The Principles of Discrete Modeling of Rod Constructions of Architectural Objects

Petro Kulikov, Vitaliy Ploskiy, Volodymyr Skochko

Kyiv National University of Construction and Architecture
Povitroflotskiy prosp., 31, Kyiv, Ukraine, 03680, e-mail: vladimir-skochko@yandex.ru

Summary. This article describes the basic principles of rod spatial building constructions modeling by means of discrete geometry. The mathematical dependence that form the basis of this approach are the differential regularities between the geometric and physical parameters of the modeled constructions, as well as the parameters of the external loads which determine the final shape of the model.

Key words: geometric modeling, discrete model, mesh structure, rod constructions, differential regularities.

INTRODUCTION

As is well known, the most common approach to the projecting of any building construction can be conditionally divided into three stages:

1) determination of the shape of future construction;

2) calculation of the internal efforts, acting in the construction as a result of action of different loadings;

3) selection of structural elements that could be able to withstand the load acting therein. Only after that, it is possible to carry out the architectural and construction drawings.

Very often, the disadvantage of this approach is the need for frequent repeating of the first and second stages in order to clarify the shape, since the architect, which invents the concept of a new nonstandard construction, not always can to predict appearance in it of excess tensions. These tensions may cause a malfunction of the whole construction, and even its destruction. Partially described disadvantage is a consequence of the rapid development of numerical methods for calculation of building constructions. Numerical methods allow us to define the internal forces in constructions and even entire buildings of almost any complexity level (including underground constructions). As a result, the architects more and more neglect the preliminary analysis of designed shapes and rely on engineering solutions of constructors.

However, require special attention spatial rod constructions. In recent years, exactly rod construction form the basis for designing of most large-span erection truss as well as shell coatings and steel cable roof. Moreover, they are successfully used as load-bearing skeletons of buildings and structures. Obviously, that engineering of rod structures requires a special responsibility and accuracy in performing the calculations.

That is why in the design of rod constructions it makes sense to perform the operations of pre-shaping taking into account the external influences that will act on these construction. Apart from external loads, must be taken into account the expected internal forces in the rods of the model.

As an effective tool to perform this pre-shaping can be used the methods of geometric modeling. The modeling process in this case reduces to constructing of a discrete geometric model of the rod construction taking into account all the external loads and boundary conditions, as well as of its subsequent analysis and correction.

PURPOSE OF WORK

Separate methods of discrete geometric modeling (such as static-geometrical method [1]) allow us to obtain the desired shape of rod constructions based on information about their topology, the value of nodal loads and features of allocation of internal forces in the elements of the model. However, the resulting shape of the model do not always correspond to the expected outward appearance, as it is often the architects have to observe the features of space-planning solutions of the design object and the style of already existing buildings. In consequence of this the shape of the model must be adjusted "by hand", which entails the impossibility of the use of geometric modeling methods and the need to use one of the well-known numerical methods (such as finite element method, finite difference method, and others [2–7]) to further define the internal forces in the system.

All of the above defines the main goals of this work:

1) to introduce universal algorithm of rod constructions forming providing the possibility of local changes in its geometry, using the same modeling methodology,

2) to demonstrate the mathematical regularities necessary for the implementation of this algorithm.

ANALYSIS OF MAIN PREVIOUS RESEARCHES

One of the most variative and suitable for shaping of rod constructions methods of discrete modeling is a static-geometrical method (SGM). SGM based on constructing of interpretative models of multi-unit non-extensible or non-compressible elastic threads and nets. The main idea is that vector loads P_i ($i=1,2,\dots,n$), which are put in nodal points, define the shape of discrete model (Fig. 1).

It is assumed directly proportional relationship between the length of the individual straight line segments of threads or nets $\delta_{i,j}$ and the absolute values of internal forces in them $R_{i,j}$:

$$R_{i,j}/\delta_{i,j} = \pm k_{i,j},\ \left(i, j = \overline{0, n+1};\ i \neq j\right),\quad (1)$$

where: $\pm k_{i,j}$ – adopted proportionality coefficient («+» – stretching, «–» – compression).

