Organization of continuous monitoring of quarry sides

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Abstract. The article discusses the fundamental conceptual positions underlying the study of the significant impact of humanity on the lithosphere, which is approaching and may exceed its limits. It is noted that most surface layers of the Earth's crust are non-renewable, and the majority of chemical elements have found practical applications, yet only about one-seventh of the extracted minerals are used in the production of final products. One of the main challenges in developing open-pit mines is maintaining the stability of the pit walls. As the depth of the pit increases, this issue becomes increasingly critical. The article emphasizes the importance of enhanced study of the fundamentals of managing rock masses in mining operations and the practical application of this knowledge, as it significantly contributes to solving problems and examples related to assessing the stability of slope walls and pit benches.

1 Introduction

The Comprehensive Monitoring System entails a comprehensive approach to monitoring the stability of quarry walls. It involves the integration of various monitoring techniques and technologies to ensure thorough surveillance and early detection of any potential instability [1].

Key components of the Comprehensive Monitoring System include:

1. Sensor Network: Installation of a network of sensors strategically positioned throughout the quarry walls to monitor factors such as deformation, temperature, pressure, and other relevant parameters.
2. Data Acquisition System: Implementation of a robust data acquisition system capable of collecting data from the sensor network in real-time. This system facilitates continuous monitoring and provides a comprehensive dataset for analysis.
3. Data Analysis and Processing: Utilization of advanced algorithms and analytical tools to process the collected data and identify any signs of instability or abnormal behavior in the quarry walls. This analysis helps in early detection and prediction of potential hazards. [2
4. Alert Mechanism: Integration of an alert mechanism to notify relevant personnel in case of any detected anomalies or potential risks to the stability of the quarry walls. This ensures timely intervention and mitigation measures.

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5. Remote Monitoring Capability: Provision of remote monitoring capabilities, allowing personnel to access real-time data and monitoring status from anywhere via secure online platforms or mobile applications.
6. Integration with Existing Systems: Seamless integration of the Comprehensive Monitoring System with existing quarry management systems and workflows to ensure efficient operation and decision-making.

Overall, the Comprehensive Monitoring System provides a comprehensive solution for continuous monitoring of quarry walls, enabling proactive management of stability and mitigation of potential risks. The system can utilize laser scanners, radars, electronic theodolites, GPS, digital levels, laser rangefinders, inclinometers, tilt sensors, weather sensors, and other equipment.

Fig. 1. Bench face angles.

The information support system for monitoring the stability of quarry benches represents a complex consisting of a set of expandable components and can be presented at the most generalized level as a combination of:

- a database allowing to store, adjust, retrieve, associate, disseminate any information related to the stability of quarry benches and slopes;
- visualization tools for spatial information of any types and formats stored in the database, including plans of mining operations, locations of mining equipment, exploration and engineering boreholes, geological structures and anomalies, seismic data, mining and land allocation maps, laser and radar scan point clouds, sketches, and photographs [3];
- cross-correlation analysis tools to enhance the reliability of decisions made;
- hardware and software complex for automatic and semi-automatic input of sketches and photographs of geological structures into the database in field conditions;
- set of tools for refining the position of quarry benches and slopes and analyzing the dynamics of their movements based on comprehensive monitoring results, as well as tools for displaying analysis results in a digital quarry (deposit) model;
- set of tools for detailed observation of identified high-risk areas for mining operations;
- set of tools for long-, medium-, and short-term forecasts of rock mass deformations;
- integration tools of early warning and evacuation systems for people and equipment from the hazardous area with the existing quarry ACS.

Means for organizing continuous monitoring of quarry benches, considering the complex geological conditions of the deposit, entail the necessity of creating new and improving existing methods and systems for controlling the stability of quarry benches. The weakening of the physical and mechanical properties of rocks in the zone of influence of major tectonic disturbances, seismic effects of mass explosions cause deformations of quarry bench slopes

in different sections, which can lead to serious disruptions in mining operations. In order to study the internal structure of the near-bench array, determine the potential sliding surface of forming deformations, identify zones of fracturing characterizing the initial stages of landslide development, it is necessary to use modern equipment that allows promptly responding to the tasks set.

