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PECULIARITIES OF THE MAIN PLANNING WORKS FOR BUILDING NOISE-BARRIER HIGH CONSTRUCTIONS

***Abstract**. One of the ways to protect the city from noise is to build noise barrier cranes that will protect the rest of the micro region buildings from noise. When building such high-altitude buildings, marking engineering-geodesic works are one of the most important and at the same time complicated stages of construction. In this work we will focus on creating the detailed methodology, that will solve the problems by the methods of non-linear programming, by minimizing the influence of random errors of RTN decisions. To define the accuracy of the algorithm, experimental works were accomplished on the reference polygon in the conditions of construction site. The suggested analytical solution of providing the projected construction size and the mutual allocation between it by the way of looking for optimal parameters of transformation between the genplan coordinates system and USK-2000 solves the problem of the errors of the horizontal location of geodesic network points.*

***Keywords:** GNSS measurements, marking works, coordinates, RTN method*

Introduction

One of the most widely spread factors of environment pollution is noise – accumulation of the numerous sounds the frequency and power of which quickly change. According to the research, 30-50% of modern cities population is influenced by constant or periodic (during the day) noise, level of which exceeds the performance standard, e.i. is in the area of acoustic discomfort [7, 8]. For this reason, it's important to provide acoustically suitable conditions for habitation when creating and implementing projects for architectural replanning and reconstruction of current city areas.

One of the ways to protect the city from noise is to build noise barrier cranes that will protect the rest of the micro region buildings from noise. The peculiarity of this type of construction is that noise proof buildings are located on the red lines as nearly as possible to the traffic artery. Noise barrier building should be long (at least 100 m) and tall enough (see fig. 1). The building should have P shape and protruding noise barrier (glazed) balconies and stanzas.

When building noise barrier multi-functional high-altitude buildings, planning and engineering-geodesic works are one of the most important and at the same time complicated stages of construction. The fact is that they have to not only comply with the requirements of project documentation and construction specifications, but the high pace of construction as well. Because of all these reasons, it's crucial to improve the current and create the new methods of geodesic construction, that will comply with the accuracy requirements and high construction pace. According to the functioning documents, during marking works it is necessary to follow the projected buildings sizes and mutual arrangement between built and projected constructions with 3-5 mm accuracy. At the same time, sites of the geodesic network and/or red lines are fixed on the area with the 50 mm [5, 6] error in the axis position, which is the subject for repeating measurements. All these factors condition a necessity to improve the existing and develop new methods for geodesic support of construction.

Methodology

When building a large complex of buildings and industrial objects, planning and marking engineering-geodesic works are one of the most important and complicated construction stages. During the horizontal planning, the project of buildings allocation is made together with the transport and other communication lines. During the horizontal planning, the project of buildings allocation is made together with the transport and other communication lines. For this purpose, the system of construction adjustment lines is created first on the plan, that shouldn't be lapped over by the buildings. When projecting the residential area, the system of red lines is created to separate the quarters from the streets and passages. The location of red lines is determined by the coordinates of junction points, angles of direction and distances between the points. The important factor is that the mutual location and building sizes determined in the system of general plan coordinates are errorless, when the site coordinates (especially red lines and even sites of geodesic base) have 5 cm of systematic accuracy and may even contain rough errors.

Herewith, It's important to keep in mind that on big residential or industrial objects, it's convenient to use the coordinate system of general plan when rendering project elements of construction. The system of general plan coordinates has a lot of advantages during the marking works. One of the benefits is that calculating the site coordinates with the parallel lines of coordinates axes construction comes down to summing up the technological sizes of the building and the projected distances between them. This approach almost eliminates the calculation errors. At the same time, all the construction elements should have the coordinates in the State Geodesic Network of Ukraine (USK-2000). For this reason, one of the requirements for the creating the geodesic network on the construction [5, 6] is the opportunity of conversion to different coordinate systems, including determining the transformation parameters between the coordinate systems data.

This issue is especially pressing for building noise barrier multi-functional high-rise constructions. Due to their uniqueness and complexity, the projecting engineers require increased accuracy during geodesic marking works.

