BALANCE OF THE KNOT OF THE DISCRETE TWO-DIMENSIONAL AND ONE-DIMENSIONAL STRUCTURE ON THE AREA

J. Romanova*

Summary. In this work it is identified the dependence between the options of external load and coefficients of proportionality of the efforts of tension or compression of fastening to their lengths in a balanced knot at the given coordinates of the knots of the discrete two-dimensional and one-dimensional structure on the area.

Keywords: **discrete structure on the area, balance of the knot, control options, coefficients of tension in fastening.**

Formulation of the problem. Static-geometrical method of forming discrete structures can determine the discrete point frame of continuous patterns (lines, surfaces and so on.) with any specified step or unknown sample as well as control the structure of the form [1]. Supporting contour, coordinates of certain internal components, options of external formative load (direction and dimension of efforts), the coefficients of proportionality of efforts tension or compression of fastening to their lengths can be control options. The impact of the last options on the shape of structure hasn't been studied enough.

Analysis of recent researches. There are some works [2,3], where various factors of tension of the discrete of two-dimensional grid were used only to manage the contour shape [3] or take into account the different warp tension and to form the surface of the awning coverings [2]. In addition, factors of tension of fastening of contour were appointed the same for all the contours [3] or were the same all along the warp that means that factors of tension along the one direction grid had the same value.

Formulation of article purposes. The purpose of the article is to determine the dependence between the external load parameters and coefficients of proportionality of efforts of tension or compression of fastenings to their lengths in a balanced knot at the given coordinates of components of the discrete two-dimensional and one-dimensional structure on the area.

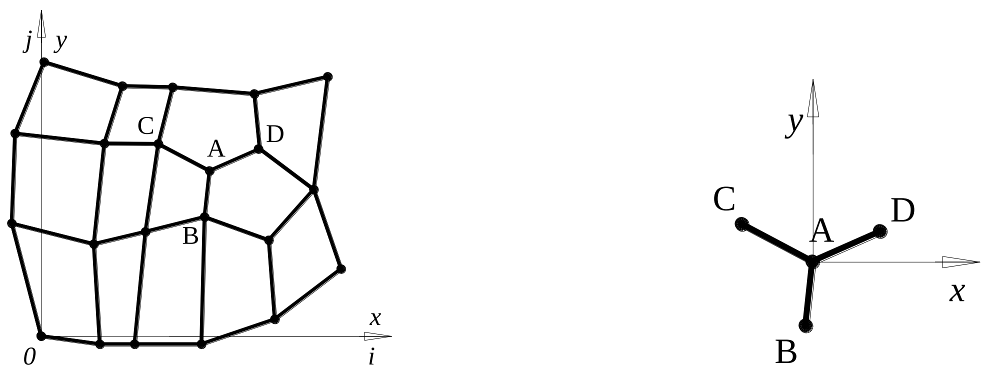
Main part. Endless set of options of external distribution of efforts in the knots is possible. The balance of the knot is provided by various coefficients of tension in fastenings. There are lots of possible variations of these coefficients.

In static-geometric method certain efforts in fastening considered to be proportionate to the length of fastenings, which provides linearity of a system of equations balance and, as a result - a possibility of choice from variety of solutions.

---

*Supervisor – Prof. S.M. Kovaljov

Coordinates of internal knots and coefficients of tension may be unknown for a given knots of contour. The balance of a net with coordinates of knots (Fig.1, a) can be provided, according to the static-geometric method, due to various coefficients of tension in fastenings. Their number should be equal to the number of equations of balance. In such a way it's possible to determine the ratios in which components of the net will occupy a given position.



a *b*

Fig. 1.

The star is the element of such a net, that consists of a central knot; fastenings, which converge in this knot and surrounding knots which belong to these fastenings (Fig. 1b).

In general case, *n* fastenings may converge in the knot A. To select a single solution it is necessary to make a parametric analysis of a balance of one knot.

