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PRELIMINARY ANALYSIS OF THE GEODETIC NETWORK OF THE ALMALYK INDUSTRIAL ZONE

Abstract: *the article discusses the role of a geodetic network for a mining facility. GPS measurements are analyzed to improve the accuracy of geodetic points in the vicinity of the quarry. A dispersion analysis of the accuracy of coordinates in the plane, in height and in the covariance matrix for a geodynamic point near the Almalyk industrial zone was performed. A scheme for thickening the geodetic network around the quarry, including points of the Central Asian geodynamic network and projected GPS points, is proposed.*

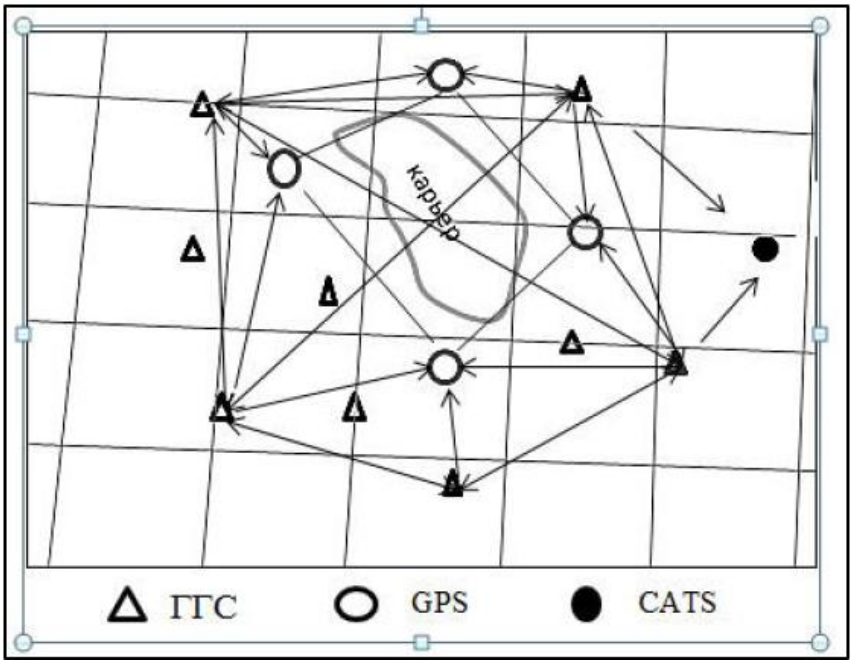
Keywords: *GNSS, CATS, AFGS, triangulation, leveling.*

The design of a geodetic network is the selection of the location of points on the surface, following certain instructions. The density of points should correspond to the purpose of the network, and the shape of the network should ensure the definition of network elements with the calculated accuracy. Field measurements associated with the reference geodetic network, geocentric coordinate system, figure and gravitational field of the earth must be reduced to a certain epoch, taking into account the variation in the speed of the earth's rotation, the movement of the earth's crust and other effects. And if industrial facilities are located or built near this network, then their role acquires a special status due to changes in spatial dimensions due to mining. Therefore, during the construction of a mining facility, one of the important areas is the creation of a planned high-altitude basis of a geodetic network.

In 1960-1990 during the construction of structures and objects, angular and linear measurements were made using optical theodolites and levels [1]. With the advent of high-precision satellite navigation receivers, the accuracy of points increased by several orders of magnitude [2]. The advantage of using these receivers is the rapid processing of measurement results with the ability to export data in any format. Existing classical methods of adjustment differ from satellite methods in accuracy of coordinates of points. The combination of classical and satellite measurements on the example of the Almalyk industrial zone (APZ) will give an accurate and correct system for determining coordinates near the quarry.

The APL geodetic network is characterized by high accuracy in determining the relative position of adjacent points in the local coordinate system (Fig. 1). The last time this network was re-equalized was in 1980. enterprise No. 12 of the main department of geodesy and cartography based on triangulation and leveling. Adjusted rectangular coordinates in the longitudinal-transverse Gauss-Krüger projection and orthometric heights are stored in a special coordinate catalog [3]. Naturally, open access to these data is limited due to the specifics of the work and the accuracy of topographic maps. However, triangulation and leveling points located in the vicinity of the quarry can be used for global navigation satellite systems (GNSS). Topographic maps of scales 1:100000 - 1500000 are available in the public domain and can be copied from the Internet. A 1:100 000 scale map of the APL territory was copied from [4], compiled on the basis of a 1:50 000 scale based on aerial photography in 1957, and updated by the stereophotogrammetric method in 1980-1990. Solid horizontal lines are drawn through 40 meters at a height of the relief section from 1 to 10 degrees, and at a section height of 10-40 degrees, solid horizontal lines are drawn through 200 m. 40 years have passed since the network was updated, which indicates the need for clarification, both in terms of accuracy and the situation. Figure 1 shows a diagram of a quarry with GGS points marked with triangles, the coordinates of which are stored in the archive, but approximate coordinates can be calculated from the map. The plotted circles around the pit are designed GPS points for GNSS measurements. To control the

measurements and calculate the coordinates of the points of the geodetic network, it is advisable to bind to the coordinates of the point of the Central Asian Geodynamic Network (CATS - Central Asian Tectonic Science) “ALMA”. Thus, an increase in the accuracy of the entire network around the pit is achieved. The coordinates of the points should be periodically redefined and equalized, but, due to organizational measures, topographic measurements in the APL were made sporadically.



