

JUSTIFICATION FOR USING THE ALIGNMENT METHOD IN OBSERVING DUMP SUBSIDENCE

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Abstract This article examines issues related to observing the deformation and subsidence of dumps generated in the mining industry. The significance of mine surveying observations in determining the processes of dump subsidence and displacement is analyzed. Alongside traditional geodetic methods, particularly observation through geometric leveling, the potential for using the alignment method is scientifically substantiated. The advantages of organizing observation work, the degree of accuracy, and the application conditions based on the alignment section scheme and the sequential alignment scheme are analyzed. The research results indicate that the alignment method yields high-precision results in determining dump deformation and is one of the key methods for the effective organization of mine surveying observations.

Keywords: dump, deformation, subsidence, displacement, mine surveying observations, geodetic measurements, alignment method, leveling, mining, geodesy.

ОБОСНОВАНИЕ ПРИМЕНЕНИЯ СТВОРНОГО МЕТОДА ПРИ НАБЛЮДЕНИИ ЗА ОСАДКОЙ ОТВАЛОВ

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Аннотация. В данной статье рассматриваются вопросы наблюдения за деформацией и осадкой отвалов, образующихся в горнодобывающей промышленности. Проанализировано значение маркшейдерских наблюдений при определении процессов осадки и сдвига отвалов. Наряду с традиционными геодезическими методами, в частности методом геометрического нивелирования, научно обоснована возможность использования створного метода. Проанализированы преимущества, степень точности и условия применения организации наблюдений на основе схемы створных отрезков и схемы последовательных створов. Результаты исследования показывают, что створный метод при определении деформации отвалов даёт высокоточные результаты и

является одним из важных методов для эффективной организации маркшейдерских наблюдений.

Ключевые слова: отвал, деформация, осадка, смещение, маркшейдерские наблюдения, геодезические измерения, створный метод, нивелирование, горное дело, геодезия.

Introduction. Mining is one of the most important and strategic sectors of human activity. This field plays a crucial role in the development of industry and in ensuring the stable operation of the energy and production sectors. Mining operations encompass processes such as the exploration of mineral deposits, their extraction, the primary processing of extracted raw materials, and the construction of mining enterprises.

During the mining process, large volumes of rock are excavated, and a certain portion is deposited in dumps as production waste. Over time, such dumps can undergo deformation due to various natural and anthropogenic factors. Therefore, monitoring their stability and identifying settlement and displacement processes is one of the key tasks of the mine surveying service at mining enterprises.

Currently, among the primary responsibilities of the mine surveying service, monitoring dump deformation is of particular importance, as it plays a significant role in ensuring mine safety and environmental sustainability.

Literature Review and Research Methods

The deformation of dumps primarily occurs under the influence of their own weight, natural conditions, and anthropogenic factors. These processes depend on the mechanical properties, moisture content, temperature, and geological structure of the rocks.

The main types of deformation observed in dumps are as follows:

Settlement Deformation - This deformation occurs as a result of rock compaction under its own weight. In this case, the internal structure of the rock does not change significantly.

Compaction Deformation - Rocks compact due to external influences, and during this process, a change occurs in their structure. Examples include: the moistening of rocks, the thawing of frozen rocks, changes in hydrogeological conditions, etc.

Swelling Deformation - The volume of rock can increase as a result of chemical reactions or changes in moisture and temperature.

Subsidence Deformation - This occurs as a result of an imbalance in rock masses during the extraction of underground mineral resources.

The mathematical characteristic of dump settlement is expressed by the vertical distance between the initial and settled positions of the dump.

Settlement is divided into the following types:

- *Uniform settlement* - the settlement value is the same at all points;

- *Uneven settlement* - settlement values are different at various points.

In practice, uneven settlement is often observed. This situation can lead to the tilting, bending, and displacement of the dump layers.

Results and Discussion

Deformation monitoring on dumps begins with the formation of the dump and continues until its operation ceases. Monitoring work is carried out based on a special technical assignment.

The technical assignment specifies the following:

- dump sections to be monitored;
- location of initial benchmarks;
- observation frequency;
- required accuracy level;
- reporting documents.

Geodetic leveling methods are typically used to determine the settlement of dumps. Leveling work is divided into three classes based on accuracy:

Leveling Class	Permissible Error
Class I	1 mm
Class II	2 mm
Class III	3 mm

Leveling is performed using high-precision levels such as the H-05 and Ni-002.

However, in modern mining conditions, traditional leveling methods sometimes do not provide sufficient accuracy. Therefore, in this article, we will consider the feasibility of using alternative methods, including the alignment method.

