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Reliability Assessment of RC Structures: Progress of the Failure Probability Calculating Methods

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The progress of probabilistic approaches to assessing the structural safety of load-bearing members (including reinforced concrete) of buildings and structures is a highly relevant scientific problem. Moreover, with the progress of digital technologies and the increasing capabilities of numerical calculations today, there is also an urgent need for the development of stochastic approaches in construction - based on mathematical statistics, theories of probability, and reliability.

According to the findings of many researchers [1-3], for the design of RC structures taking into account the requirements of ensuring their strength and durability, the principle of safety can be realized to the maximum level only if the following fundamental issues are further developed:

- Representation of loads and materials strength in the form of random variables and processes;
- Probabilistic nature of reliability coefficients;
- Failure probability as a multidimensional integral over the failure area;
- Safety characteristic (reliability index) β;
- Characteristics and functions of random variables;
- Methods for assessing the reliability of structures;
- Optimal and normative level of reliability;
- Probabilistic design optimization;
- Risk identification, etc.

One of the most important tasks in calculating the reliability of RC structures is the selection and justification of probabilistic models of random variables. This task in practice is significantly complicated by the data uncertainty, obtained as a result of a lack of statistical information. Uncertainty, in this case, represents material properties (for example, strength of reinforcement or concrete), external loads, geometric dimensions, operating conditions, etc. [4, 5]. These uncertainties, if ignored, can lead to low reliability of engineering structures and even catastrophic consequences (especially relevant for buildings of the CC3 consequence class). To solve this problem, the reliability theory of building structures was developed.

All reliability indicators that can be used in formulating normative requirements for structures are functions of the failure probability over a certain time. Therefore, the main task of probabilistic calculations is to calculate the failure probability.

When random changes in input parameters (variables) are insignificant (up to 20 %), we can use the statistical linearization method. In this case, to calculate the function's statistical characteristics, it is linearized by expanding into the Taylor series at the point of its mathematical expectation. However, no random variables distribution function is strictly linear and since the error permissible value in the nonlinear systems failures calculation depends not only on the number of input random variables but on the volumes of their statistical samples - the search for an analytical solution using this method will be almost impossible.

On the contrary, the method of statistical simulation (so-called Monte Carlo methods) - the universal method for calculating a wide class of probabilistic problems - is especially effective for nonlinear systems. The main idea of these methods consists of the sample (based on the statistical distribution) construction for each random variable involved in the task - and as these methods deal with the simulation of the limit state function - the larger the sample is taken, the more accurate the structure's failure probability will be [6].

As a result, the choice of random variable model probabilities for further calculation of the reliability of structure members will depend on the amount and type of statistical information obtained about the random variable. It can be added that the promising and relevant directions in the development of probabilistic models of random variables and methods for analyzing the reliability of RC structures (especially with incomplete statistical information) are the following:

- Use of numerical modeling methods (Monte Carlo methods);
- Progress of approaches to the modeling of members work based on FEM (including BIM technology);
- Durability monitoring (including based on IoT concepts).

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