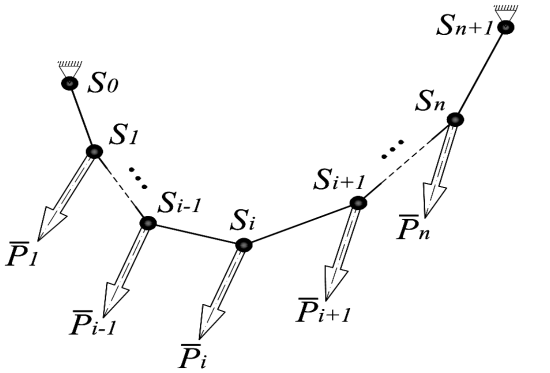

Fig. 1. The multi-unit elastic thread

The vector equation of static equilibrium of the i-th node of two-dimensional elastic thread with n free loaded nodes is as follows (Fig. 2):

$$\overline{R}_{i,i-1} + \overline{R}_{i,i+1} + \overline{P}_i = 0. \quad (2)$$

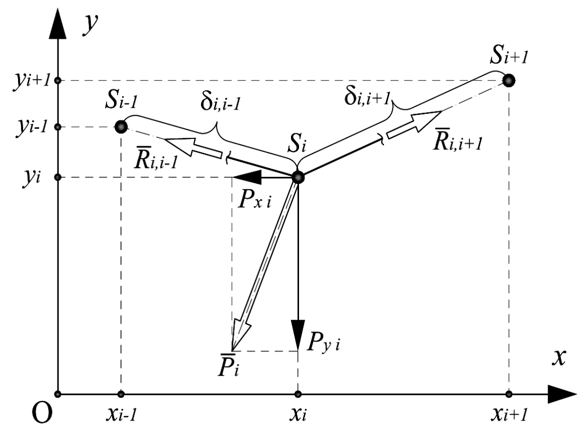

Fig. 2. The equilibrium of the i-th node which cut out from multi-unit elastic thread

In the projections, the system of equilibrium equations of SGM for the i-th node of multi-unit thread with the same for all segments coefficients $+k$ has the following form:

$$-2\cdot s_i + s_{i-1} + s_{i+1} = -P_{s\,i}/k\,, \qquad (3)$$

where: s – generalizing designation of coordinates.

Forming process basically boils down to the selection of the external loads. Typically, load vectors have a formal mathematical sense and are the parameters of variation.

However, the method does not require the formalization of these parameters and, if necessary, they may correspond to the actual physical vector quantities.

This approach was suggested to use in [8]. This eliminates the need to establish a constant coefficient of proportionality, and it can be changed in each element of discrete model.

If we know the laws or properties of the investigated process or object, it can be interpreted by a set of vertices, which correspond to the parameters of the process or object in specific points of the space and form a grid. Then the equilibrium state of i-th vertex of the grid, which connected to its other n vertices, in accordance with the SGM can be described by the following system of equations:

$$-\left(\sum_{j=1}^{n} k_{i,j}\right)\cdot s_i + \sum_{j=1}^{n} k_{i,j}\cdot s_j = -P_{s\,i}. \qquad (4)$$

This system can be used for static and dynamic processes and objects modeling, since the coefficient $k_{i,j}$ and the components of the external influence $P_{s\,i}$ may be the non-linear functions not only on the coordinates of vertices of the grid, but also on additional parameters, for example, measures such as time. In [8] was proposed to use a generalized form of SGM for modeling of heat and mass exchange process occurring during the heating of the porous building materials with electrocution, as well as for the numerical modeling of the elements of stress-strain state of building structures, which are under the influence of external loads.

