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Research paper

Steel Statically Uncertain Transverse Frames Probabilistic Calculation

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Abstract

The aim of the work is probabilistic calculation and evaluation of steel statically uncertain frames reliability parameters and recommendations development for reducing their material content by controlling the reserves of the load bearing capacity of the.
A method for evaluating the reliability parameters of steel statically uncertain frames by all able-bodied statens is developed. Logical probabilistic methods of statically uncertain systems work are used. The probability estimation method of statically uncertain systems failure based on the boundary equilibrium method, taking into account the correlation of individual destruction schemes, is obtained. The method of calculating the significance and contribution of individual frame elements and their influence on the system failure probability as a whole is proposed. The practical method of designing steel statically unidentified frames with the use of steel statically uncertain constructions reliability coefficient γs is offered. The scientific novelty of the work is to develop a scheme for determining frames failure probability by estimating the working capacity. In particular, the fragile and plastic fracturing failures of the frame section are considered. The algorithms for calculating the steel frames failure probability are determined by the probabilistic method of graphical equilibrium. The steel frame separate elements significance indexes are determined. The numerical experiment on the developed programs on a PC is presented for estimation of steel frames failure probability of various sections. the of of steel statically uncertain constructions reliability coefficient γs is proposed for usage.
The practical value is more complete consideration of the structures and the probabilistic nature of strength and load, the use of the reliability coefficient. The possibilities of obtaining more economical frames in the design of new ones as well as reconstruction of existing buildings and facilities are identified. Based on the proposed methodology, algorithms and developed programs on the PC for the probabilistic calculation of steel statically uncertain frames for various purposes are compiled.

Keywords: *contribution, failure, probability, reliability, significance.*

1. Introduction

One of the important tasks facing the building science is the reduction of material content, labor intensity and cost at the stages of designing, construction and operation of buildings and structures, while ensuring their durability and reliability. Reliability theory application in the calculations of building designs provides favorable prerequisites for the normalization of structure design parameters on a probabilistic basis. Algorithm of calculations is based on probabilistic approach. The calculation can be attributed to many types of designs, including steel statically uncertain frames. Such structures are used in the frameworks of buildings and structures of various purposes. It is known that in steel statically unspecified structures, there are some reserves of non-dry capacity, not taken into account in the design. It reserves exist due to the work of the system in the plastic stage with the appearance of a number of plastic joints. The work of steel statically uncertain structures is not studied in a probabilistic production with regard to the random nature of strength and load, as well as the occasional nature of the failures of elements. In this regard, the development of steel statically uncertain structures probabilistic calculations methods, which can be implemented into the engineering design practice, is an important and relevant task in the present conditions.

2. Main Body

Steel statically unspecified structures can be used in frameworks of buildings of different purposes, workstations, shelves for technological equipment, etc. One of the most important circumstances in the analysis of the structure work is to take into account the plastic properties of the material. According to the recent research, the bearing capacity of statically uncertain systems is maintained after the appearance of plastic deformations in its elements. Problems of the elastic-plastic methods use in the calculation of engineering structures are devoted to the work [1 - 6]. In particular, [1] presents a new analytical model for predicting the elastic-plastic characteristics reaction of beams under load. The proposed model is verified by the finite element method and is used to construct a deformation mechanism as well as a graphical characteristic. In [2], it is found that residual stresses in materials affect their resistance to initiation of fracture. In [3] the modification of the numerical-analytical model for the study of beam elastic-plastic characteristics is presented. The model combines Rayleigh beam theory and the Stronge model. The elastic-plastic transition of the beam reaction influence and the propagation of the impact waves is solved as model of the differences. The presented model is verified by experiment. Comparison of numerical results with the results of experimental studies shows the reliability. The presented model is highly efficient and suitable for parametric research. It is proved that various influence parameters, such as impact masses, velocity, plasticity and location, have an effect on the beam response. An approach based on elastic and plastic methods for the analysis of fire resistance [4] is presented. It is intended to fill the gap between the simple method of calculation and the method of finite elements, which is currently used by engineers. This approach can be applied to simple frame structures, for which the temperature of fracture is calculated. The elastic method includes the effect of the interaction between the thermal load and the static load. The load ratio is calculated in accordance with the limit temperature. The plastic method is based on the concept of plastic hinge. In [5] a dynamic analysis of frame structures with elastic-plastic material properties deviations is presented. The analysis of the structure motion is used. The method of moving averages is developed on the basis of vector mechanics, which analyzed the continuum or structure. It is described by a set of particles directly regulated by Newton's laws. The interaction between particles is supplemented by a generalization of effort and is evaluated by the vector form of finite elements. This form is capable of regulating the movements of large-sized structures and large deformations of frame structures. The procedure for numerical analysis of elastic-plastic bending and elasticity of beams with asymmetric intersection is presented in [6]. The material solidification elastic-nonlinear behavior is assumed and considered as isotropic, as well as the kinematic strengthening of the models. Exact geometric expressions for large deflections and larger revolutions are taken into account in the bending process. The full load is taken into account including the effect of local load when monotonically reducing the load. Numerous examples confirm the strong influence of the load on the final and elastic rotation of the neutral axis, the displacement and distortion of the beams of different sections and materials.