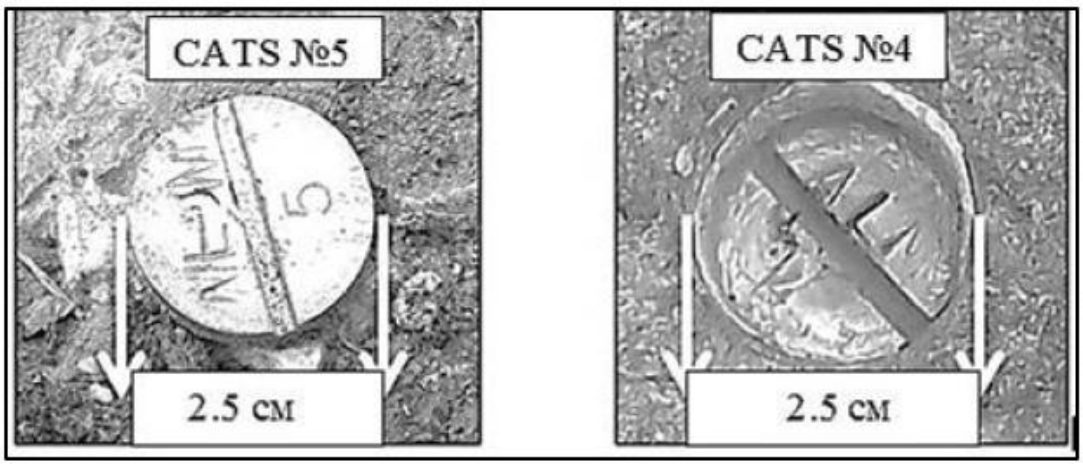
Rice. 1. Geodetic points in the vicinity of the Almalyk quarry

In 2006, the Central Aerogeodetic Enterprise of the Republic of Uzbekistan made measurements on the territory of the APL, but no final results were obtained due to the lack of special software.

In 2016-2015 employees of the Department of Geodesy and Mine Surveying of the Tashkent State Technical University measured the angles and elevations inside the quarry using an electronic total station and an H3 level. In the process of grade 3 leveling, 50 benchmarks were laid on the northwestern slope of the quarry, of which only 8 have survived.

In 2013, employees of the Department of Geodesy, Cartography and Cadastre of the National University of Uzbekistan (NUUz.) reconnoitered CATS points near the Almalyk quarry in order to use it as a reference point for the geodetic network and newly designed GPS points [5]. The Magelan mobile navigation satellite

receiver was used to search for geodynamic points. The spatial and spheroid coordinates of the "ALMA" site under study were previously known. During the reconnaissance, 2 points of the geodynamic network were found with the designations "NEW 5" and "ALMA 4" (Fig. 2). The approximate coordinates of these points were re-determined.



Rice. 2. Items CATS ALMA № 4, №. 5

In 2019, teachers, masters and students of the Department of Geodesy and Geoinformatics of NUUz. made GNSS measurements at points № 4 and № 5 of the "ALMA" CATS network using the TRIMBLE R4 GNSS navigation receiver. Despite the fact that about 30 years have passed since both points were established, no damage or deformation was found, which cannot be said about the signals and pyramids of traditional networks that require reconstruction and restoration [6]. It is possible that changes in the coordinates of the ALMA sites occurred under the influence of global and local displacements of microplates. First of all, this concerns the quarry itself, which changes over time. Secondly, soil displacement due to groundwater located under the quarry. A total of 10 measurement cycles were made with an interval of 10 minutes in the RTK mode in the absence of external factors.

Based on the measured data, the department assessed the accuracy of measurements and calculated the spatial coordinates of the points. The initial data for processing the measurement results were the parameters of the reference ellipsoid, the reference system and the correction to the coordinated time system (UTC - Coordinated Universal Time). After post-processing, coordinates were