Consequently, without the detailed methodology of comparing the points of support geodesic network and eliminating the building elements that contain rough errors, it's impossible to conduct the planning geodesic works and search for transformational parameters. Classically this problem is solved in the following way. The long-lasting static GNSS measurements are conducted on at least four points with the known project coordinates. To define the position of the sites in the state geodesic coordinate system with the 3-5 mm accuracy, the duration of the measurements on one point should be at least six hours [9]. The next step is to make the network even with the help of Credo or any other specialized geodesic program. According to the results of measuring, the transformational parameters are found. Such process is very time consuming and not suitable for the fast construction pace nowadays. In this work we will focus on creating the detailed methodology, that will solve the problems described above by the methods of non-linear programming. The methodology will be tested on the high-rise construction in Ivano-Frankivsk on Mazepy street with the help of redundant high-precision measurements (fig. 1).

Let's define the position of the geodetic control network points and construction red lines with the help of RTN (Real Time Networks) method. The peculiarity of this type of positioning is that when following the methodological recommendations in the short period of time (30-60 s), we can get the points coordinates in USK-2000 with the 20-30 mm systematic accuracy.

However, the existence of all construction elements in the coordinate system of General Plan and Ukrainian System of Coordinates. 2000 results from GNSS measurements makes it possible to analytically solve this task by setting the dependencies of the technological (regulatory) limitations of the geometrical parameters evenness of already existing buildings. They are characterized by the deviations from the projected lengths and determined from the results of GNSS measurements ΔS_i.

This task is somehow related to the tasks of calculating the optimal data for preserving the correlation of RU details like VVER-1000 and optimal regulation of sizes between the axis of anchor foundation bolts and anchor holes of base equipment plate, solution of which is provided in the works [1, 4]. In this work, it is mentioned that the task is solved with any objective function and the solutions are brought to the coordinate view when the $\sum \Delta S_i^2 = \min$.

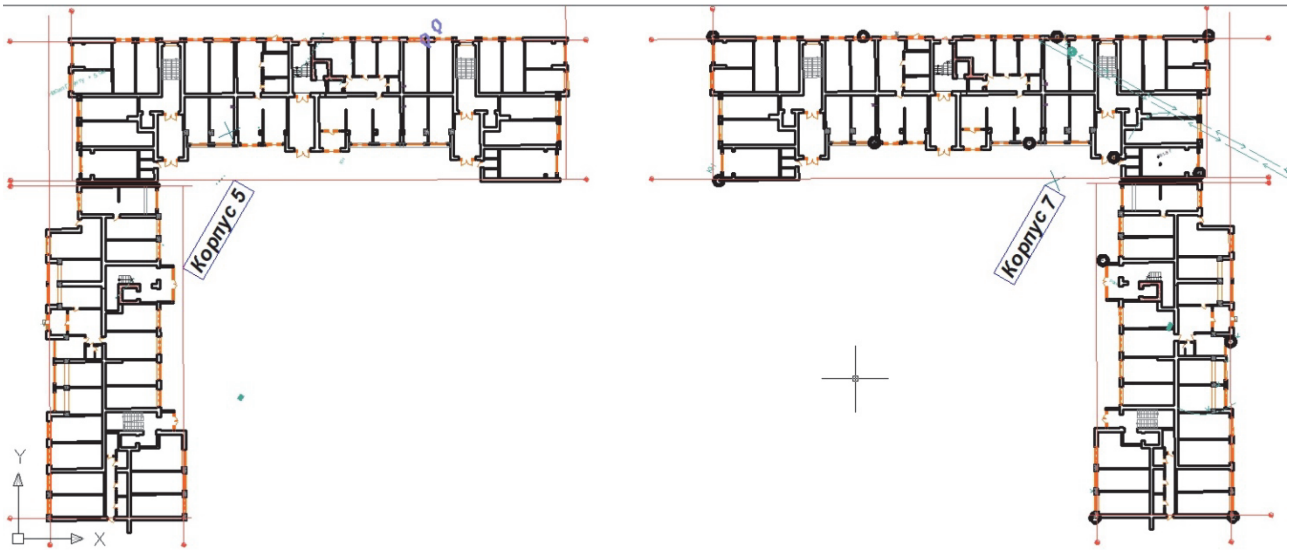

FIGURE 1. *General plan of building the noise barrier multi functional high construction in Ivano-Frankivsk city on Mazepy 5 Street*

Let's show the practicability of this approach. To provide the evenness of the geometrical parameters of buildings between the projected sized and their practical results on the construction site, the instrumental method of the electronic tables Excel as Solver will be used, that operates the universal methods of solving the mathematical programming tasks: algorithm of the non-linear optimization and algorithm of the simplex method for solving the linear and integral tasks with limitations. The appliance of Solver allows to solve this task with any objective functions and set limitations when necessary (according to the requirements). Let's prove the efficiency of this methodology by providing the evenness of the geometrical parameters and their practical values according to the GNSS measurements results.