Modern issues of the reliability of building structures, in particular calculations of the steel frames reliability, are presented in [7 – 17]. In [7] a method is suggested for an effective evaluation of the elastic-ideal plastic structures reliability. The boundary condition is estimated from the perspective of the probability multiplier. The load is estimated by solving a series of linear programming tasks, the answers that underlie the linear elastic model and the independent distribution of stresses. The effectiveness of the proposed procedure is ensured by the simplicity of the mathematical programming problem, the basic structural models are solved on each iteration, the simulation subset efficiency. The validity of the approach is ensured by the dynamic adaptability theory, which is illustrated by the example of a steel frame. The studies [8] consider the system of resistance coefficients through the analysis of the reliability of two moments of steel frames under a combined load of own weight and wind load. The frames are designed using second-order inelastic analysis and evaluated for strength and reliability. Influence on the system reliability of system resistance coefficient and the coefficient of load on wind and weight is considered. The features of the designing methodology on the basis of system reliability are revealed. In [9] we consider the choice of effective length of beams for frame models, widely used seismic resistance of the system, in order to minimize the amount of dispersion in structures. The estimation is carried out with the help of the proposed equation, taking into account the different height of structures prone to bias. In addition, the assessment of the reliability frame structures is carried out in accordance with the verification of the proposed equations, taking into account the probability of failure for each model. Correspondence of the effective length of the beam is achieved on the basis of deterministic analysis using the proposed equations and probabilistic analysis. In [10], the potential collapse of metal structures, the destruction of compounds with the uncertainty of material properties, such as the yield line, the load, and the elastic modulus, are analyzed. The beam ends of the rotation were used as members-the level of boundary states on the progressive collapse. Modeling of structures with three different types of compounds is carried out after removal of one of the columns. The volatility curves are obtained based on the probability of exceeding the given boundary state for vertical displacement. The algorithm for reliability on the basis of seismic designing of constructions is presented, which includes approximate methods of estimation of efficiency and structural optimization [11]. The offered algorithm allows automatic design of steel frames resistance, using reliability criteria. Such criteria allow the installation of engineering constraints and the building constructions of improved performance and low cost. In this paper a simplified approach is proposed that allows to calculate the boundary state of an average annual frequency without significant loss of accuracy. The problem of optimization is solved by a specially developed algorithm. The three and nine-story steel frame is used to demonstrate the effectiveness of the proposed procedure, which leads to the optimal construction of the building.