In the given coordinates of knots of the discrete two-dimensional structure in the knot M on the area may be possible ∞^n options of the balance of the knot at the directional load kP (Fig. 2) (where n - number of fastenings in the knot), as in fastening it's possible to set one-parameter means of efforts kP. Then the equation of the balance of the knot M looks like:

$$\begin{aligned}(x_A - x_M)k_{AM} + (x_B - x_M)k_{BM} + \ldots + (x_N - x_M)k_{NM} + kP_x = 0,\\ (y_A - y_M)k_{AM} + (y_B - y_M)k_{BM} + \ldots + (y_N - y_M)k_{NM} + kP_y = 0.\end{aligned} \quad (1)$$

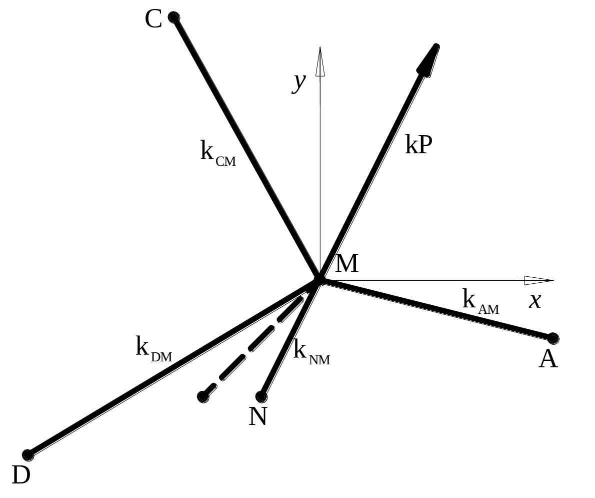


Fig. 2

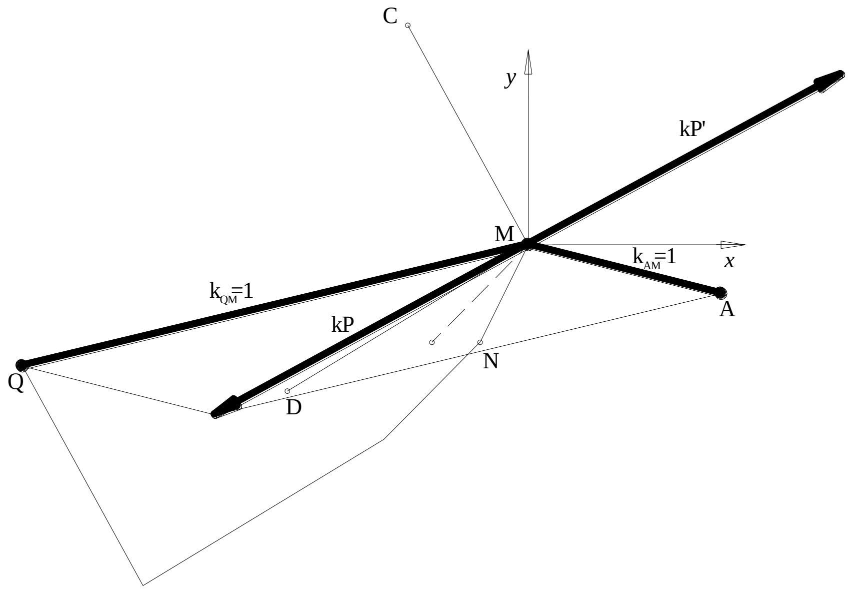


Fig. 3

If the load is unknown, discrete two-dimensional structure can be transformed into one-dimensional (Fig. 3) as specified *n-1* efforts are reduced to a single resultant $\overline{MQ}$ (k_{MQ}=1). Efforts in the fastening AM (k_{AM}=1) seemed to be given.

The balance of the knot of one-dimensional discrete structure on the area

The separate case 1. In the given knots A_{i-1} and B_{i+1} it's possible ∞^2 of options of the balance of the middle knot M_i of one-dimensional discrete structure on the area with directional external load kP and two variable parameters k_1 and k_2 (Fig. 4). The equation of the balance of the knot M_i is:

$$k_1(x_{i-1}-x_i)+k_2(x_{i+1}-x_i)+kP_x=0,$$
$$k_1(y_{i-1}-y_i)+k_2(y_{i+1}-y_i)+kP_y=0. \qquad (2)$$