For recommended method, one has to set S_i, as function from the parameters that have to be found: values of bias of the coordinates x_0, y_0 beginning and the angle of coordinates Q axes rotation. Also it's important to set limitations on the correlation of the calculated values and providing the evenness of the projected buildings sizes and correlated allocation between the constructed and projected buildings with 3-5 mm accuracy.

Let's admit that the points of the main axes of existing and projected buildings are characterized by the planning coordinates – from the general plan $X_i^{'}, Y_i^{'}$ and X_i, Y_i GNSS measurements. With the help of famous transformation formulas, let's find the relation between the construction elements in two coordinate systems.

$$\begin{cases} X_i^{'} = X_0 + X_i \cos Q - Y_i \sin Q \\ Y_i^{'} = Y_0 + X_i \sin Q + Y_i \cos Q \end{cases} \tag{1}$$

With the help of (1) let's find the vector lengths, that characterize the deviation of the point after its calculation into the coordinates system of the general plan from its projected coordinates. This deviation is caused by both the errors of the fixed points of the geodesic network and/or red lines and errors of GNSS receiver.

$$S_i = \sqrt{\left(X_0 + X_i \cos Q - Y_i \sin Q - X_i^{'}\right)^2 + \left(Y_0 + X_i \sin Q + Y_i \cos Q - Y_i^{'}\right)^2} \rightarrow \min \tag{2}$$

Next step is to set the technological (regulatory) limitations of the evenness of the geometrical parameters of buildings according to the general plan and results of GNSS measurements.

$$\Delta S = S_i - S_i^{'} = \sqrt{\left(X_B^{'} - X_A^{'}\right)^2 - \left(Y_B^{'} - Y_A^{'}\right)^2} - \\ -\sqrt{\left(\cos Q\left(X_B - X_A\right) - \sin Q\left(Y_B - Y_A\right)\right)^2 + \left(\sin Q\left(X_B - X_A\right) + \cos Q\left(Y_B - Y_A\right)\right)^2} \le 5 \text{ mm} \quad (3)$$

Based on the expressions (2) and (3), let's solve the task with *n* equations with (3) unknown quantities that allows to formulate the optimization task and find the value of transformational parameters, where S_i value will be minimal with the compulsory technological (standard) limitations where $\Delta S \le 5$ mm.

Results

To illustrate the capabilities of the recommended methodology, let's review the measurements of the planned deviations of the points of geodetic control network and red lines contours on the example of noise-barrier multi-functional high building on Mazepy 5, that were already conducted on the built-in points after main marking works. To check the accuracy of the methodology on the construction, we have conducted the recurrent high-accuracy measurements were conducted and the points errors were defined. The mutual direction of the errors has occured due to the systematic element of errors common for RTN method. This issue was studied in the previous work [2].

Table 1 provides the projected points coordinates, their contorted values in the coordinate system USK-2000 and corresponding shifts.

Table 1. *Coordinate points of the geodetic network control*

№	General plan		USK-2000		Δ	
1	100	100	5424201,1268	5329669,4572	0.032	-0,02
2	100	150	5424157,8117	5329694,3884	0.048	-0,037
3	100	200	5424114,4646	5329719,3506	0.032	-0,023
4	150	100	5424226,0730	5329712,7913	0.03	-0,017
5	150	150	5424182,7429	5329737,7365	0.031	-0,02
6	150	200	5424139,4128	5329762,6818	0.032	-0,023
7	200	100	5424251,0232	5329756,1154	0.032	-0,024
8	200	150	5424207,6851	5329781,0727	0.025	-0,015
9	200	200	5424164,3570	5329806,0139	0.032	-0,02

To minimize the displacement vector of the point (S_i) by the methods of non-linear programming, let's use the Solver add-on (solution) in Excel. In this case, we have calculated the optimal value for all the points of network with sequential usage of two object functions $\sum \Delta S_i^2$ and $S_{i\max}$ and applied technological (standard) limitations $\Delta S \le 5$ mm (3). To check the invariance and to make a choice according the coordinate beginning, the additional calculations were done with the help of Silver when choosing the coordinates starting point in the left low angle or center with the minimal value $\sum \Delta S_i^2$ and $S_{i\max}$.