Probabilistic loss of indeterminate frames stability is studied using a stochastic finite element method [12]. Statistics of the loss of elastic frames stability with random initial nonlinearity, indeterminate sections and properties of the material are derived from the statistics of the main parameters of the system using the stochastic method of finite elements. The influence of geometric nonlinearity, intersection and material properties variation on differences in stability and durability is studied. The frames nonlinearity failure probability, consisting of random parameters of systems, taking into account casual loads, is calculated in the loading space. The factors that affect the reliability of the frame are determined. According to the recent studies, sectional properties, forms and size of geometric nonlinearity can have a significant effect on the reliability of the frame. In [13] it is noted that the design of steel structures based on extended analysis leads to a more efficient design process and provides a more even level of structural reliability of the system. The main obstacle to implement this method in practice is the obvious difficulty in assigning the appropriate resistance to constructive systems. In this paper, the reliability assessment and the development of system resistance factors for the 3D series of low and medium surface steel frames are considered. The study is conducted taking into account the uncertainty and geometric properties of the material. Frames are analyzed by gravity loading and system resistance factors obtained for different target reliability levels. Frames for providing different modes of system failure, such as instability of the inability of elements are selected. The recommendations of the extended analysis for the corresponding target reliability and their associated resistance factors are presented for use in the design of 3D steel frames. An effective numerical method for determining the reliability based on the optimization of the steel frame design is also proposed [14]. In this task, the target function is aimed at minimizing the weight of the entire steel frame. The variables in the design are beams and columns of the cross-section, which are considered as discrete variables and selected from a set of a wide-flanged steel profile. Random variables relate to the properties of materials and applied loads. To analyze the behavior of steel frames, the finite element method for frame structures is used. All probability limitations turn into deterministic constraints. It helps to transform the problem into a deterministic optimization problem, which can be solved with standard optimization algorithms, to reduce computing costs to solve the original problem.

Precise and efficient numerical procedures are presented in [15] for assessing the reliability of a steel frame system with semi-rigid connections. The ultimate strength and behavior of the frame are predicted using a model of elastic-plastic joint. Sensitivity of model reliability is studied. The Monte Carlo modeling is used to evaluate the failure probability and reliability index of the system. Two examples of frame structures under combined and wind load are considered, parameters of reliability of the system of strength and efficiency to the limiting state are evaluated by random loading, material and geometric properties and semi-solid connection. The results show that the reliability of the frame is very much dependent on the semi-solid connection. The effect of different load sequences on the deterministic stability of steel structures (inelastic range) is a well-studied phenomenon [16]. However, the effect of different load sequences on the reliability of steel elements and frames were not studied in the past. The results of the study indicate the importance of the sequence of loading at the level of distribution and not exceeding the probability of resistance. The potential consideration of the loading sequence in assessing the steel frames reliability is considered. In [17], the main factors influencing the stability of steel frames are considered and a comprehensive method for assessing the reliability of a steel frame system is developed on the basis of available statistical information. The main random variables of steel frames are their statistical parameters. The reliability of the steel frame system is evaluated under two main load schemes. The results show that the ratio of the material flow margin between the various components in the frame has a more significant effect on the reliability of the frame system than the dependence of the elasticity module of the sections between the various components. Also, the authors use the term "reliability" to analyze various types of data systems [18].

Separately, the probabilistic calculation of steel frames is presented in [19]. Three probabilistic models of snow load on the basis of the Poisson process and the block maximums method are considered, which follows from the second moment of the probabilistic description of the monthly extreme values of snow load [19]. To compare the models obtained in the upper order of the asymptotic approximations of their cumulative distribution function of the probabilities of annual maxima. The productivity of the model is verified by the probabilistic modeling and verification of constructions of low-rise industrial buildings exposed to snow and wind loads using the first order method of reliability (form). The Poisson process model is applied to the probabilistic optimization of stock ratios for a standardized frame design. In order to optimize, variable safety factors are proposed to be differentiated for frames from light to heavy weight of the roof. It is shown that this differentiation significantly reduces the spread of the level of reliability around the target value.

Modern experimental data show that the boundary equilibrium method allows us to reliably assess the bearing capacity of steel statically uncertain structures. The features of the boundary equilibrium method are presented in [20 – 21].

The most important property of the object is faultless [21], which is to maintain efficiency during a given time. It is defined as the probability of failure for a certain period of time $Q(t)$. For this work, reliability is evaluated by the criterion of bearing capacity.

Estimated values in building structures can be divided into two main groups. The first group refers to generalized load carrying capacity $\tilde{R}$, the second group refers to a generalized load $\tilde{F}$. In accordance with [22], the condition of non-failure is:

$$\tilde{S} = \tilde{R} - \tilde{F} > 0 . \tag{1}$$

In the statement bearing capacity and load of structures are presented as random variables. For the proposed work, they are subject to the normal laws of the distribution of random variables.