However, it should be noted that in the above-mentioned work the solutions of practical problems have been implemented on the basis of the control of parameters $k_{i,j}$ using additional discrete models, which characterize the current physical state of the model in its different areas. In this approach hasn't been proposed to construct a unified geometric model of the area of the medium or object, allowing at the same time to describe the physical state of the elements of the model and the character of external influence on its nodes.

The mathematical regularities between the geometric and physical parameters of the network structures and the characteristics of acting on the nodes of model loads were presented in [9]. The influences of external loads, in accordance with [9], presented in the form of a vector field $\overline{\Im}_i$. In this case, the field $\overline{\Im}_i$ must be a scalar and have a scalar potential φ_i at each point of the needed area of space:

$$\varphi_i = \varphi(s_i) = \varsigma(x_i, y_i, z_i). \qquad (5)$$

The values $\overline{\Im}_i$ and φ_i are related by the following relationship:

$$\Im_{s_i} = \partial\varphi_i/\partial s_i\,. \qquad (6)$$

The complete system of equations, which describe the static equilibrium of the *i*-th node of 3-dimensional network structure, and deformed-stress state the acceding to this node bonds is as follows:

$$\begin{cases} \sum_{j=1}^{n}\left(x_j - x_i\right)\cdot R_{i,j}/\delta_{i,j} + \Im_{x\,i} = 0, \\ \sum_{j=1}^{n}\left(y_j - y_i\right)\cdot R_{i,j}/\delta_{i,j} + \Im_{y_i} = 0, \\ \sum_{j=1}^{n}\left(z_j - z_i\right)\cdot R_{i,j}/\delta_{i,j} + \Im_{z\,i} = 0, \\ \sum_{j=1}^{n} R_{i,j}\cdot\delta_{i,j} - \varphi_i + G_i = 0, \\ \sum_{j=1}^{n} R_{i,j}/\delta_{i,j} - \left(d/2\right)\cdot\rho_i\left(x_i, y_i, z_i\right) = 0, \end{cases} \qquad (7)$$

where: $\rho_i(x_i, y_i, z_i)$ – distribution function of the density of the field sources,

d – constant of that reflects empirical prop-

erties of the environment in which is located a rod structure, in the case when it interprets the physical process,
G_i – constant of integration.

This system can be written in a more convenient form, if the relations of effort and bond lengths will be replaced by parameters of the state of bonds (or rigidity parameters of bonds) $\aleph_{i,j}$:

$$\aleph_{i,j} = R_{i,j} / \delta_{i,j}\,. \tag{8}$$

Here we intentionally replace the coefficient $k_{i,j}$ to state parameter $\aleph_{i,j}$, since the first one is the constant in the process of influence on the construction by various loads, while the second one can change its value, as in the real working conditions of rod constructions.

As a result of this replacement, the system (7) takes the following form:

$$\begin{cases} \sum\limits_{j=1}^{n} (x_j - x_i)\cdot \aleph_{i,j} + \Im_{xi} = 0, \\ \sum\limits_{j=1}^{n} (y_j - y_i)\cdot \aleph_{i,j} + \Im_{yi} = 0, \\ \sum\limits_{j=1}^{n} (z_j - z_i)\cdot \aleph_{i,j} + \Im_{zi} = 0, \\ \sum\limits_{j=1}^{n} \delta_{i,j}^2 \cdot \aleph_{i,j} - \varphi_i + G_i = 0, \\ \sum\limits_{j=1}^{n} \aleph_{i,j} - (h/2)\cdot \rho_i(x_i, y_i, z_i) = 0. \end{cases} \tag{9}$$

The system (9) is important because it gives an opportunity not only to find the position of free nodes of rod constructions, but also allows to use additional characteristics of the field of external influence (such as the scalar potential φ_i and the density of the field sources ρ_i) to correct positions of the nodes and rigidity parameters of rods.

PARAMETRIC EQUATIONS OF THE RODS

It is obvious that control of the shape of the rod construction should be carried out by the system solution.

