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MODERN GIS PROPOSITION FOR CONSTRUCTION INTO HISTORICAL PART OF THE CITY

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Problem statement

The construction of the biggest Kharkov SEC (Shopping and Entertainment Center) “Nikolsky” has been continued in 2013. The center area will be more than 130 thous. sqm. These are the main features of this construction:

- foundation pit more than 20 meters deep with a revetment wall was not in use for 8 years;
- revetment wall of the foundation pit borders on the Pushkinskaya roadway – one of the city central streets;
- construction is located in Kharkov historical center, surrounded by old-established buildings of architectural importance, such as the State Library of Vladimir Korolenko and the synagogue.

Geoinformational support should be offered and developed by the start of the construction. This will help designers and engineers to make the right decisions about strengthening the revetment wall. First, the detailed analysis of design features of the revetment wall should be carried out. Also an approach to structural monitoring should be developed. Both revetment wall of the foundation pit and the surrounding historic buildings should be the objects of observation. Second, geoinformational maintenance (laser scanning and monitoring) must be performed in a single coordinate system.

Analysis of recent researches and publications

Recently a lot of researches on the use of ground-based laser scanning for the inspection of buildings and structures were developed [2,3]. In some cases scanning technology has been successfully used for monitoring purposes. Application of the scan for structural monitoring was considered to be unpractical during the "Nikolsky" center construction. This is associated with the large number of construction equipment on the building site and hight-density development around the building site.

Unsolved part of the problem

It is extremely hard to create control survey network for structural monitoring in conditions of high-density development of the historical part of the city and the high-intensity of construction works.

Furthermore, the complicated construction of the revetment wall requires a special approach to the observation of the displacement of individual fragments (planes) of the wall. It should also be considered that several different coordinate systems (CS) are used in Kharkov. Except the state USC-2000, land cadastre is implemented in SC-63. Also the local coordinate system of the city is used. Therefore, pre-excavation survey of the foundation pit should be coordinated with the laser scanning data and planned altitude coordinates of the control network.

Statement of the Problem

The problem is to determine the best possible approach to the use of modern geoinformational technologies for structural features of the revetment wall of the foundation pit analysis and to find the implementations of control survey network support. The technology of ground-based laser scanning is considered to be the most appropriate for constructing measure drawings of a revetment wall and 3D – model.

The usage of GNSS-stations permanent network gives the undeniable advantage in creating control survey networks. Due to the fact that Kharkov region is covered by the network NGCNET of the company "Navigation and geodesic center", there are some positive prerequisite for making a single gridding of all performed works.

The main material

The main tasks within geoinformational support of the center "Nikolsky" center were:

- creation of the detailed 3D - model and the accompanying drawings of the revetment wall of the foundation;
- implementation of measures to create engineering and geodesic maintenance for the monitoring tasks of deformation of the revetment wall;
- determination of the parameters of sliding and sagging.

Creating 3D - models and drawings

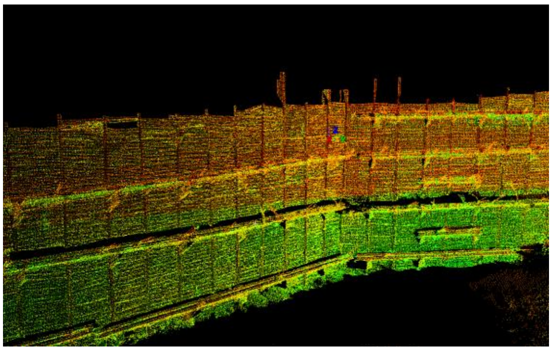
The use of laser scanning technology (LT) is the most appropriate due to the abundance of small details and revetment wall dimensions. This technology is able to provide the most complete and detailed information about the object in the form of a point cloud for a minimum period of field work.

Point cloud is the set of points with space coordinates (X,Y,Z), describing the surface of the scanned object. The main advantages are: the survey speed, data redundancy and independence from illumination (laser scanning may be performed both in bright light and in complete darkness).

This project used the laser scanner Leica ScanStation. This is a pulsed laser scanner with integrated dual-axis compensator. It has a large measurement range of distances and 360 ° × 270 ° field angle.

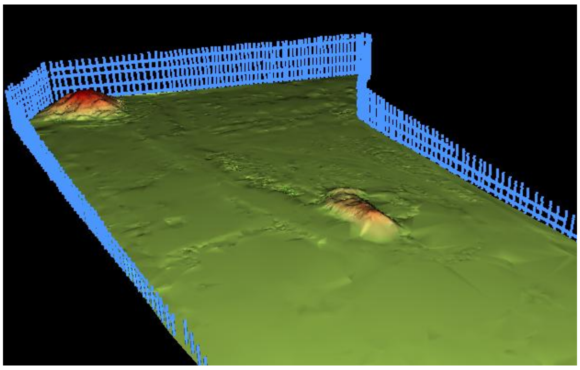
Leica Geosystems Cyclone software was used to run the scanner and to process the results. This product has a fairly wide range of tools both for 3D-modeling and for more specific tasks.

Field work took 8 days, more than 145 million points were obtained in result. There is a fragment of the point cloud, cleared from the mush, on pic. 1.