Analysis of Results and Discussion. The results of observing dump deformation make it possible to determine the strength of the rock mass and prevent the occurrence of settlement. To address these issues, high-precision results are obtained by carrying out the following mine surveying and geodetic observation work using these two methods:

1) *Geodetic measurement work* - is divided into three classes of leveling based on accuracy. The results of leveling performed twice should not exceed 1 mm for Class I leveling, 2 mm for Class II leveling, and 5 mm for Class III leveling.

Deep benchmarks can be metallic, bimetallic, and double-rod. Deep benchmarks are constructed with lengths ranging from 2 m to 100 m, and even longer. The benchmarks must be installed 0.5-2 km away from the zone of influence of the construction pressure.

Deep benchmarks are installed only when the settlement of a dump must be measured with first-order leveling accuracy. If the settlement of the structure is measured with second- or third-order leveling accuracy, then ground benchmarks are installed. There must be no fewer than four ground benchmarks.

Benchmarks are built for long-term preservation. Their degree of stability

$$\leq \pm m_{n.b.k.x} \sqrt{2nM}$$

is found from the expression. Where n is the number of stations;

$m_{n.b.k.x}$ is the root-mean-square error of the relative height determined from a single station. For first-order leveling, this value is required to be ± 0.15 mm, for second-order leveling, ± 0.5 mm, and for third-order leveling, ± 1.0 mm.

2. *Geometric Leveling Method.* The accuracy of observing the settlement of many dumps with a homogeneous composition is ensured by using Class I or II leveling methods.

Only in certain cases are special high-precision leveling methods used to determine settlement.

In the Class I leveling method, the determination of dump settlement is performed at two instrument horizons, in forward and reverse directions, using high-precision levels such as the H-05 and Ni-002. An Invar staff is used in leveling.

Leveling is performed when the external environment is favorable and the staff markings are clearly visible.

Although the methods discussed above are widely used, modern standards demand high-precision results. Therefore, we will consider implementing unconventional methods that differ slightly from those we use in practice.

One method that is unconventional for us is the alignment method, which includes the following types:

- *The complete alignment scheme;*
- *The partial alignment scheme;*
- *The sequential alignment scheme;*
- *The closing alignment method.*

Since the partial alignment scheme and the sequential alignment scheme are the most effective of these methods, we will apply them in practice.

The Partial Alignment Scheme. In this scheme, the distance between observation points I-II, which are established on the dump, is divided into approximately four equal parts: 1.2, 2.4, 4.6, 6.11 (Figure 1). First, the position of the middle point 4 is determined relative to the overall alignment I-II.

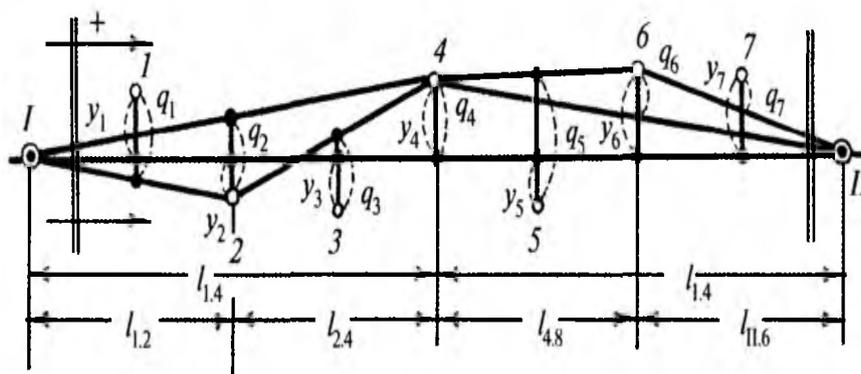


Figure 1. The established partial alignment scheme.

Then, the displacement of points 2 and 6 is measured relative to the half-alignments 1-4 and 4-6. After that, the displacement of all other observed points in each quarter-alignment (1-2, 2-4, 4-6, 6-1) is determined. Thus, the total alignment is only used to determine the displacement of the point located in the middle. Measurements are carried out in forward and reverse directions. These tasks are repeated at the times specified in the instructions, and by comparing them with the previous ones, displacement, settlement, and slides are predicted.

In this scheme, since the measurements are performed on different alignments, the issue of reducing the determined displacements to a common alignment arises.