To allow adjustment of the model shape is necessary that the quantity of equations containing parameters of variation, corresponds to the amount of rods of the model. A method of producing of parametric equations depend on whether the quantity of rods exceeds the quantity of its nodes in the model [10]. Besides, there are two types of parametric equations describing the state of the two types of rods:

1) the rods, which connect the two free (loaded) node of the model (I type),

2) the rods, which connect one free and one fixed (basic or reference) node of the model (II type).

If the number of nodes in the model exceeds the number of its rods, parametric equations have the form:

1) for the rod S_aS_b of I type:

$$\begin{gathered} \sum_{i=1}^{m-1} \delta_{a,i}^2 \cdot \aleph_{a,i} + 2\cdot \delta_{a,b}^2 \cdot \aleph_{a,b} + \\ + \sum_{j=1}^{n-1} \delta_{b,j}^2 \cdot \aleph_{b,j} - (\varphi_a + \varphi_b) + D_{a,b} = 0, \end{gathered} \tag{10}$$

2) for the rod S_aS_{ref} of II type:

$$\begin{gathered} \sum_{i=1}^{m-1} \delta_{a,i}^2 \cdot \aleph_{a,i} + 2\cdot \delta_{a,ref}^2 \cdot \aleph_{a,ref} - \varphi_a + \\ + \left(R_{xref}\cdot x_{ref} + R_{y_{ref}}\cdot y_{ref} + R_{zref}\cdot z_{ref}\right) + \\ + D_{a,ref} = 0, \end{gathered} \tag{11}$$

where: m and n – number of nodes adjacent to the a-th and b-th (or ref-th) nodes.

If the number of nodes in the model is less than the amount of its rods, parametric equations have the form:

1) for the rod S_aS_b of I type:

$$\begin{gathered} \sum_{i=1}^{m-1} \left[\left(\delta_{i,a}^2 + (x_i - x_a)\cdot x_b + \right.\right. \\ \left.\left. + (y_i - y_a)\cdot y_b + (z_i - z_a)\cdot z_b \right)\cdot \aleph_{a,i} \right] + \\ + \sum_{j=1}^{n-1} \left[\left(\delta_{j,b}^2 + (x_j - x_b)\cdot x_a + \right.\right. \\ \left.\left. + (y_j - y_b)\cdot y_a + (z_j - z_b)\cdot z_a \right)\cdot \aleph_{b,j} \right] + \end{gathered} \tag{12}$$

$$
\begin{gathered}
+\left(\Im_{xb}\cdot x_a+\Im_{yb}\cdot y_a+\Im_{zb}\cdot z_a\right)+\\
+\left(\Im_{xa}\cdot x_b+\Im_{ya}\cdot y_b+\Im_{za}\cdot z_b\right)-\\
-\left(\varphi_a+\varphi_b\right)+D_{a,b}=0;
\end{gathered}
$$

2) for the rod S_aS_{ref} of II type:

$$
\begin{gathered}
\sum_{i=1}^{m-1}\Big[\Big(\delta_{i,a}^2+\left(x_i-x_a\right)\cdot x_{ref}+\\
+\left(y_i-y_a\right)\cdot y_{ref}+\left(z_i-z_a\right)\cdot z_{ref}\Big)\cdot \aleph_{a,i}\Big]+\\
+\left(\Im_{xa}\cdot x_{ref}+\Im_{ya}\cdot y_{ref}+\Im_{za}\cdot z_{ref}\right)+\\
+\left(R_{xref}\cdot x_a+R_{yref}\cdot y_a+R_{zref}\cdot z_a\right)+\\
+\left(R_{xref}\cdot x_{ref}+R_{yref}\cdot y_{ref}+R_{zref}\cdot z_{ref}\right)-\\
-\varphi_a+D_{a,ref}=0.
\end{gathered}
\tag{13}
$$

In the formulas (10) – (13): S_a and S_b – arbitrarily connected free a-th and b-th nodes, S_{ref} – some basic node of the model, $\overline{R}_{ref}$ – the vector of support reaction in the reference node S_{ref}; $D_{a,b}$ и $D_{a,ref}$ – the total integration constants.