At present, problems with the probabilistic calculation of steel statically uncertain structures remain poorly investigated. In engineering practice there are no methods and programs that take into account the actual work of the material, as well as probabilistic characteristics of strength and load. The study of statically uncertain systems is complicated by the redistribution of effort after the failure of individual elements. System destruction models are characterized by a complex branching structure of ways of elements failure, which at the end transform the structure into a variable system. For a practical assessment of the reliability of statically uncertain systems, it is necessary to use simple, but at the same time quite close to the real work methods of calculation. One of these methods is the probabilistic method of boundary equilibrium.

The methods of probabilistic calculation of steel statically uncertain frames for various types of bounce of elements are considered. The most fully takes into account the course of the destruction of a construction method is a search for all possible states. Graphically, the state method is represented in the form of a directed graph. The vertices of the graph express the condition in which the structure is, and the edges represent the probability of failure of the corresponding elements. To calculate the probabilistic characteristics of graph trees, methods of mathematical logic are used. The probability of failure of statically uncertain systems as a whole Q_s, according to the graph of failures, is the expression of the logical addition (disjunction) of all possible (*i*-th) ways (conjunctions) of denial of intersections q_{ij}:

$$Q_s = \bigvee_{i=1}^{m} \left(\bigwedge_{j=1}^{n} q_{ij} \right), \tag{2}$$

where m – total number of ways (subgraphs) of failures for this design; n – the number of j-th bits of intersections, entering in the i-th way.

The model of failure of a frame in the form of a graph of states is mathematically represented as a matrix of direct relationships. Such a matrix by the method of exclusion of nodes is transformed into a matrix of complete bonds. An element of the matrix of complete bonds analytically expresses all logical connections between the input and the output of the state graph.

Fragile and plastic design failures are considered. With fragile failures, the element is excluded from work, and the structure as a whole continues to function. Plastic failure involves the intersection of the hinge of plasticity.

The general scheme of probabilistic calculation by the state method is shown in in Figure 1.

Analysis of the ways of destruction of the design shows that the probability of failure of the system as a whole is often numerically approaching the probability of failure on one of the most probable way of failure crossings. The value of the probability of system failure is much less than the failure probability to the first failure of the frame crossings. The method for the selection of states can be used for small frames (<20 crossings), due to the sharp increase in the volume of calculations. To overcome the difficulties in increasing the size of the problem, a method of calculation is proposed, constructed using one of the most probable (true) destruction mechanism.

It is known that the division of effort during plastic fracture does not depend on the history of the load and the behavior of the structure to its complete plastic destruction. Therefore, for the calculation of steel statically uncertain frames made of elastic-plastic material, it is possible to consider the phase of of structure carrying capacity exhaustion and plastic destruction.

The above position is used in the boundary equilibrium method. The following prerequisites for the use of the boundary equilibrium method are taken into account:

1) the application of the load belongs to the quasi-static type;
2) material of structures is ideally elastic-plastic and is subject to Prandtl's diagram;
3) the equations are formed for a non-deformed circuit;
4) the intersection of the elements are of an ideal shape, so the zone of plastic hinge is limited to a point;
5) the main active efforts are bending moments.