The table 2 provides the optimization results of points shift according to the errorless genplan coordinates for red line points and geodetic network control of the noise-barrier multi-functional high construction taking into account the applied technological (standard) limitations. The results of the optimization were analyzed when the coordinate beginning is located in the center of the area and the right angle during transformation.

TABLE 2. *Results of the external marking network optimization*

№ points	Data S_i before optimization [mm]	$\sum\Delta S_i^2$ [mm]		$S_{i\,max}$ [mm]	
		midpoint	right	midpoint	right
1	37.7	25.3	4.9	13.8	8.3
2	60.6	45.0	18.3	43.2	20.9
3	39.4	28.9	4.1	39.2	4.7
4	34.5	15.1	4.6	6.2	14.0
5	36.9	8.0	2.6	17.8	8.1
6	39.4	19.6	2.6	36.2	7.1
7	40.0	9.3	6.3	17.8	11.0
8	29.2	13.1	7.1	32.3	20.9
9	35.6	19.2	1.6	43.2	15.6
∑	353.3	183.5	52.1	249.7	110.6
AM	37.7	25.3	4.9	13.8	8.3

As the demonstrating material, we have used the graph of the displacement vector on the points before and after optimization.

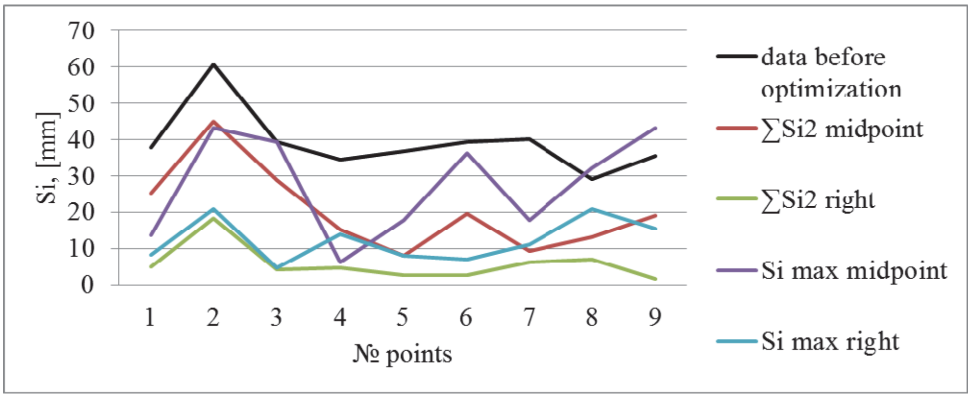

FIGURE 2. *Comparing the results of optimization of using different objective functions*

After analyzing the obtained results, we can claim that Solve effectively solves the task of minimizing the translation vector of the point (S_i), by determining the optimal parameters of transformation (X_0, Y_0 and Q) for this network.

Because of this test for invariance using two purpose functions, the following conclusion was made: coordinate points were disfigured by the accidental values, that lie under the distribution law. After calculating this model, we can also state that the vectors of errors in this network are directed into one side. This specific of general vector direction is common for the most geodesic networks. It can be explained as both the inheritance (errors of the output data are transferred to all construction elements) and peculiarity of the marking works with RTN measurements (general direction of the systematic error component [2, 3, 10]).

By obtaining the transformational parameters (X_0 = 5424237,90645862, Y_0 = 5329532,89983849, Q = 1,04845947220014 that fully comply with our network (were obtained when minimizing the objective function with the datum point on the left), we can conduct the main marking works with dual frequency receiver set by RTN method. The main advantage of which is that all the measurements are made by a single geodesist in a short period of time.

Conclusions

The suggested analytical solution of providing the projected construction size and the mutual allocation between it by the way of looking for optimal parameters of transformation between the genplan coordinates system and State Geodesic Network of Ukraine gives the opportunity not only to avoid errors when determining the connections between the systems and the following rendering of the construction elements by RTN method, but also to provide the accuracy of the marking works.

This method allows to eliminate errors both in geodesic base network and on points, measured by GNSS receiver without additional measurements. The analysis of the research results described in table 2 allows to recommend the optimization non-linear programming methods for comparing special linear angle networks, both by creating the template of electronic table and including the corresponding software unit in the system of automated processing.

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