage analysis method, dangerous mode analysis method, neural network analysis method, and state space analysis method. The purpose of using these methods is to identify and find errors and risk factors in construction systems. The occurrence of failure in some civil engineering systems such as structures (such as trusses and frames), underground arterial networks (such as water and gas networks), etc., usually with a logical equation A complex or a combination of multiple failure events is expressed. Unlike the existing methods of reliability analysis, MSR and SCM methods are used in any type of system, including series, parallel and complex, and even can consider the dependence between parameters. don't Unlike old methods, new methods do this automatically and accurately using artificial intelligence and machine learning algorithms. These methods can identify small and large errors in construction systems and increase safety and reduce the risks associated with them. The sequential combination method can be used for systems with a large number of components, without adding to the cost and time of calculations. In general, using new methods to assess the safety of civil engineering systems improves performance and reduces risks in civil systems. Considering the potential of these methods, more research is needed in the field of their use in the operational industry. Also, the results show the high speed and accuracy of this method in calculating the reliability of structural systems, compared to other existing methods.
Keywords: Reliability, system safety evaluation, new safety methods, MSR and SCM systems, civil engineering

1. Introduction

In today's world, civil engineering systems face many complexities and challenges. These systems usually include various factors that need to be properly analyzed and evaluated to ensure that they will function properly and that any possible risks and threats are minimized. [2]

Considering the level of complexity and risks associated with civil engineering systems are increasing, there was no need for new methods to evaluate the security and validity of the systems. In the past, traditional methods were used, which are generally based on the previous experience and knowledge of the individual. However, with the emergence of new technologies and scientific advances, new methods have been created to evaluate the security of systems. [4]

In this article, the review and introduction of new methods for evaluating the security of civil engineering systems will be discussed. These methods include the use of artificial neural networks, genetic algorithm, fuzzy system, and other artificial intelligence methods that can analyze the data of researchers and provide

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accurate analysis results about the security of the performance system. By using these new methods, researchers and specialists will be able to check different systems in a safely and reliably way with higher accuracy and less time.

Engineers have officially recognized the existence of uncertainty and its effects on the analysis, design, and planning of engineering systems. Although traditional methods, for simplification, consider non-deterministic parameters in a deterministic way or use safety coefficients instead of uncertainties. These methods may give an incorrect estimate of the safety level or give us wrong information to reach maximum safety against the optimal design. [2]

One of the important issues is how to use these probabilistic methods. This requires a large volume of calculations to combine uncertainty and possible scenarios, other than deterministic methods. In other words, mixing a non-linear system of mechanical, structural, and statistical models complicates the problem and also increases the cost of calculations [3]

Analytical methods include first-order second-anchor methods (FORM-SORM), which are used to describe the failure of a system with a given limit state (or only failure control). The second aspect (FORM-SORM), which has been presented to describe the failure of a system with a limited state (or only failure control), can be named. These analytical methods, despite having an error, have a higher yield than Simulation methods in the calculation have reliability [3]

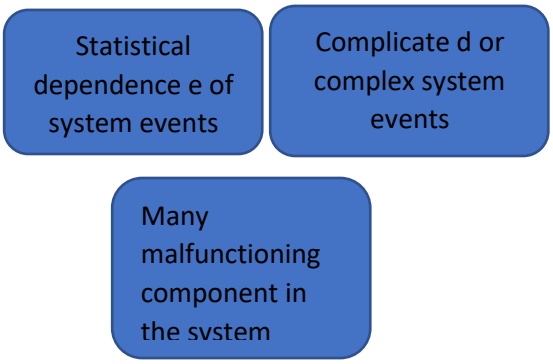

Chart No. 1: Reasons for the complexity and problems of system reliability analysis

1-1**problem statement**

The issue of the article is about the use of new methods to evaluate the safety of civil engineering systems. In the field of civil engineering, the safety of buildings and structures is very important and any defects in design, construction, or maintenance may lead to serious and dangerous accidents. Therefore, a correct and accurate evaluation of these systems is necessary.

Today, with the advancement of technology and analysis methods, new and advanced methods have been used to evaluate the safety of various performance systems. In general, analytical methods of various effects (especially earthquakes) on a performance system, including normal and advanced analytical methods, analytical methods based on networks (numerical methods), and analytical methods based on genetic algorithms are used.