Pic. 1. The revetment wall model in the form of point cloud

The 3D - model of revetment wall was obtained after the point cloud cleaning from mush with the help of standard set of basic elements of Cyclone software (pic. 2).



Pic. 2. 3D - model of the object

Creation of control networks

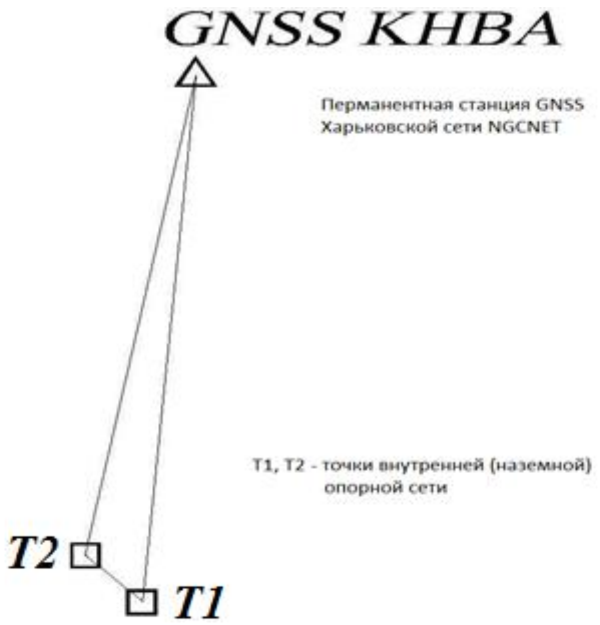
The main task for monitoring works is to determine places, where the observations will be held. While examining the territory of building site, 4 stations were identified (the internal control network). Concrete pylons with the mounting pad for device were mounted on these stations to obtain the required precision work. (pic. 3).

Pic. 3. Pylon with the mounted device

The network of permanent GNSS reference stations – NGCNET was used as starting (control) base to determine the coordinate points of the geodesic travers.

Determination of the coordinate points of geodesic travers performed with the help of bifrequency geodesic GNNS - receivers in a static survey mode. Network method of a static survey allows you to control the geometrical conditions in triangles, formed by base vectors. The magnitude of the residual error in triangles leads to the conclusion about the accuracy of measuring distances in each triangle.

Observation sessions were carried out from two basic receivers to provide surveillance with redundant data, required for adjustment. Duration of the session was not less than 5 hours due to baseline length up to 5 km (pic. 4). Number of satellites was at least seven (average 8-9). The position of condensation points and permanent pinning points were determined with the help of GNNS receiver GS08 NetRover produced by "Leica Geosystems" (Switzerland). Processing results of field measurements was performed with the help of software Leica Geo Office v.7.0.1.



Pic. 4. Clamping circuit of base points

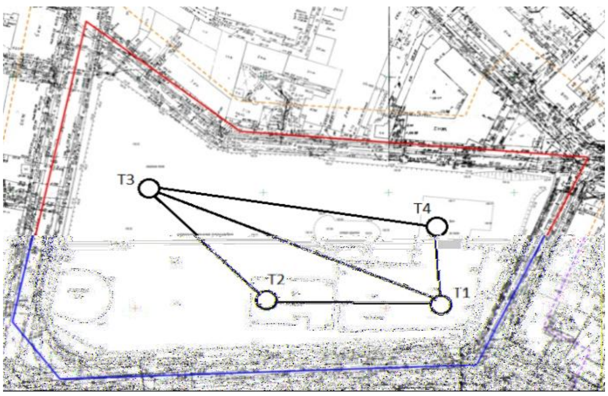
Type Codes:
△ – base GNSS station - NGCNET;
□ – base GNNS-the point of the control network.

Position of identified points have a priori mean squared error, which is equal to 25 mm (planned components of coordinates) and is equal to 35 mm (high-altitude of coordinates component) in reference to the State Geodesic Network.

Connection of internal network polygons (pic. 5) was performed in 5 actions 10 rounds. Angular discrepancy in the triangles does not exceed the acceptable error:

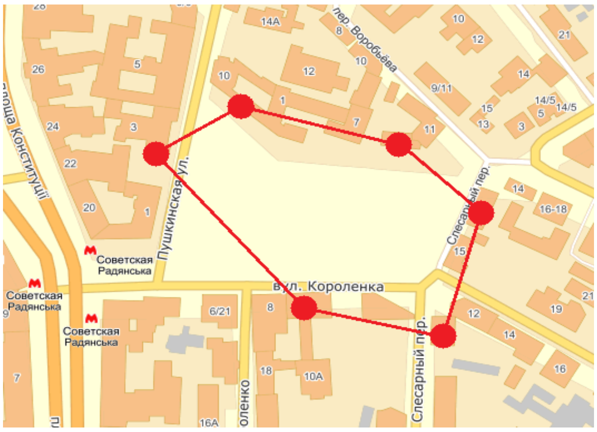
$$f_{\text{доп.}} = \pm 1' \sqrt{n}\,, \qquad (1)$$

where n – is the quantity of angles.