2 Materials and methods

The main activity direction of the geomechanical service is to determine deformation-hazardous areas of quarry benches, record the early stage of deformation with a forecast of their scale and consequences, which is achieved on foreign quarries by using:

- automatic theodolites;
- radars;
- laser scanners;
- satellite geodesy systems;
- seismographs;
- a complex of geophysical measurement means;
- special equipment (photogrammetry, laser scanning, aerial photography, space probing, drones, etc.).

Purpose and scope of monitoring tools for quarry benches and slopes on foreign quarries:

- Monitoring Tool Purpose Application Area

Automatic theodolites Medium- and long-term forecasts of the observed object's condition. Local monitoring of prisms on bench ledges, as well as buildings and structures in the array displacement zone.

Radars Short- and medium-term forecasts of quarry bench condition. Stationary and mobile continuous monitoring installations scanning large areas and hazardous sections of quarry benches.

Laser scanners Medium- and long-term forecasts of quarry bench condition based on detecting movement trends of arrays over a long period of time. Area monitoring in the zone of increased deformation risk of the array or point monitoring of buildings and structures in the quarry.

3 Results and discussion

Based on the results of considering this issue, it can be said that methods for protecting the quarry walls from various deformations should be chosen based on the study of the physical and mechanical properties specific to each quarry. The possibility of drilling contour wells with the necessary parameters should be taken into account. The quarry walls should be divided into zones (A, B, C) and investigated accordingly. Following this, a mining technology should be selected for each zone, as well as designing the slopes and benches.

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Existing methods for studying the physical and mechanical properties of rocks and the gravel obtained from them by particle size fractions are based on the experimental determination of their key characteristics, such as mineralogical and bulk density, water absorption, compressive strength, resistance to impact loads, frost resistance, structural stability against disintegration, and others. Tests are conducted both at the stage of geological

exploration of deposits to assess possible directions for their use and during industrial operation (periodic quality control tests of gravel, certification tests) [4-5].

Table 1. Classification of quarry edges.

Type of deformation	Source	Characteristic
Cave-in	Excessive angle of inclination or height of the embankment. Presence of separation cracks.	The detachment and rapid displacement of large volumes of rock masses comprising a slope occur almost instantaneously.
Landslide	Exposure to weathering. Impact of explosions.	Detachment of individual particles, rock fragments, and their rolling down to the base of the slope.
Slip	Presence of plastic layers and weak contacts within the rock strata. Waterlogging of the rocks.	Detachment and slow movement of rock masses along the sliding surface due to the force of gravity.
Subsidence	Moistening of highly porous deposits. Compaction of spoil heaps or filled quarries.	Vertical settling of the banks of loose rocks without the formation of a sliding surface.
Erosion	Absence of drainage systems. Intense atmospheric precipitation.	Movement of water-saturated loose rock masses.

Seismographs provide early warnings of mass deformations, but there is uncertainty in identifying measurement results. The complex of geophysical measuring tools (land electrical and seismic exploration) provides early warning of mass deformations, determines weakened zones and boundaries of mass displacement, and applies proven methods and measuring instruments. However, preliminary research is required to eliminate uncertainty in identifying measurement results. Special means of monitoring involve real-time situation assessment, requiring special equipment and specialists for maintenance. Theodolite-automatics are used as a means of local monitoring of ledges, buildings, and structures by the position of reflective prisms installed in the zone of increased risk of mass movements. Radars, pioneered by Australian company Ground Probe and South African company Reutech Mining for monitoring ledges and quarry edges, can be applied in stationary or mobile versions. Laser scanners, introduced relatively recently for monitoring ledges and quarry edges, were pioneered about 9-10 years ago, around the same time as radars. British company 3D Laser Mapping was one of the first to offer laser monitoring systems for ledges and quarry edges based on Rigel lasers and their own original software, 3DLM Site. Satellite geodesy systems are used for medium- and long-term forecasting of quarry edge conditions based on detecting trends in mass movements over a long period. The use of satellite geodesy systems has allowed obtaining vectors of horizontal displacement of control points and building a deformation model of the quarry. Seismographs are used to forecast possible deformation of the quarry edge by registering and measuring the amplitude of microseismic events within the mass. The collected data are interpreted by geophysicists, and an increase in seismic activity in a specific location may serve as an early warning of possible mass