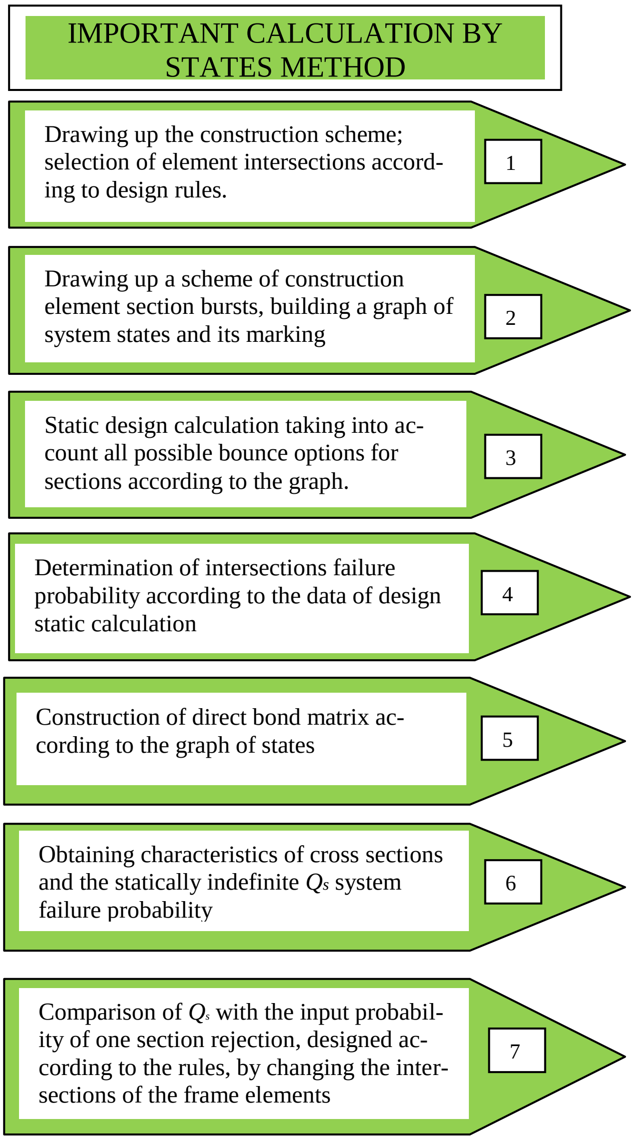

Fig.1: A scheme for calculating the reliability of the frames by states checking method

The procedure for calculating the reliability of statically uncertain systems is developed, in which the conditions for plasticity joints are the form of hyperplane equations in $(k+1)$ – dimension hyperospaces:

$$\sum_{j=1}^{k} M_{ij}\cdot x_j + q\cdot M_{io} = M_{i,pl} \quad (i = 1,2,...,n), \tag{3}$$

where $M_{i.pl}$ – the limiting moment in the i -th section; M_{ij} – moment in the i -th crossing of the main system from the unnecessary unknown; $x_j = 1$; M_{io} – moment in the i -th section of the external loads q , the parameter of which is accepted $q = 1$.
The intersection of hyperplanes determines the vertex of the polyhedron of conditions, from which the maximum load value q_{max} is calculated. From the solution $(k+1)$ of the linear equations (4) and the substitution of the right half of the mean boundary points $\overline{M}_{r,pl}$. Passing to the field of random variables the mathematical expectation of the frame strength as a whole is:

$$\bar{q} = \sum_{r=1}^{k+1}\frac{A_{r,k+1}}{D}\cdot \overline{M}_{r,pl} = \sum_{r=1}^{k+1}\frac{A_{r,k+1}}{D}\cdot \mu_r \cdot \overline{M}_{o,pl} , \tag{4}$$

where D is a determinant of the equation system; $A_{r,k+1}$ – algebraic addition of elements $\overline{M}_{r.pl}$ of determinant D ; $M_{o.pl}$ - average value of frame limiting point parameter; μ_r – component of the vector of frame boundary moments relations; r is the plasticity hinge number.
The strength of the frame in the space of the load parameter will be determined:

$$\hat{q} = \sqrt{\sum_{r=1}^{k+1}\left(\sum_{r=1}^{k+1}\frac{A_{r,k+1}}{D}\cdot \hat{M}_{r,pl}\right)^2} = \rho_2 \cdot \hat{M}_{o,pl} . \tag{5}$$

According to the algorithm for the composite program, calculations are made of the failure probability of thirty different frames. Separate design or operational load is assigned. Calculated probabilities of failure of statically uncertain systems as a whole have a slight discrepancy from $3.99\cdot 10^{-11}$ to $1.6\cdot 10^{-16}$. Calculations are carried out with the variability of strength and load of 0.1 and 0.2 and the deviation of the calculated values from the average strength and load of 3 and 5 standards, respectively. It gives the probability of a failure of a single element, a value $Q_{icx} = 5{,}6\cdot 10^{-8}$ projected according to norms.
The system reliability evaluation in general by one mechanism of destruction is numerically justified, but there are indeed mechanisms that have a probability of appearance, close to the most likely mechanism. Therefore, the responsibility of the elements included in these mechanisms is rather high, and they must be taken into account in the probabilistic calculations of statically uncertain systems.
The probabilistic method of boundary equilibrium is developed for assessing the reliability of steel statically uncertain frames when plastic elements fail.
According to the equation of external and internal virtual work, the probability of failure for an individual and the mechanism of destruction are the following:

$$P(E_i) = P\left(\sum_{j=1}^{m}\tilde{P}_j\cdot f_j > \sum_{k=1}^{n}\tilde{M}_{pl,k}\cdot v_k\right) = P\left(\tilde{F}_i > \tilde{R}_i\right) \tag{6}$$

where P_j is the value of j -th external load; $M_{pl,k}$ is plastic moment in the k -th section with plastic hinge; f_j, v_k is turning or moving knots and rods accordingly.
For the frame, the main (elementary) mechanisms of destruction are determined:

$$l = j - k , \tag{7}$$

where j is the number of dangerous cross sections, k is the degree of static uncertainty of the frame.
Among the main mechanisms of destruction are beam, sliding (floor) and knot mechanisms. The arguments in equations of equilibrium reveal random parameters of load and strength. Further, the main mechanisms through their combination receive combined mechanisms. These mechanisms reflect the versatility of the design failures considered. Upon receipt of combined mechanisms, a selection of the most probable ones is proposed ($Q_i > Q_{limit} = 10^{-30}$). Also excluded are those mechanisms in which the number of plasticity hinges is more than the degree of static uncertainty of the frame plus one.
According to the kinematic theorem of the boundary equilibrium, the construction collapses when at least one of the events of E_i is realized. Therefore, the probability of failure of the system as a whole is determined by the following formula:

$$Q_s = P(E_1) + P(E_2) + ... - P(E_1 \wedge E_2). \tag{8}$$

Refusal of two mechanisms simultaneously $P(E_i \wedge E_j)$ should be considered taking into account the correlation connection, depending on the plastic joints and loads. The coefficient of pair correlation used for this purpose, between i -th and j -th mechanisms is:

$$r_{ij} = \frac{\sum_{k=1}^{m} A_{ik} \cdot A_{jk} \cdot \sigma_r^2 + \sum_{l=1}^{n} B_{il} \cdot B_{jl} \cdot \sigma_S^2}{\sigma_i \cdot \sigma_j}, \qquad (9)$$

where A_{ik}, A_{ij} are virtual displacements of nodes respectively for the i -th and j -th mechanisms in k -th section; σ_r, σ_s is the mean square-non-deviation (standard), respectively, of the load-bearing capacity and nau-infusion; B_{il} , B_{jl} are virtual displacements of rods from the l load; σ_i , σ_j are standards of reserve of strength for the i -th and j -th mechanisms of destruction.
The failure probability calculation of the two mechanisms simultaneously $P(E_k \wedge E_l)$ taking into account the correlation dependence in the normal distribution of random variables is:

$$Q_{kl} = (0.5 - \Phi(v_k)) \cdot (0.5 - \Phi(v_l)) \cdot \sqrt{1 - r_{kl}^2} \cdot exp(r_{kl} \cdot v_k \cdot v_l), \qquad (10)$$

where Φ is the Laplace tabular function; β_k, β_l – safety specifications are replaced by

$$v_k, v_l : v_k = \frac{\beta_k}{\sqrt{1 - r_{kl}^2}}, \quad v_l = \frac{\beta_l}{\sqrt{1 - r_{kl}^2}} \quad .$$

The probabilistic method of boundary equilibrium is implemented in calculating of statically uncertain systems failure probability as well as the method of generalized covariance [23] and the PNET method [24]. All these methods in the field of small probabilities yield close results. The scheme of boundary equilibrium probabilistic method calculation is shown in in Figure 2.
One of the factors that affect the bearing capacity of statically uncertain system elements is the longitudinal force. This force is taken into account in the probabilistic boundary equilibrium method for compressed-curved rods as a particle in the boundary bending moment:

$$M_{pl,n} = \left[1 - \left(\frac{N}{N_{pl}}\right)^j\right] \cdot M_{pl} = m_k \cdot M_{pl}, \qquad (11)$$