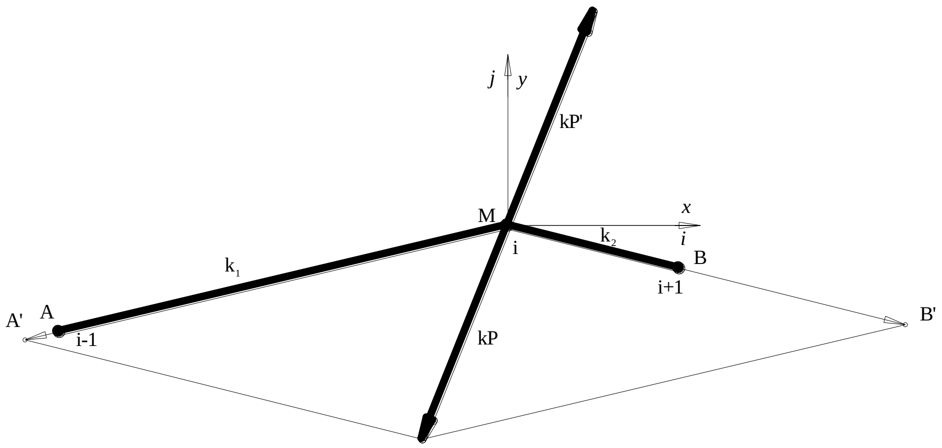


Fig. 4

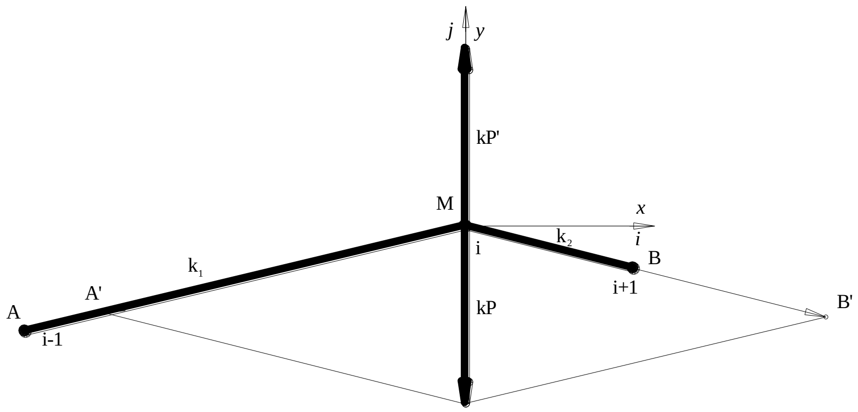


Fig. 5

Parameters of external load P and coefficients of tension in fastenings k_1 and k_2 are connected by the functional dependence:

$$k_2 = \frac{k[P_x(y_{i-1} - y_i) - P_y(x_{i-1} - x_i)]}{x_{i-1}(y_{i+1} - y_i) + x_i(y_{i-1} - y_{i+1}) + x_{i+1}(y_i - y_{i-1})}, \tag{3}$$

where it's possible to determine the dependence of each parameter P_x, P_y, k, and k_1 from the rest. For example:

$$P_x = \frac{kP_y(x_{i-1} - x_i) + k_2[x_{i-1}(y_{i+1} - y_i) + x_i(y_{i-1} - y_{i+1}) + x_{i+1}(y_i - y_{i-1})]}{k(y_{i-1} - y_i)}, \tag{4}$$

$$k_1 = \frac{k[P_x(y_{i+1} - y_i) - P_y(x_{i+1} - x_i)]}{x_{i-1}(y_i - y_{i+1}) + x_i(y_{i+1} - y_{i-1}) + x_{i+1}(y_{i-1} - y_i)}. \tag{5}$$

Equation (3) - (5) describes the linear dependence between the parameters k_1, k_2, P_x and P_y.

The separate case 2. If the external load is vertical, it is possible ∞^1 variations of the balance of the knot (Fig. 5), as each meaning kP corresponds to the one pair of parameters k_1 and k_2.