deformation. The complex of geophysical measuring tools includes equipment at specially equipped stations for studying seismic manifestations and vertical electrical sounding. Special monitoring means (photogrammetry, laser scanning, aerial photography, drones, etc.) provide safe and detailed mapping of geological structures, especially in inaccessible and hazardous areas, with the obtaining of a 3D image of the quarry edge from two parts: a 3D point cloud and a photograph. This combined image is then used for subsequent interpretation of geological and potentially hazardous structures in the quarry edge [6-12].

Justification of the economic benefit of implementing continuous monitoring of quarry slopes with the GeoMoS deformation monitoring system involves the following aspects:

1. Full service maintenance: Including on-site storage of critical spare parts, software updates, etc.
2. Acquisition of additional laser scanning system components: Including software.
3. Development of additional tools and software modules for information support systems.
4. Assessment of additional interface development by company specialists.

4 Conclusion

The return on investment in monitoring systems with significant investments is achieved by reducing the risk of sudden rock collapses as the quarry slopes steepen, thereby reducing additional costs for removing unplanned volumes of collapsed overburden and losses from halting ore mining. It's also important to consider direct losses from the loss of mining transport equipment, reputation-related losses, and those associated with industrial injuries, especially considering that slope collapses often result in fatal accidents. Continuous monitoring of the condition of slopes and edges of deep quarries should be an integral attribute of quarry operations. It's worth remembering that each of the devices listed (laser, radar, etc.) has its own area of application, and the implementation of the entire or only part of the program to create a comprehensive monitoring system depends on the level of risk. Over time, quarry slopes begin to collapse, so for maximum preservation, artificial slope support can also be used.

References

1. R.Ergashev, J.Rashidov, B.Saparov, B.Meliyev, B. Kholbutaev, E3S Web of Conferences **410** 05007 (2023)
2. Sh. Khairulloev, M. Smetullaev, *Processing of quartz dust to reduce dust concentration when developing mineral deposits in the open method*, Interpretation and Researches. extracted from (2024)
3. A Mambetov, Berdiboy Bekbauliyevich Saparov, A Niyetbaev, Information Horizons: AMERICAN Journal of Library and Information Science Innovation **01(08)** (2023)
4. B.Saparov, I.Kannazarov, International Bulletin of Engineering and Technology, 70-74 (2023)
5. E.E. Kameneva, Bulletin of the Kazan Technological University **18(18)**, 29-32 (2015)
6. A. Nietbaev, D. Ibrakhimov, *Disadvantages of a rotary excavator and their solutions,* Interpretation and Researches (2024)
7. C.L. Lin, J.D. Miller, C.H. Hsieh, *Particle damage during HPGR breakage as described by specific surface area distribution of cracks in the crushed products*, International Mineral Processing Congress, (New Deli, Indie, 2012) **687**, p. 3397- 3410

8. O.A. Yakushina, M.S. Khoziainov, X-Ray ComputerMicrotomography for Geological Investigation. Abstr. XIXInt. Symp. «NEC-2003», (Varna, Bulgaria, JINR, 2003), p. 35
9. H. Dong, Phys. Rev. E., 1539-3755 (2009)
10. D. Wu, X.F. Peng, Asian Research **36(4)**, 198-207 (2007)
11. K.S. Sanakulov, U.Z. Sharafutdinov, Tsvetnye Metally, **10,** 46–49 (2019)
12. A.M. Muzafarov, M.A. Mustafoev, R.A. Kulmatov, U.Z. Sharafutdinov, Mining Informational and Analytical Bulletin, **3(1),** 110–118 (2021)