JUSTIFICATION OF THE METHODOLOGY OF CONTROLLING THE VOLUMES OF CRUSHED STONE STORAGE USING GEOINFORMATION SYSTEMS

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ABSTRACT. Mineral reserve accounting is a key and responsible procedure that completes a comprehensive study of a deposit and determines its industrial value. At the same time, an important task of surveying support for mining operations is the determination of the volumes of mining operations and conducting drilling and blasting operations, as well as control over the volumes of crushed stone storages. Careful accounting of natural resources, their rational and integrated use is the main task of surveying works. Determining the volumes of crushed stone storages is an urgent scientific and practical task. Increasing the accuracy of determining the volume, the efficiency of this process, and the possibility of its automation make it possible to significantly increase the efficiency of the stone mining enterprise.

Key words: digitisation, crushed stone raw materials, volumes of crushed stone storage, tacheometric surveying, photogrammetric surveying.

ОБОСНОВКА НА МЕТОДИКАТА ЗА КОНТРОЛ НА ОБЕМИТЕ НА СЪХРАНЕНИЕ НА НАТРОШЕН КАМЪК С ИЗПОЛЗВАНЕ НА ГЕОИНФОРМАЦИОННИ СИСТЕМИ

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РЕЗЮМЕ. Отчитането на запасите от полезни изкопаеми е ключова и отговорна процедура, която завършва цялостното проучване на находището и определя неговата индустриална стойност. В същото време важна задача на геодезическата поддръжка на минните операции е определянето на обемите на минните дейности и извършването на сондажни и взривни операции, както и контролът върху обемите на складовете за трошокаменни суровини. Внимателното отчитане на природните ресурси, тяхното рационално и комплексно използване е основната задача на геодезическите работи. Определянето на обемите на складовете за трошен камък е спешна научно-практическа задача. Повишаването на точността на определяне на обема, ефективността на този процес и възможността за неговата автоматизация позволяват значително да се повиши ефективността на каменодобивното предприятие.

Ключови думи: цифровизация, трошонокаменни суровини, обеми за съхранение на трошен камък, тахеометрично заснемане, фотограметрично заснемане.

Introduction

Recently, there has been an increase in the demand for building materials in Ukraine. The economic development of Ukraine and EU countries has led to increased construction of roads, overpasses, residential buildings, structures, and other objects. This increases the demand for crushed stone, the primary building material among the natural stone materials used in construction (Cherniaiev et al., 2023). Natural crushed stone is a natural material formed by crushing rocks, gravel, and boulders, mining waste from ores, and processing non-ore minerals. Natural stone, from which crushed stone is obtained, is mined in quarries, crushed in crushers, and screened into different fractions. The most common rock for the production of crushed stone is granite (Bozhyk et al., 2022).

An essential factor in sustainable mining is high-quality surveying support for the mining and processing rocks to obtain high-quality crushed stone. Engineering support for the process of mining and processing crushed raw materials includes the performance of relevant work at all stages of the development of the deposit, namely: discovery of the deposit, calculation of explored reserves, implementation of elements of the technical project in the area, surveying support for drilling and blasting works, operational calculation of the volume of mining works, control over compliance with technical solutions, etc. In addition to the accuracy of surveying work, production processes require timely receiving of survey results (Saik et al., 2023).

The modern geodetic and surveying equipment market offers a wide selection of universal high-precision electronic tachometers, which can be used for various geodetic tasks. Many geoinformation systems allow you to process geodetic measurement data and solve several tasks to extract crushed stone (Kunytska et al., 2023). Therefore, the performance of surveying works with the help of modern technical means of measurement, and processing of results with the help of special computer programs for determining the volumes of crushed stone storages is an urgent scientific and practical task.

Theoretical part

Among the mining and surveying tasks, one of the most important is the calculation of mineral reserves, in particular, the choice of the most optimal method. Mineral reserves are the number of minerals discovered and estimated at the place of occurrence based on geological survey data of open deposits. (Armands et al., 2020).

The process of counting stocks includes the main stages:

- contouring of the deposit;
- distribution of reserves by economic value, degree of exploration, categories of occurrence, and mining conditions;
- determining the calculation parameters;
- quantitative calculation;
- assessment of the accuracy of the results.

Depending on the shape and conditions of the deposit, the nature of the change in the content of valuable components, the reconnaissance system and the density of reconnaissance points, and the goals and purpose of the calculation, different calculation methods are used. In practice, there are more than 20 such methods (Mantey and Aduah., 2021). In modern conditions, effectively controlling crushed stone raw materials in storages of crushed stone becomes an essential element for optimising production processes and resource management

(Mykhailov, 2024). Growing competition, requirements for product quality, and the need for efficient use of resources, all make the issue of accurate control of crushed stone volumes significant in order to ensure the stable operation of the enterprise (Levytsky and Tolkach, 2017).

