# On the calculation forces from the regulation forces in the structure with variable design scheme

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***Abstract* – The expressions to determine forces from the regulation forces in the "redundant" linkage of the design scheme that meets the steel structure at some reconstruction stage is presents. These forces are defined by linear combination of unit basic forces that obtained from solving a matrix system of equations finite element method with multiple right parts for the basic design scheme. Factors of the linear combination of unit basic forces proposed to determine by system of linear equations that taking account peculiarities of forces.**

Key words: steel structures, reconstruction, reinforcement, bar structures, the design scheme, the stress-strain state.

## I. Introduction

During the reconstruction and reinforcement of the static undefined steel structures, usually, change the structural scheme and regulation forces in the "redundant" linkages. The sequence of the appropriate works on reinforcement the whole structure or its separate elements affect its stress-strain state. When designing the reconstruction and reinforcement of the steel structures should take into account changes in the design scheme, stress-strain state and sequence of these works. Calculation of different design schemes of a structure requires forming and solving a few systems of equations finite element method.

Methods for calculating forces by changing the structures that are economical by volume computation, are proposed in [1-4]. One of these methods is described in [4], allows for the analysis the stress-strain state by its different design schemes, which differ as a result of changes in the design scheme in a liquidated of the "redundant" linkages, to form and solve only one matrix system of equations finite element method with multiple right parts.

Formalization the process of reconstruction and reinforcement of the bar structures to account for other changes in the design scheme of optimization algorithms such structures is proposed in [5]. This process is proposed to represent the sequence of reconstruction stages, each of which can include a set of elementary change of design scheme as input hinges (liquidated of the "redundant" linkages), imposed of linkages and regulation forces in the "redundant" linkage [5].

The general method for the calculation of forces by changing the structures, which takes into account given in [5] formalization the process of reconstruction and reinforcement the steel structures was developed in [6]. Calculation of the steel structures in the design of reconstruction and reinforcement of the present method is realized in program optimization OptCAD [6, 7].

Method determination of the stress-strain state of steel structure with different similar design schemes shown on the example problem with two schemes, which differ by one "redundant" linkage [6]. Based on this basic idea of determination the stress-strain state of steel structure during the design of reconstruction and reinforcement was formulated. According to this idea at first enough to form and solve a matrix system of equations finite element method with multiple right parts for the basic design scheme, which contains all linkages from set $L$ [6]. Then, using the obtained basic forces, forces at any reconstruction stage represent sum of the appropriate basic forces from external loads and linear combinations of unit basic forces. Necessary to obtained the expressions for determine forces at any reconstruction stage of steel structures, in particular forces from regulation forces in the "redundant" linkages.

**The purpose of the article** is to obtain the expressions for determine from unit basic forces the forces arising during regulation force in the "redundant" linkage of design scheme, which appropriate the steel structure at any reconstruction stage.

## II. The main material

Sometimes the during the reconstruction and reinforcement of steel structures carried successive structure changes. Some of these changes may be include regulation force which result are arise of the appropriate forces in steel structures. Some of these changes may include regulation forces leads to the corresponding forces in steel structures. Each of these forces can be represented as a linear combination of unit basic forces.

The determine forces from the regulation force in one $k$ "redundant" linkage of steel structure at any reconstruction stage. The assume that the current design scheme at this reconstruction stage differs set of imposed linkages $L_c$ ($k \in L_c$, $L_c \subset L$) on the basic design scheme as a result of the realization of the elementary changes of design scheme at earlier reconstruction stages.

Enter some notation. Any type of forse (e.g. internal force, moment) denoted by $S$. $S_i^{bu}$ i $S_k^{cu}$ – unit forces in the current design scheme and in the base design scheme from pair of unit forces applied to sections that are on the bar infinitely near the liquidated of the $i$ and $k$ "redundant" linkage appropriate [6]. The unit base forces denoted by $S^{bu}$ ($S_i^{bu} \in S^{bu}$). $S_k^{cr}$ – searched unknown forces from regulation force in the $k$ "redundant" linkage the known value $s_{kk}^{cr}$.

Known that the forces $S_k^{cr}$ can be defined as follows:

$$S_k^{cr} = s_{kk}^{cr} S_k^{cu}. \qquad (1)$$

[2] This work was done under the direction of CSc., associate professor Peleshko I.D.

Necessary according to (1) build a unit of forces $S_k^{cu}$ the current design scheme. This diagram has the following peculiarities:

1) zero forces at all $m$ linkages of set $L \setminus L_c$ (forces is absent in the hinges);

2) unit value of force $s_{kk}^{cu}$ in $k$ linkage;

3) any value of forces in other linkages of the current design scheme, in particular and in the linkages of set $L_c$.

These values of forces are different from the values of appropriate basic forces $S_k^{bu}$.

To determine the forces $S_k^{cu}$ use appropriate in basic design scheme an unit of forces $S_k^{bu}$ and unit basic forces $S_i^{bu}$, where $i = \overline{1,m}$, from load of pair of unit forces the liquidated "redundant" linkages of set $L \setminus L_c$. Using a linear combination of these forces define of forces $S_k^{cu}$:

$$S_k^{cu} = \sum_{i=1}^{m+1} \alpha_{ki} S_i^{bu}, \qquad (2)$$

where $\alpha_{ki}$ – factors of the linear combination of the appropriate unit basic forces.

Factors of the linear combination $\alpha_{ki}$ must be determined from the system of $m+1$ linear equations with $m+1$ unknowns that taking account peculiarities of forces $S_k^{cu}$:

$$\begin{cases} \alpha_{k1} s_{11}^{bu} + \ldots + \alpha_{ki} s_{1i}^{bu} + \ldots + \alpha_{kk} s_{1k}^{bu} = 0; \\ \alpha_{k1} s_{21}^{bu} + \ldots + \alpha_{ki} s_{2i}^{bu} + \ldots + \alpha_{kk} s_{2k}^{bu} = 0; \\ \ldots \\ \alpha_{k1} s_{i1}^{bu} + \ldots + \alpha_{ki} s_{ii}^{bu} + \ldots + \alpha_{kk} s_{ik}^{bu} = 0; \\ \ldots \\ \alpha_{k1} s_{m1}^{bu} + \ldots + \alpha_{ki} s_{mi}^{bu} + \ldots + \alpha_{kk} s_{mk}^{bu} = 0; \\ \alpha_{k1} s_{k1}^{bu} + \ldots + \alpha_{ki} s_{ki}^{bu} + \ldots + \alpha_{kk} s_{kk}^{bu} = 1; \end{cases} \qquad (3)$$

Factors of the linear combination $\alpha_{ki}$ must be determined from the system of $m+1$ linear equations (3) using the methods of linear algebra.

Given the expressions (1) and (2), forces $S_k^{cr}$ can be defined as follows:

$$S_k^{cr} = s_{kk}^{cr} \sum_{i=1}^{m+1} \alpha_{ki} S_i^{bu}. \qquad (4)$$

## Conclusion

Using a linear combination of the unit basic forces are presented forces from regulation force in the "redundant" linkage of design scheme, which appropriate the steel structure at any reconstruction stage. Factors of the linear combination determined from the system of linear equations that taking account peculiarities of forces.

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