The measurements are carried out as follows:

For point 4, located in the middle, the value of the measured displacement (y) and the reduced displacement (q) are equal, i.e.:

In this case, the distance between points and the vertical angles are determined using a theodolite on benchmarks located at points between points I-II.

$$y_4 q_4 = 8 \text{ m}$$

For the second point:

$$y_2 q_2 \delta_2 y_2 = + \text{ or}$$

δ_2 Here it is calculated using the following ratio:

$$\frac{\delta_2}{y_4} = \frac{l_{1.2}}{l_{1.4}}$$

For point 6:

$$y_6 = q_6 q_4 \frac{l_{11.6}}{l_{11.4}} +$$

For point 1:

$$y_1 q_1 \delta_1 + \delta_2 = +$$

where

$$\delta_1 = q_2 \frac{l_{1.1}}{l_{1.2}} \quad \delta_2 = q_4 \frac{l_{1.1}}{l_{1.4}}$$

from this:

$$y_1 q_1 q_2 \frac{l_{1.1}}{l_{1.2}} + q_4 \frac{l_{1.1}}{l_{1.4}} = +$$

In the reverse direction (from point II relative to point I), measurements at the points are performed in the following order: 4, 6, 2, 7, 5, 3, 1.

If, as before, we assume the error of the midpoint, point 4, to be equal to 1, then the permissible error for other points will be as follows:

Points 1 and 7 ----- 0.43

Points 2 and 6 ----- 0.71

Points 3 and 5 ----- 0.83

Point 4 ----- 1.0

As can be seen, the error values between these points have approached those of the full alignment scheme. However, the error of the points located in the middle is 2 times greater than that of the points at the edge of the alignment. This is the main drawback of this scheme.

This method, unlike others, makes it possible to obtain accurate results and determine each observation based on distances. Its disadvantages are that problems arise when measuring inaccessible points and that the errors in each measurement differ from one another.

Sequential Alignments Scheme. This scheme utilizes a well-known principle in geodesy: orientation accuracy increases when sighting distant points, while distance measurement accuracy is highest at short distances. The essence of the sequential alignments scheme is as follows.

A theodolite is set up at the starting point of the alignment, which is divided into approximately equal parts, and a sighting mark is placed at the end point (Figure 2). Relative to the overall I-II alignment, only the displacement of point I is measured. Then, the measurements are continued in the reverse direction. The theodolite is set up at point II, and the sighting mark is placed at point I.

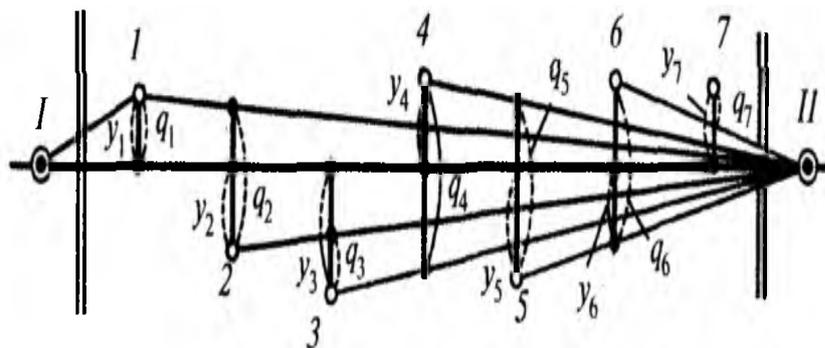


Figure 2. Sequential Alignments Scheme.

The expression for referencing to the overall I-II alignment is written as follows:

$$y_1 = q_1$$

$$y_2 = q_1 \frac{l_{2,11}}{l_{1,11}} q_2 +$$

$$y_3 = q_1 \frac{l_{3,11}}{l_{1,11}} q_2 \frac{l_{3,11}}{l_{2,11}} + q_3 +$$

If we assume the error of observation point 4, located in the middle of the alignment, is equal to 1, then the errors of the remaining points will be as follows:

- Points 1 and 7..... 0.70
- Points 2 and 6..... 0.87
- Points 3 and 5 0.97
- Point 4 1.0

In this scheme, the displacement measurement was performed with a similar level of accuracy for all points compared to the other schemes considered.

$\sqrt{2}$ The error at the weakest point in the middle increases by a factor of [missing value] compared to the points at the edges.

In this scheme, an accumulation of errors is observed during the measurement process, which is a major drawback.

Conclusion

Monitoring the settlement of waste dumps is one of the key factors in ensuring safety at mining enterprises. The research results showed that using the alignment method alongside traditional geodetic methods increases the accuracy of monitoring work.

Alignment section and sequential alignment schemes provide highly accurate results in determining dump deformation. Since these methods combine the capabilities of trigonometric leveling and distance measurement, they are often more effective than geometric leveling methods.

In the future, the combined use of modern geodetic instruments, such as laser scanners, GNSS technologies, and digital monitoring systems, can further increase the effectiveness of monitoring waste dump deformation.

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