where j is the index of degree, for a two-tier is equal to 1.5; N is the longitudinal force in the element; N_{pl} is plastic bearing capacity of the compressed element; M_{pl} is plastic bending moment for this element.
The coefficient of work conditions m_k takes into account the effect of longitudinal force in compressed-bent elements, previously received-equal to 0.85.
In order to be able to influence statically uncertain systems without reducing its efficiency, it is necessary to use such a characteristic as the contribution of the i -th element to the robustness of the design in general, R_s , it is as:

$$B_i = R_i \cdot \xi_i = R_i \cdot \frac{dR_s}{dR_i} = Q_s - Q_{s1}, \qquad (12)$$

where ζ_i is the significance of the i -element; Q_{sl} is the probability of system failure with the reliability of the individual element $R_i = 1$.
It is shown in the paper that it is efficient to use the definition of main destruction mechanisms contribution, rather than separate dangerous sections.
To take into account the statistical nature of strength and load, it is proposed to introduce a coefficient of reliability γ_s into the calculation of steel statically uncertain frames. The reliability ratio is as follows:

$$\gamma_s = \frac{M_{o(pl)}}{M_{o(VMPR)}}, \qquad (13)$$

where $M_{o.(pl)}$ is the limiting moment obtained from the elastic-plastic calculation of the frame; $M_{o.(vmpr)}$ is the limiting moment obtained by the probabilistic method of boundary equilibrium.
It is possible to use γ_s when selecting the intersections of elements of steel frames as a coefficient of working conditions. When calculating, taking into account one parametric load to thirty frames, the coefficients 1.2 – 1.4 are obtained. Their possible use will provide significant material savings.

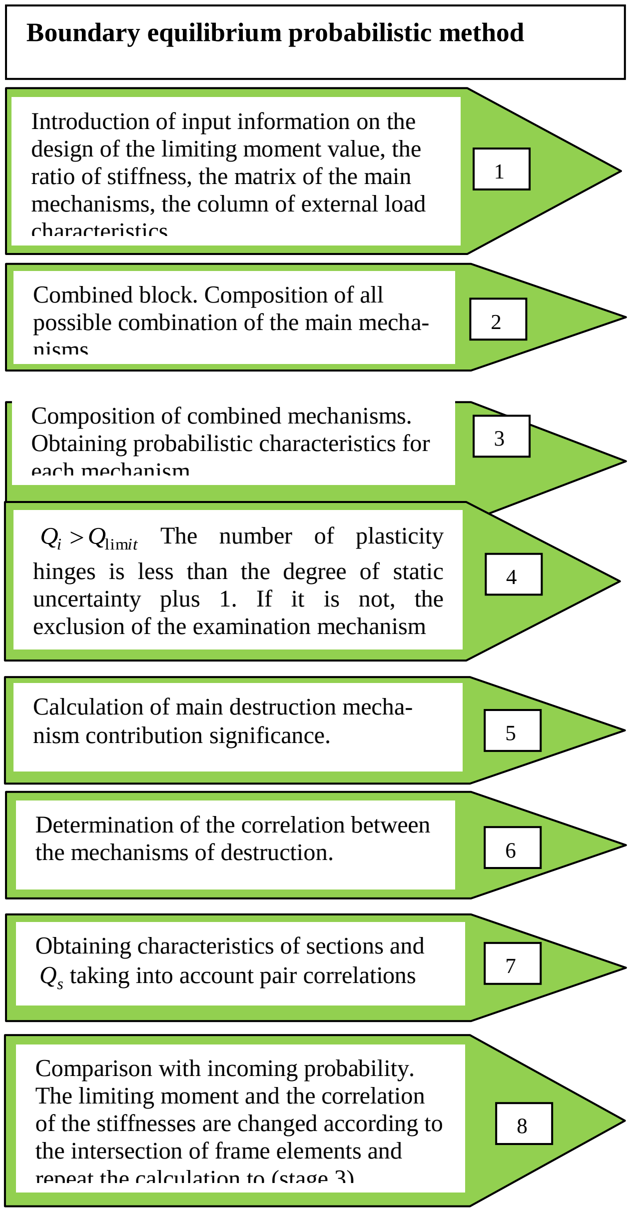

Fig.2: Calculating the probabilistic method of boundary equilibrium block diagram

For practical use in engineering calculations of steel statically uncertain frames, it is recommended that the coefficient $\gamma_s = 1.1$. Its introduction does not require additional calculations of reliability frames. The use of higher coefficients prevents calculations according to the developed method.