Pic. 5. Scheme of the internal control network

Duing the subsequent, more intensive construction, supervisions with pylons mentioned above will be impossible, so in order to conduct further observations outside (external) control network has been developed and installed (pic. 6).



Pic. 6. Scheme of the externall control network

Totally 6 prismatic reflectors on neighboring buildings across the object were installed (pic. 7). Buildings that became the subjects for prismatic reflectors were chosen due to the location of the object (at least 5 reflectors are visible from each observation point), as well as all the buildings older than 5 years (saggings and slidings are terminated after the passage of this period).

Connection of the external control network was carried out with pylons of internal network by repeated observations of each point in 3 actions 6 rounds.

Pic. 7. Appearance and location of the fixed reflector

Installation and engineering

Materials of data processing of laser scanning helped to find the best possible place for grades and prismatic reflectors fixation. Due to the size and physical characteristics of the revetment wall, it was decided to install 127 grades and 20 reflectors. This decision helped to create uniform coating of the entire surface of the complex metal structures. To ensure the complete accuracy, grades Leica GZM31 and prisms Leica GPR111 have been used.

In consideration of works complexity at a height, professionals with experience in high-altitude installation were engaged in grades and reflectors fixation. Stamps were installed with a mounting adhesive, prismatic reflectors were installed on previously welded special pintles. (pic. 8 - 9).

Pic. 8. Appearance of fixed prismatic reflectors

Pic. 9. Appearance of fixed grades

Monitoring of sagging and displacement

The main requirements for monitoring are regularity, accuracy and efficiency of data acquisition. Therefore, any modern, developed system for obtaining and processing monitoring data must meet these requirements. Before commencement of works, the frequency of observations with the technical state of the object and the total duration of monitoring should be determined. In the instant case the observations are suggested to make on a weekly basis on a certain day. One day is given to process results. The results will be given the day after the date of observations.

As monitoring implies a comparison between the reference and the current settings, there is some uncertainty due to the lack of reference parameters. In this case, it was suggested to make a number of additional observations to make a set of statistics to calculate the average numbers used as reference values. The purpose of observing this object is the systematic tracking of changes in parameter values of construction's sagging and displacement.

Observations are made by remote sensing method with the help of total station Leica FlexLine TS06 2 ". From each control point (pylon) three rounds of observations are held to give a set of three groups of space coordinates (X,Y,Z) of each grade and reflector.

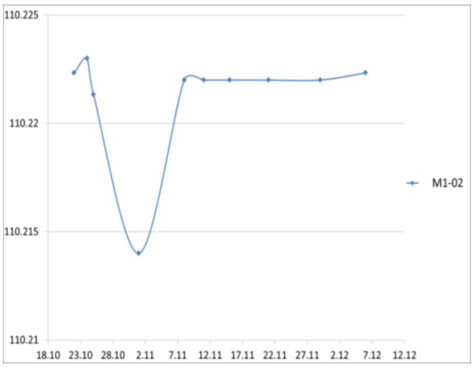
These measurements are equally accurate, as carried out with fixed static control points and by a single instrument. Reasoning from this fact, the elimination of crude errors is performed by predetermined algorithm.

Considering the complexity and specificity of data processing of monitoring the complex metal structure, the appliance of deformation tensor is a necessity. Deformation tensor is a tensor, which determines the position of the body points after deformation with respect to their position prior to deformation.

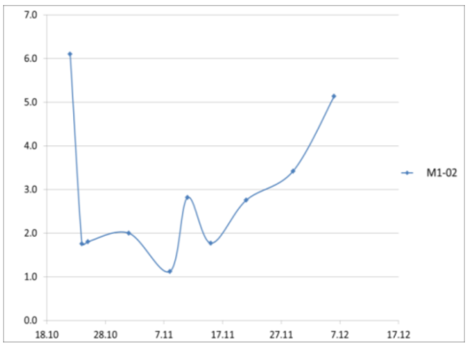
To calculate the displacement vector to the center, it was decided to divide conditionally the composite construction of revetment wall of the foundation pit in 5 planes, each of which provides a certain amount of grades and reflectors.

Adapting the methodology of tensor analysis to the specific conditions of observation with specific research object and features, which a priori data has, formulas for calculating the sliding for each plane due to its deviations in Kharkov coordinate system were obtained.

The results were presented in tabular form, as well as in the form of graphs of sliding and sagging, where parameter point (at a given value) and the date of observation (data for 2013) are the axes. Examples are shown in pic. 10 - 11.



Pic. 10. The graph of sagging due to the grades in m.



Pic. 11. The graph of sagging due to the grades in mm.

Conclusions

The application of modern GIS technologies gives a distinct advantage over traditional methods and means of construction provision. Ground-based laser scanning allowed to inspect the construction of a revetment wall and to get a 3D model, which is an important step to strengthen the wall. Statistics of GNSS-stations network allowed to implement various projects in the same coordinate system. So, the structural monitoring of the revetment wall was made on the basis of survey networks pegged to NGCNET network.

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Modern GIS proposition for construction into historical part of city

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The article is proposing use of modern geographic information technologies (laser scanning, structural monitoring) in the construction of a large facility into historical part of the Kharkov city.