The equation of the balance of the knot M_i looks like:

$$k_1(x_{i-1} - x_i) + k_2(x_{i+1} - x_i) = 0,$$
$$k_1(y_{i-1} - y_i) + k_2(y_{i+1} - y_i) + kP_y = 0. \quad (6)$$

Parameters kP and k_1, k_2 are connected by the functional dependence:

$$k_2 = \frac{-kP_y(x_{i-1} - x_i)}{x_{i-1}(y_{i+1} - y_i) + x_i(y_{i-1} - y_{i+1}) + x_{i+1}(y_i - y_{i-1})}, \quad (7)$$

where it's possible to determine the dependence of each parameter P_y, k_1 from the rest:

$$kP_y = \frac{-k_2[x_{i-1}(y_{i+1} - y_i) + x_i(y_{i-1} - y_{i+1}) + x_{i+1}(y_i - y_{i-1})]}{x_{i-1} - x_i}, \quad (8)$$

$$k_1 = \frac{-kP_y(x_{i+1} - x_i)}{x_{i-1}(y_i - y_{i+1}) + x_i(y_{i+1} - y_{i-1}) + x_{i+1}(y_{i-1} - y_i)}. \quad (9)$$

Equation (7) - (9) describes the linear dependence between the parameters P_y, k_1 and k_2.

In general, as it is shown in Fig. 2, the power kP is set, the task is to establish the balance in three-connected knot (Fig. 6). It's necessary to specify the coefficients of tension in *n-2* fastenings. All the given *n-2* efforts are reduced to one resultant $\overline{MQ}$ (k_{MQ}=1).

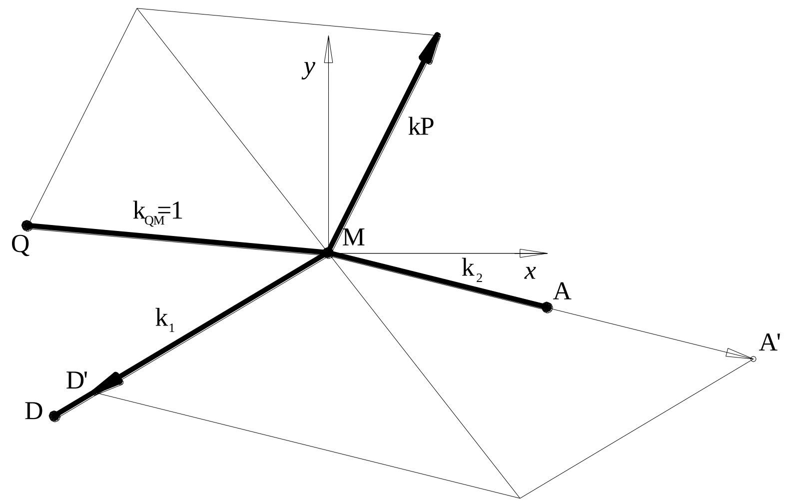


Fig. 6

Parameters of external load kP and coefficients k_1 and k_2, tension in the fastenings are connected by the functional dependence (10), (11):

$$k_1 = \frac{x_A(y_Q + kP_y) - y_A(x_Q + kP_x)}{x_D y_A - x_A y_D}, \quad (10)$$

$$k_2 = \frac{y_D(x_Q + kP_x) - x_D(y_Q + kP_y)}{x_D y_A - x_A y_D}. \quad (11)$$

Conclusions. It was identified the dependence between the options of external load and coefficients of proportionality of the efforts of tension or compression of fastening to their lengths in a balanced knot at the given coordinates of the knots of the discrete two-dimensional and one-dimensional structure on the area.

Literature

1. Ковалев С.Н. Формирование дискретных моделей поверхностей пространственных архитектурных конструкций: дис. … д-ра техн. наук: 05.01.01/ С.Н. Ковалев. – М.:МАИ, 1986. – 320 с.
2. Королюк С. В. Формообразование тентовых поверхностей с учетом деформации материала покрытий: дис. … канд. техн. наук: 05.01.01 / С.В. Королюк. – К.:КИСИ, 1986. – 164 с.
3. Чан Хонг Хай . Управление формой растянутых систем на основе функционального сложения: дис. … канд. техн. наук: 05.01.01 / Чан Хонг Хай; КНУСА. – К., 1994. – 124 с.