In order to take into account the random nature of the external factors acting on the construction of the boundary equilibrium probability method, a lot of parametric imposition is used. Each load is presented as a random parameter. For a combined mechanism, the total load is in accordance with random magnitudes compilation rules with the obligatory consideration of the correlation relations between the loads.

The probabilistic calculation is completed by the equation of system failure probability as a whole Q_s and one section failure probability Q_{icx} designed in accordance with the norms.

Calculations of steel statically uncertain frames with real and proportional loading in the elastic and elastic-plastic stages are done. According to the probabilistic method of boundary equilibrium, 30 frames of different purpose and con-shaping (one, two, three, three, one, two, three, transverse) are calculated. Frames loaded with current or design loads. There is a comparison of bending boundary moments, which come in single rigidity.

According to the results of the calculations, it is confirmed that the introduction of an elastic-plastic calculation into the practice of designing statically uncertain systems allows one to take into account, in the middle, 10% of the reserve capacity of the frames in comparison with the elastic calculation. Calculation of the probabilistic method of boundary equilibrium when comparing the probability of failure of the frame with one element failure probability to the first allows for an additional 20-25% of the bearing capacity reserve to be considered additionally. Calculation of the probabilistic method gives the following results in comparison with the elastic-plastic calculation.

According to the developed method for determining the significance, contribution and specific contribution of destruction main mechanisms, calculations of thirty frames are carried out. As a result, charts of specific contributions of individual key mechanisms are compiled. In the study of diagrams, it can be noted that the contributions in general are distributed unevenly for most frames. The spread of deposits of various elements (10 - 30% by the size of the bearing capacity) opens a possible field of activity for their comparison and taking into account the emerging reserves of structures. On the charts of specific contributions for most frames, one or two (more often than one) elementary fermions are selected, which form the basis of the most likely mechanism.

The divergence of individual section specific contribution to the reliability of the frame as a whole reaches an average of 10-% and approaches the specific contributions of destruction main mechanisms.

3. Conclusion

This paper is devoted to the development of the probabilistic calculation statically uncertain steel frames of various purposes and configurations. The calculation is made taking into account the actual work of the material and the load. The main results of the work are the following:

1) a method for evaluating the reliability of statically uncertain systems state checking method is developed. According to the method graphoanalytic transformations are used and plastic and brittle failures of elements are taken into account;

2) in order to obtain a lower estimate of the probability failure of the structure as a whole, the calculation method is proposed. This method uses the most probable mechanism of destruction based on the method of boundary equilibrium;

3) the proposed logical-probabilistic method for calculating the probability of failure of the system, which takes into account all models of destruction of the structure;

4) the probabilistic method of boundary equilibrium is developed to determine the probability of failure of static statically uncertain systems. The calculations take into account a variety of forms of structural failure and a correlation between the mechanisms of destruction. Also, the probability of failure system is compared with the probability of failure of one element, designed in accordance with the rules.

The algorithm of estimation significance, contribution and specific contribution separate basic mechanisms of fracture and dangerous sections of elements statically uncertain steel frames in the reliability of the system as a whole is developed.

A method for determining the reliability coefficient for statically uncertain γs systems with one parametric and many parametric load of constructions is proposed. This method takes into account the random variability of strength and load. According to the probabilistic method of boundary equilibrium, rotated coefficients γ_s up to 30 frames are equal to 1.2-1.4. Use of γ_s will save 5-20% of material. In practical calculations of steel statically uncertain systems it is recommended to apply γ_s = 1.1.

Acknowledgement

The results of the research are taken into account in the development of the norms "General principles of ensuring the reliability and safety of building structures and foundations” and "Steel structures. Basic principles of designing, manufacturing and installation ". Working condition coefficient γ_s = 1.1 for statically undetectable systems is presented.

The results of calculating bearing structures of a combined single-span three-tier frame are taken into account when designing the retaining wall of a stone crushing plant at the Poltava Gas Condensate Plant.

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