In each mining enterprise, a surveyor needs to measure the volumes of warehouses of finished products or waste rock dumps. For this, they can use several methods, depending on the conditions in which the object of the shooting is located. The main types of measurement include tacheometric surveying and modern photogrammetric surveying using specialised software (Fomychov et al., 2018). Tacheometric surveying is the most common method for determining the volume of quarry mining operations. It is used for one-off and repeated surveys in all types of open-pit mining, especially in large quarries with a great depth of development.

To calculate the volume of crushed stone storage in the survey area, a storage of 20-40 mm of crushed stone fractions was selected. A *Nikon NPL-332* total station was placed near it to perform measurements and obtain values from the surface of the storage. The *Nikon NPL-332* total station provides high reliability and performance. The increase in productivity is achieved due to the ability to make high-precision distance measurements directly to objects without using reflective prisms. Tacheometric surveying is the most common method of surveying for quarries. Surveying is carried out by optical tacheometers with an accuracy of reading in a vertical circle of no less than 1 minute or automatic tacheometers with a vertical rail (Kovanič et al., 2024).

In the case of a control survey of the volume of crushed stone storage, the difference between the primary and control determinations of the volume should not exceed the values given in Table 1 below.

Table 1. *The difference between the primary and control definitions of the volume of the crushed stone storage*

Volume of the crushed stone storage, m^3	Up to 200	200–500	500–2000	Over 2000
The relative difference between the two independent definitions is permissible, %	12	8	4	3

During the measurements, the total station's location was changed three times to remove the barrier from all sides. Fifty points were measured to enter them into the *AutoCAD Civil 3D* software.

Most points are located near the lower edge of the barrier to specify the contour of the barrier, and the rest are on the surface to determine the height in space. The location of points in the simulation space is shown in the figure (Fig. 1).

The next stage was the creation of two surfaces, which form the surface of the crushed stone storage and the surface of the area on which it is located.

Figures 2 and 3 show the simulation in space with different views and angles.