Therefore, in this article, the review and evaluation of new and advanced methods used in this field will be discussed. The main goal of this article is to highlight and analyze the effects of the performance system of huge buildings and its response to earthquake loads. Using new methods, researchers will be able to improve the performance of the performance system of huge buildings against earthquake loads, which is one of the characteristics of the economic development of any country.

With the help of the reliability theory of engineering systems, it is possible to express the uncertainties arising from the statistical nature of the engineering system parameters in the form of mathematical relations and reduce the safety and performance considerations. entered the design process. According to this theory, in addition to studying the failure probability of a particular element, the failure probability of the entire system can be studied. [10]

As we know, the systems studied in civil engineering include the simplest systems (with a small number of components, such as a beam with a single head) and the most complex systems (with several There are

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many problems with dependent parameters, such as the investigation of the failure of a transportation network or building, etc., in order to calculate their capability, there is a need to use modern and more efficient methods.

In calculating the reliability of engineering systems with old methods, researchers were forced to consider considerations such as assuming dependent and independent parameters. The moments cause errors in the results, while the matrix-based reliability method (MSR) and the sequential combination method (SCM), it is able to calculate the reliability of the systems without the large number of components and dependencies. Its parameters are, and they are also applicable for the types of parallel, series, and compound systems, also by using this MSR method, the sensitivity of the system parameters can be calculated. [2]

2. **The basics of research**

The article "Using new methods to Evaluate the Safety of civil engineering systems" deals with the basics of research in the field of safety evaluation of civil engineering systems. In this article, new and advanced methods for evaluating and analyzing the safety of construction structures and systems have been reviewed.

The first basis of the research in this article is the definitions and key concepts in the field of security and safety of the construction structure and system. With a precise definition of the basic concepts, the possibility of a collapse of an integrated construction system has been found in general and suitable methods for its analysis have been obtained. [7]

The second basis of the research is the discussion about the new methods of evaluating the safety of construction structures and systems. In this part, various methods such as risk analysis and human factors analysis, artificial neural networks, genetic algorithms, and other advanced methods have been reviewed to evaluate and analyze the safety of construction structures and systems. [9]

The third basis of the research is a case study in the field of using new methods to assess the safety of a construction project. In this part, how to use innovative methods to analyze and evaluate a specific construction project is discussed.

2-1 **MSR method**

The MSR method has been investigated and used as a method that can the ability to provide an accurate point of failure probability. This method effectively provides us with an accurate point of failure probability of various types of systems, including series, parallel, and compound, as well as the sensitivity of the system parameters. [9}

Also, the MSR method can be used to calculate the conditional probability of component failure. These conditional probabilities are useful for determining the relative importance of the system components according to the system event.

The researchers (2007) investigated the reliability of a bridge transportation network. The assumptions of the question according to Figure 1 are that the transportation network between 8 cities, through 12 bridges. There are single-lane and double-lane bridges, and the only means of communication between the cities are stairs. City number 1 is the most important city in this network due to the location of the hospital. Each of the cities has a specific distance from the source of the earthquake, and the earthquake is assumed to be the only cause of the failure of the stairs. The earthquake probability density function in this problem is assumed as a shortened exponential function [10].

In general, the general formula 2 can be used to construct the performance vector of the i-th component for a system with n components:

Formula number 2:

$$C_{[n]}^{E_i} = \left[\underbrace{\overbrace{111\ldots1}^{\text{Sum of '1' is } 2^{i-1}} \overbrace{000\ldots0}^{\text{Sum of '0' is } 2^{i-1}} \overbrace{111\ldots1}^{\text{Sum of '1' is } 2^{i-1}} \ldots}_{\text{Repetition times is } 2^{n-i}} \right]$$

The occurrence vectors of each component 1, 2, 3, and 4 are easily obtained by formula 2 as follows.

2-2 **SCM method**

Despite the advantages of the MSR method, this method has limitations such as increasing the size of the matrix exponentially due to the number of components. For this purpose, for the effective analysis of the

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reliability of engineering systems with a high number of components, the sequential combination method was presented in 2010 by Kong and Song. The basis of this method is based on the FORM first-order reliability method, which transfers the problems obtained from the reliability analysis results of the components in the form of the multivariate normal integral form [13].

2-**3 Reliability methods of engineering systems**

Based on the number of specific values related to each non-deterministic parameter that is included in the reliability analysis of a system, in general, reliability analysis methods can be applied as follows She made an arrangement.