The equations (10) – (13) have been obtained by differentiating the equations of the 1-st – 3-rd type from the system (9), as well as using algebraic operations on the equations of the 4-th type from the same system (9) [9, 10].

These equations have a several disadvantages. Thus, the identities (10) and (11) are bounded in the use of topological features of the rod system. With solving the system of equations (12) and (13) the matrix of coefficients always have zero diagonal. If the model has a large quantity of elements, then under certain its topological features the determinant the matrix of coefficients can tend to zero. In this case, the system of these equations will be degenerate.

The solution of the above-mentioned problems can be a replacement of diagonal elements or the non-zero. Since equations (10) and (11) have a simpler form of notation, it makes sense to modify exactly them.

To do this, we add to the equations (10) and (11) the following identities:

$$
(\chi-2)\cdot\delta_{a,b}^2\cdot\aleph_{a,b}-H_{a,b}=0, \tag{14}
$$

$$
(\chi-2)\cdot\delta_{a,ref}^2\cdot\aleph_{a,ref}-H_{a,ref}=0, \tag{15}
$$

where: χ – some non-zero constant.

As a result, we obtain:

$$
\begin{gathered}
\sum_{i=1}^{m-1}\delta_{a,i}^2\cdot\aleph_{a,i}+\chi\cdot\delta_{a,b}^2\cdot\aleph_{a,b}+\\
+\sum_{j=1}^{n-1}\delta_{b,j}^2\cdot\aleph_{b,j}-\left(\varphi_a+\varphi_b\right)+B_{a,b}=0,
\end{gathered}
\tag{16}
$$

$$
\begin{gathered}
\sum_{i=1}^{m-1}\delta_{a,i}^2\cdot\aleph_{a,i}+\chi\cdot\delta_{a,ref}^2\cdot\aleph_{a,ref}-\varphi_a+\\
+\left(R_{xref}\cdot x_{ref}+R_{yref}\cdot y_{ref}+R_{zref}\cdot z_{ref}\right)+\\
+B_{a,ref}=0,
\end{gathered}
\tag{17}
$$

where:

$$
B_{a,b}=D_{a,b}-H_{a,b}, \tag{18}
$$

$$
B_{a,ref}=D_{a,ref}-H_{a,ref}. \tag{19}
$$

In (14), (15), (18) and (19): $H_{a,b}$ and $H_{a,ref}$ – constants, determined by the value of χ.

The ability to perform such a procedure is explained as follows.

In the simplest case, the process of correcting the position of the model's nodes should be to replace the current values of node potentials to such that belong to a known isosurface of the scalar potential field φ. Form of these isosurfaces must take certain set of nodes and rods in the correcting of construction process. As a result should be selected optimal distribution of internal forces and the state parameters of the model. In the beginning of the selection we need to calculate the values of the integration constants $B_{i,j}$ for all rods of the model, taking into account the initial internal forces $R_{i,j}$. After that, it becomes possible to solve the inverse problem of determining the internal forces taking into account the previous values of the constants of integration and the corrected (at the current stage of the iterative computation) values of the scalar potential φ.

Clearly that the inclusion of additional terms in the parametric equations at the previous stage of the calculation will only lead to a change in the value of the constants $B_{i,j}$ in the next step of calculation, in no way affecting the character of the potential φ. This may change the rate of convergence of the iterative calculation. As a result, the zero diagonal elements of the matrix of coefficients will be replaced by $\chi \cdot \delta_{i,j}$.