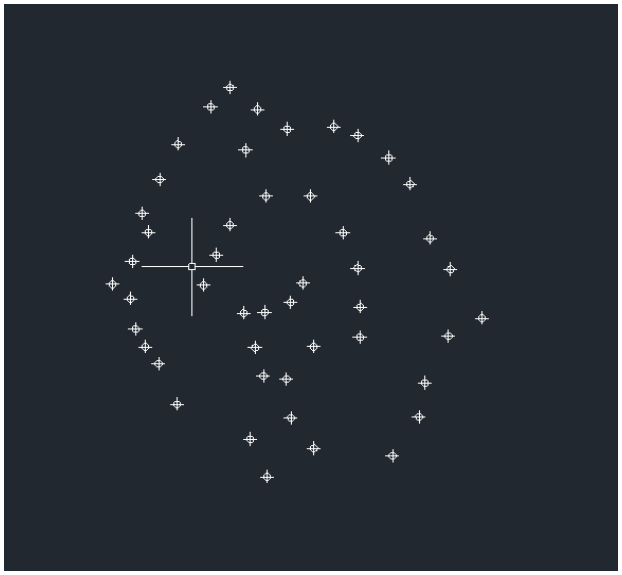

Fig. 1. Location of capture points in Civil 3D

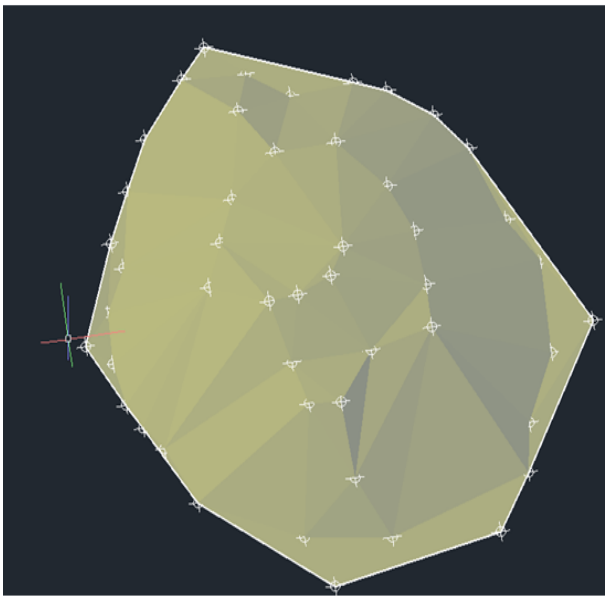

Fig. 2. Crushed stone storage surface

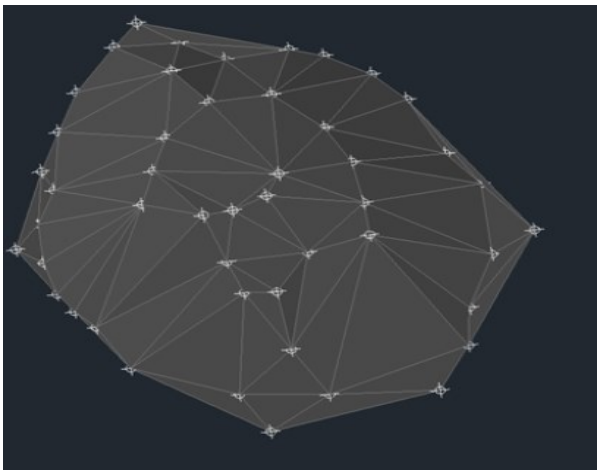

Fig. 3. Located area of crushed stone storage

As a result of the calculation, the storage volume is 793.91 m^3.

One of the modern methods of determining the volumes of crushed stone compositions is photogrammetric surveying.

To create the surface of the crushed stone barrier, the barrier was photographed from all sides using a hand-held 3D laser scanner, *AlphaGEO SLAM R100*.

SLAM R100 is a portable real-time 3D reconstruction device developed by *AlphaGEO*, which integrates a LiDAR module, a high-precision inertial navigation module, and high-performance computer modules. Thanks to the integrated system and simple management, built-in *AlphaGEO Multi-SLAM* reconstruction algorithm, the laser scanner can be used to directly acquire point clouds in true colors and create 3D models.

In the *Agisoft Metashape* software, modelling was performed using the built-in optimiser of the positions of the shooting cameras in space. One hundred and fifty-four photos taken around the warehouse were used for modelling. Figure 4 shows the location of the removal positions and the constructed cloud of points that form the storage.

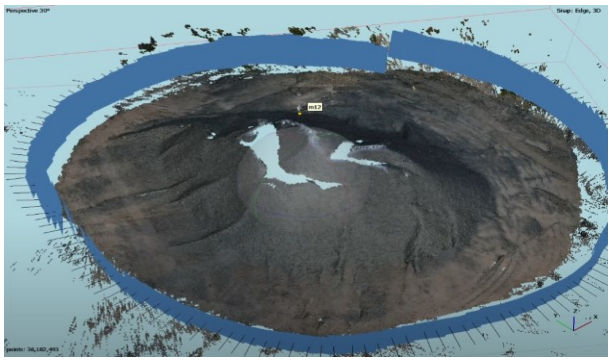

Fig.4. Dense cloud of points and positions of photographing centres

The next stage was creating a digital model of the height and contouring of the barrier according to the visual contour to automatically calculate the volume of the dam above the contour to be created. Automatic calculation determines the volume in and above the contour line drawn on the digital model (Fig. 4.).

As a result of the calculation, the storage volume is 794,24 m^3.

Figure 5 shows the results of measuring the volume of crushed stone storage with fractions 24-40 mm by different methods.

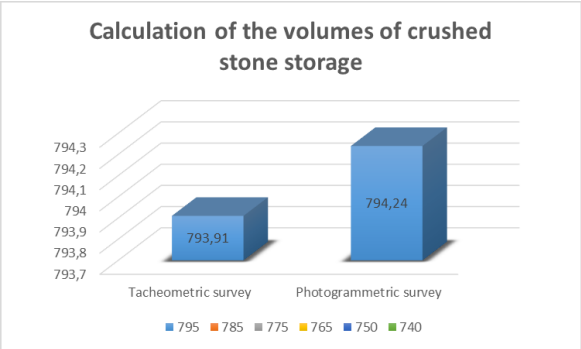

Fig.5 The results of measuring the volume of crushed stone storage

Results and discussion

It was determined that tacheometric surveying has been well established over a long period of its use. However, determining the coordinates of points with the help of laser scanners has gained popularity and accuracy for performing any measurements that will provide the necessary conditions and accuracy.

In modern conditions, effectively controlling the volumes of crushed stone raw materials in the warehouse of finished products is a key element of optimising production processes and resource management. Increasing competition, requirements for product quality, and the need for efficient use of resources all make the issue of accurate control of the volumes of crushed raw materials urgent to ensure the stable operation of the mining enterprise. Two measuring methods were used to calculate the volume of crushed stone products: total station and photogrammetric.

Conclusion

The measurements by the two methods showed that the volumes were almost the same, and the difference was 0.04%, which completely met the requirements of the survey for determining the volumes of crushed stone warehouses. It was determined that the measurement accuracy was ensured by high-quality surveying for each method. Each method can be used at mining enterprises that extract crushed stone.

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