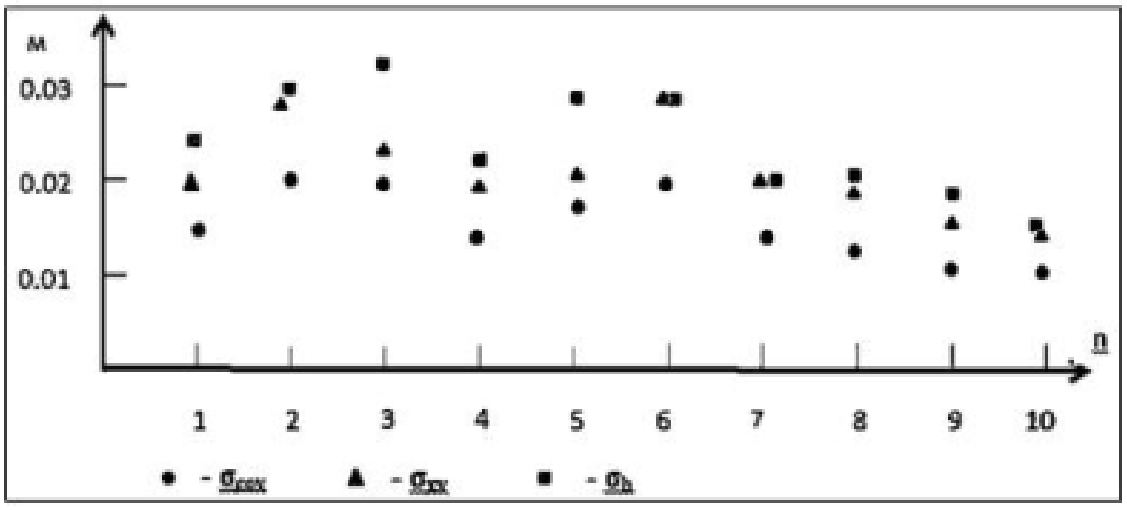
obtained on the plane (x, y), the reference ellipsoid ($L^{эл}$, $B^{эл}$, $H^{эл}$) and the world geodetic system (WGS84). The accuracy of spatial coordinates was estimated using the diagonal elements of the covariance matrix [7]. Table 1 below lists the mean square errors in plane (σ_{xy}), height (σ_h), and covariance matrix data (σ_{cov}).

Table 1.

Baseline coordinates accuracy (base - ALMA) in meters

№	σ_{xy}	σ_h	σ_{cov}	**PDOP**
1	0.020	0.024	0.015	1.518
2	0.028	0.029	0.020	1.420
3	0.022	0.032	0.019	1.418
4	0.018	0.022	0.014	1.416
5	0.020	0.027	0.017	1.413
6	0.030	0.027	0.020	1.471
7	0.020	0.020	0.014	1.403
8	0.018	0.020	0.013	1.354
9	0.015	0.018	0.011	1.352
10	0.014	0.015	0.010	1.349

Based on the data in Table 1, it can be seen that the variance of the accuracy of coordinates in the plane, in height and in the covariance matrix are close to each other and have the same trend, which indicates the correctness of the measurement results. The accuracy indicator PDOP=1.411 for all series of observations has almost the same value, i.e. the influence of external factors is insignificant. Based on the results of the dispersions, a graph of the dependence of accuracy on the number of measurements was constructed.



Rice. 3. Changing the accuracy of coordinates on the plane (x, y), along the height (h) and the covariance matrix (cov)

Analysis of the graph data shows that the accuracy of the baseline depends on the measurement cycle, although the distance between the base station and the determined point is 3m. A slight deviation is present for the 6th cycle of measurements, apparently due to the configuration of the satellites. The accuracy of determining the coordinates and the baseline satisfies all the requirements for using them as starting points when carrying out geodetic work at points around the quarry. You can also use these points when upgrading the existing and projected GNSS network [8]. Below are some recommendations for improving the APA.

Work on further development, modernization and improvement of the accuracy of the coordinates of points should continue almost continuously using modern geoinformation technologies and digital geodetic tools, including international software packages for GNSS network adjustment, both inside the quarry and in its vicinity. To do this, first of all, it is necessary to reanimate the existing network by reconnaissance and restoration of damaged signals and pyramids. Further, it is necessary to develop a general design of the Almalyk Fundamental Geodetic Network (AFGS), where all classical and reference satellite positioning should be associated with a high-precision point of the Central Asian Geodynamic Network No. 4 “ALMA” CATS and international IGS stations. Each point should become a stationary fundamental geodetic station, at which measurements should be periodically performed according to a certain program. In addition to determining the exact positions at the station, GNSS must register changes in the groundwater level, causing corresponding changes in the height of the point and the deviation of the plumb line from the normal [10]. Therefore, the transition to a higher level of accuracy will require mathematical processing of the results of geodetic measurements in the four-dimensional space X,Y,Z, t. Thanks to the creation of the AFGS and the implementation of repeated measurements according to a specific program, it will be possible to build a system of reference geodetic points, the instantaneous coordinates of which will be known with high

accuracy at each point in time. The development and gradual implementation of a specific network construction scheme depends on the skill level of specialists who will participate in this important area of geodetic science.

From the above, it can be concluded that the use of GNSS will increase the accuracy of the coordinates of points, and will also allow obtaining information about groundwater in real time. The data obtained will be the basis for the development of a spatial digital model of a quarry and modeling of man-made processes inside the facility. In this regard, it is necessary to develop a comprehensive program for the modernization of the geodetic network in the vicinity of the Almalyk quarry using GIS, GPS, CATS and seismological stations of Uzbekistan.

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