ALGORITHM OF THE ROD STRUCTURES SHAPE CONTROL

Recorded using the above equation, we formulate the order of adjustment of the shape of the rod structure [11]. The appropriate algorithm can be summarized to the serial repetition of iterative cycles, each of which is carried out before reaching the established calculation errors. In matrix form, this algorithm has the following form:

$$\begin{cases} \left[s^p\right] = \left[\aleph^{p-1}\right]^{-1} \cdot \left(-\left[g^{p-1}\right] - \left[\Im^p\right]\right), \\ \left\{\aleph^p\right\} = \left[\left(\delta^p\right)^2\right]^{-1} \cdot \left(\left\{\varphi'^p\right\} - \left\{\varphi^p\right\} + \right. \\ \qquad \left. + \left[\left(\delta^p\right)^2\right] \cdot \left\{\aleph^{p-1}\right\}\right). \end{cases} \quad (20)$$

Here: $[s]$ – matrix of coordinates (with dimension $k \times 3$, where k – the quantity of nodes of the model):

$$[s] = [X \quad Y \quad Z], \quad (21)$$

where: $\{X\}$, $\{Y\}$ and $\{Z\}$ – the column vectors of coordinates of the nodes, which have the form:

$$\{X\}^T = [x_1 \quad x_2 \quad \ldots \quad x_k], \quad (22)$$

$$\{Y\}^T = [y_1 \quad y_2 \quad \ldots \quad y_k], \quad (23)$$

$$\{Z\}^T = [z_1 \quad z_2 \quad \ldots \quad z_k], \quad (24)$$

where: $[g]$ – matrix of the boundary conditions (with dimension $k \times 3$):

$$[g] = [g_x \quad g_y \quad g_z], \quad (25)$$

where: $\{g_x\}$, $\{g_y\}$ и $\{g_z\}$ – the column vectors of the boundary conditions, which have the following form:

$$\{g_x\}^T = \left[\sum_{i=1}^{L} x_i \cdot \aleph_{1,i} \quad \sum_{i=1}^{M} x_i \cdot \aleph_{2,i} \quad \ldots \quad \ldots \quad \sum_{i=1}^{N} x_i \cdot \aleph_{k,i}\right], \quad (26)$$

$$\{g_y\}^T = \left[\sum_{i=1}^{L} y_i \cdot \aleph_{1,i} \quad \sum_{i=1}^{M} y_i \cdot \aleph_{2,i} \quad \ldots \quad \ldots \quad \sum_{i=1}^{N} y_i \cdot \aleph_{k,i}\right], \quad (27)$$

$$\{g_z\}^T = \left[\sum_{i=1}^{L} z_i \cdot \aleph_{1,i} \quad \sum_{i=1}^{M} z_i \cdot \aleph_{2,i} \quad \ldots \quad \ldots \quad \sum_{i=1}^{N} z_i \cdot \aleph_{k,i}\right], \quad (28)$$

where: $[\Im]$ – matrix of external influences (with dimension $k \times 3$):

$$[\Im] = [\Im_x \quad \Im_y \quad \Im_z], \quad (29)$$

where: $\{\Im_x\}$, $\{\Im_y\}$ and $\{\Im_z\}$ – the column vectors of the components of external influences, which have the following form:

$$\{\Im_x\}^T = [\Im_{x\,1} \quad \Im_{x\,2} \quad \ldots \quad \Im_{x\,k}], \quad (30)$$

$$\{\Im_y\}^T = [\Im_{y1} \quad \Im_{y2} \quad \ldots \quad \Im_{yk}], \quad (31)$$

$$\{\Im_z\}^T = [\Im_{z1} \quad \Im_{z2} \quad \ldots \quad \Im_{zk}], \quad (32)$$

where: $[\aleph]$ – matrix of stiffness parameters of rod structure (with dimension $k \times k$), diagonal elements of this matrix contain the negative sums of stiffness parameters of the rods connecting to those nodes of the model, for which are made up the corresponding equations (according to the topology), the other elements contain stiffness parameters of bonds, that connect the corresponding to indexes nodes with the nodes, which corresponding to the diagonal elements in that row, or zeros (operation "or" will be denoted by «∨»), such a matrix has the following form:

$$[\aleph]=\begin{bmatrix} -\sum_{i=1}^{P}\aleph_{1,i} & \aleph_{1,2}\vee 0 & \cdots & \aleph_{1,k}\vee 0 \\ \aleph_{2,1}\vee 0 & -\sum_{i=1}^{Q}\aleph_{2,i} & \cdots & \aleph_{2,k}\vee 0 \\ \vdots & \vdots & \ddots & \vdots \\ \aleph_{k,1}\vee 0 & \aleph_{k,2}\vee 0 & \cdots & -\sum_{i=1}^{R}\aleph_{k,i} \end{bmatrix}, \quad (33)$$

where: $\{\aleph\}$ – column vector of stiffness parameters of rod structure, which has the following form:

$$\{\aleph\}^{T}=\left[\aleph_{a,b_1} \quad \aleph_{a,b_2} \quad \ldots \quad \aleph_{a,b_h}\right], \quad (34)$$

where: h – the quantity of rods of the model; $\{\varphi\}$ – column vector of nodal values of the scalar potential, which has the following form:

$$\{\varphi\}^{T}=\left[\varphi_{a_1}+\varphi_{b_1} \quad \varphi_{a_2}+\varphi_{b_2} \quad \ldots \quad \ldots \quad \varphi_{a_h}+\varphi_{b_h}\right], \quad (35)$$

$\{B\}$ – column vector of constants $B_{a,b}$, which has the following form:

$$\{B\}^{T}=\left[B_{a,b_1} \quad B_{a,b_2} \quad \ldots \quad B_{a,b_h}\right], \quad (36)$$

$[\delta^2]$ – matrix of geometric parameters of rod structure (with dimension $h\times h$), the diagonal elements of which contain products of constants χ and squares of the lengths of those bonds for which are made up the equations, corresponding to the specific row of the matrix; the other elements include squares lengths of bond, corresponding to the indices of the given cell of this matrix, or zeros; such a matrix has the following form:

$$[\delta^2]=\begin{bmatrix} \chi\cdot\delta^2_{a,b_{1,1}} & \delta^2_{a,b_{1,2}}\vee 0 & \cdots & \delta^2_{a,b_{1,h}}\vee 0 \\ \delta^2_{a,b_{2,1}}\vee 0 & \chi\cdot\delta^2_{a,b_{2,2}} & \cdots & \delta^2_{a,b_{2,h}}\vee 0 \\ \vdots & \vdots & \ddots & \vdots \\ \delta^2_{a,b_{h,1}}\vee 0 & \delta^2_{a,b_{h,2}}\vee 0 & \cdots & \chi\cdot\delta^2_{a,b_{h,h}} \end{bmatrix}, \quad (37)$$

$\{\varphi'\}$ – column vector of expected nodal parameters of the scalar potential, which have the form of similar to $\{\varphi\}$, p – index corresponding to the current step of the iterative calculation.

The system (20) can be described by the following order of operations:

1. Constructing of a system of equilibrium equations of the rod construction nodes,
2. Calculation of current nodal coordinates of the rod construction per approximately given initial conditions (which include the initial values of external loads and stiffness parameters of rods),
3. Constructing of parametric equations of bonds of the rod construction,
4. Determination of the current value of the scalar potential field of external influences,
5. Determination of the constants $B_{i,j}$ from the parametric equations of bonds with the current model coordinates and scalar potentials,
6. Solution of the system of parametric equations with respect to stiffness parameters with pre-replacement of values of the current potential on the potential values, which are desired, and taking into account the previously calculated values of the constants $B_{i,j}$,
7. Substituting of founded stiffness parameters into the system of equilibrium of the rod construction nodes; solution of this system relative to coordinates of the nodes of the model,
8. Repeating of the steps 3 – 7 until a specified level of absolute or relative errors of calculation is reached.