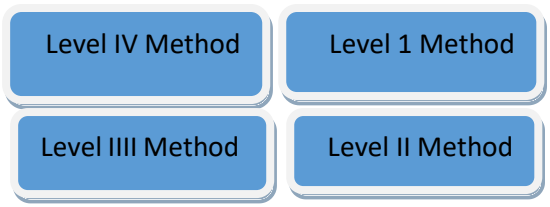

Chart No. 4: Reliability methods

A) In these methods, only one specific value of each discrete parameter (usually the mean value) is used.

b) In these methods, two specific values of non-deterministic parameters (usually mean and variance) are used and the effect of correlation between them (covariance) is also considered.

c) In these methods, the failure probability is used as a measure, and for its calculation, the joint distribution of all the non-deterministic parameters is needed.

d) In this method, in addition to the information needed in the plan, information such as the principles of engineering economy, system maintenance and repair issues, etc. is also needed.

Civil engineering systems usually consist of a large number of components or members, and to calculate their reliability, it is necessary to obtain the marginal function or limit function of each of these components, and then by one of the reliability methods for single component components, their reliability index is calculated and the whole system becomes a parallel or series or compound system and finally the reliability The system is obtained for the whole system, so the probability of failure of the whole system depends on the type of safety margin equations. For example, the behavior of a certain structure like a truss works like a series system.

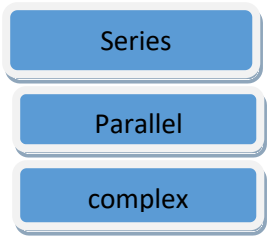

Chart No. 4: civil engineering systems

3- **Research findings**

The use of new methods to assess the safety of civil engineering systems has been investigated in various research and articles. In the following, we will mention some of the findings of these studies:

1. Use of artificial neural networks: In some research, the use of artificial neural networks has been investigated to analyze and predict the behavior of structures in abnormal conditions and dangerous situations. The results showed that the use of artificial neural networks will lead to more accurate analysis and better prediction of behavior makers in unusual conditions and dangerous situations.
2. Use of group evolution algorithms: Group evolution algorithms have been used to optimize civil engineering systems and evaluate their safety. The results showed that the use of these algorithms leads to the improvement of system performance and an increase in their safety.
3. Use of error analysis method and error tree: In some research, the use of error analysis method and error tree to identify and analyze risks in civil engineering systems has been investigated. The results showed that the use of these methods leads to more accurate and complete identification of risks, reduction of complex activities, and improvement of systems performance.

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3-**1 Evaluation of system reliability (SCM and MSR)**

The way to calculate the probability of failure for each of the loads is that first, the capability index for each of the members is obtained for the load in question and different mechanisms, then the event vector is obtained for each load. LOT is performed and also the probability vector of the system is obtained by equation 2, then for each external load value, the value of the probability of failure or reliability of the system is obtained by equation 1.

4- **conclusion**

In this article, the use of new methods to assess the safety of civil engineering systems has been investigated. Due to the advancement of technology and calculation methods, the use of new methods is very useful in evaluating the safety of buildings and structures. New methods include the use of neural networks, genetic algorithms, fuzzy logic, and information systems. By using these methods, more accurate calculations and higher accuracy regarding the security of buildings can be achieved.

Calculating the reliability of structures and frames requires the determination of various failure mechanisms and the calculation of the reliability index of each of the failure mechanisms, considering that engineering structures such as Repa and Qab as a complex system include a large number of dependent components. The MSR method is able to calculate the failure probability of these types of systems.

Frames and structures have a large number of components such as resistance of members and incoming loads, they are SCM, and most of these parameters are statistically dependent on each other. The reliability calculation method of these types of systems by considering the dependence between the parameters, is well and carefully acceptable in comparison with the Monte Carlo method.

The comparison between the analysis time of the SCM method and the MSR and Monte Carlo simulation methods, in the analysis of the reliability of the truss and frame, shows the high speed of the analysis of this method compared to the other two methods.

In general, the conclusion is that the use of new methods in evaluating the safety of civil engineering systems has significant advantages. By using these methods, more accurate calculations and higher accuracy regarding the security of buildings and structures can be achieved. Also, by using new methods, it is possible to obtain the necessary information for security assessment more accurately and faster.

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