It should be noted, that in modeling of rod architectural constructions the external loads can be invariable in all nodes of a model, irrespective of the coordinates nodes. At the same time, scalar potential field may not reflect the potential gravitational field of the Earth (as one might think). This is completely acceptable from a mathematical point of view, as in the continuum (theoretically) can exist any number of scalar fields. Some of them can be mutually neutralized. Therefore, if the construction has to take the form of iso-surface of one of a pair of these "mutually neutral" fields, the nodes of the model will not take the mechanical action of the gradient vector from not one of these fields.

That is why the offered algorithm for control of the rod construction parameters allows giving it almost any shape, admissible of its topology.

CONCLUSIONS

On the basis of the generalized form of the static-geometric method of discrete geometry, was developed a new approach to solve the problems of shaping of rod spatial constructions. This approach allows not only to determine the preliminary shape of a designed construction by given conditions of external influence, but also, if necessary, to correct it by a system solution of parametric equations of rods of the model.

The proposed formulas allows determining the internal forces in the rods of the building structure. This makes it possible simultaneously to attribute this method to instruments of architectural forming and to instruments of numerical simulation.

REFERENCES

1. **Kovalev S. 1986.** The formation of discrete surface models of spatial architectural structures. Dissertation of the Dr. Sci. Tech. Moscow, MAI, 348.
2. **Brebbia C. 1984.** Boundary Elements Techniques. Theory and Application in Engineering. Berlin – New York – Heidelberg – Tokyo, Springer-Verlag, 526.
3. **Fenner R. 1975.** Finite Element Method for Engineers. London, The Macmillan Press Ltd.
4. **Forrest A. 1972.** On Coons and Other Methods for the Representation of Curved Surfaces. New York, Comp. Graf. and Image Proc., 341-359.
5. **Holand I. 1969.** Finite Element Method in Stress Analysis. Trondheim, Tapir-Verlag.
6. **Richtmyer R. 1967.** Difference Methods for Initial-Value Problems. New York – London – Sydney, INTERCIENCE PUBLISHERS: a division of John Wiley & Sons, 419.
7. **Schutz B. 1979.** Geometrical methods of mathematical physics. Cambridge – London – New York – New Rochelle – Melborn – Sydney, Cambridge University Press, 303.
8. **Skochko V. 2013.** Special geometrical models of processes which develop in continuum. Dissertation of the Ph. D. Kyiv, KNUBA, 269.
9. **Skochko V., Skochko L. 2012/2013**. The differenttial laws between the geometrical and physical parameters of the mashes and the fields which balance them. Kyiv, Base and foundations, Nr 33, 85-95.
10. **Skochko V., Skochko L. 2013.** The equation of state and condition parameters of the mesh structure relationships. Kyiv, Base and foundations, Nr 34, 47-57.
11. **Ploskiy O., Skochko V. 2014.** Algorithm of meshwork's communications controlling based on adjustment of the scalar potential of external influences. Kyiv, Energy efficiency in the construction, Nr 6, 224-230.
12. **Ploskiy O., Skochko V. 2014.** The discrete cages of surfaces constructing using equations of state's parameters and conditions of the mesh structure's communications. Lutsk.

ПРИНЦИПЫ ДИСКРЕТНОГО МОДЕЛИРОВАНИЯ СТЕРЖНЕВЫХ КОНСТРУКЦИЙ ОБЪЕКТОВ АРХИТЕКТУРЫ

Аннотация. В публикации раскрываются основные принципы моделирования стержневых пространственных строительных конструкций средствами дискретной геометрии. Приведены математические зависимости, составляющие основу данного подхода и представляющие собой дифференциальные закономерности между геометрическими и физическими параметрами моделируемых конструкций, а также параметрами внешних нагрузок, определяющих конечную форму модели.

Ключевые слова: геометрическое моделирование, дискретная модель, сетчатые структуры, стержневые конструкции, дифференциальные закономерности.