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The Geodetic Monitoring of the Engineering Structures Stability Conditions

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Abstract: The study considers the determination of the deformation of the engineering structures and other facilities located in area of mining operations and evaluation of their technical condition. Significant changes in the theory and practice of the engineering and surveying for determination of the deformation of the engineering structures and other objects of industrial and civil construction have taken place in recent years. New techniques, tools and methods for determining the deformation and the geodetic regulations have been developed. However, at the same time, some information stagnation is observed in recent years: the number of the published technical literature on special engineering issues has sharply decreased in particular in the geodetic measurement methods. The researchers conducted the geodetic monitoring of the facilities located in the industrial area of the Maykain mine in Kazakhstan. The monitoring was conducted using modern surveying instruments: satellite technologies, electronic total stations and laser levels. On the research basis, the researchers suggest the methods of determination of the facilities settlement and faulting. The ultimate goal of the research is to ensure the safety of the engineering constructions.

Key words: Mining operations, industrial sites, engineering structures, deformations, sedimentary mark, ultimate

INTRODUCTION

The modern mining industry is characterized by the steady growth of the plant capacity, intensification of industrial process, increasing of the depth and life service of the open-casts. In these conditions, maintenance of stability has particular importance as of the open-cast high walls and well as the civil engineering and communications in the mining operations affected area. The industrial site should be understood as the complex of buildings (processing plants, mini plants, electrical substations) and facilities which provide the mining production with energy and transport.

Current methods of geodetic monitoring do not me et all the requirements of the industry for example-the system (Intrieri *et al*., 2012) tracks the changes only in a limited number of points and is able to track only the criticalearth movement. The system (Intrieri *et al*., 2012) traces a very wide territory up to the entire mining area but the accuracy of monitored changes is also small. At the same time, there are high-accuracy solutions for geodetic measurements which application in monitoringmine slopes would be novel in terms of accuracy.

In this regard, there is a need to develop new integrated programs of geo-monitoring and reliable calculation methods to ensure the long term stability of the open-cast high walls and serviceability of the industrial site facilities. For that purpose, the researches of the mass stability were conducted in open-casts with the assessment of the technical condition of the industrial site facilities, located in the mining operations area where the strata movement and the mass deformations are possible to ensure reliability, safety and functional fitness of the operated facilities.

The need to address the stability of the open-cast high walls with the assessment of the technical condition of the industrial site facilities and communications, located in the on the industrial site in the mining operations affected area, occurs at all stages of the mineral deposit development. This task is complex and includes a wide range of issues. Therefore, the industrial site buildings and facilities as well as any major geotechnical system is a result of blending technological factors. Timely forecast of these factors is necessary to ensure the stability and safety operation of not only of the engineering structures but also of the mining plant in the whole. According to this position, the aim is set, the

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idea is proved and the research tasks are formulated. The research idea is to develop the methods of the high precision survey geodetic measurements using the modern equipment to conduct an integrated monitoring of the mass to determine the actual parameters of the engineering structures.

The practical significance of the research is to develop the recommendations for stability management of the open-casts high walls, providing their long-term stability as well as civil engineering.

An integrated method of the instrumental observation based on a common system of the reference points which eliminates the initial errors of the closure and orientation and to establish a direct connection between the mass displacement and the deformations of the engineering structures was developed in this study for the first time.

The review of the published references, patent searches and the results of the implementation lead to conclusion that the level of the performed work corresponds to the modern scientific and technical level in this field. The stability of the high walls and pits is affected by the following factors:

- Geology and hydrogeology of the mine
- Physical and mechanical properties of the rocks
- Structural and tectonic features of the rock mass
- The effect of the mass explosions on the stability of the slopes and sides

Based on the above-mentioned main factors, affecting the stability of the benches, sides and on the structures in the industrial site, the references review is given below summarizing the experience of the leading companies and foreign practice of the studied subject.

Issues of the rock masses stability have more than two centuries history and originate from the research of prominent French scientists C.A. de Coulomb and C. Colomb, who proposed in 1773 a method to calculate the stability of retaining walls and soil slopes. Important milestones in the development of this research should be considered the researches by Rankine (1872), Nadai (1954), Tertsagi (1961), Sokolowsky (1960) and Golushkevich (1968) and other researchers Maier (1971) and Egger (1980).

Researches on the stability of the pit slopes are associated with intensive development of opencast mining in the twentieth century and increasing of the depth of the pits. In the Soviet Union, the most important results and achievements in this branch are related with the activities of the research and design institutes, the institutes of mining and the leading universities. To address this urgent and applied problem, the specialized departments were created, laboratories, sectors and groups, involving many prominent scientists. In this time, the foundation of the national school of the stability of the pits and slopes research was laid with the large contribution of the research by Pevzner (1978) and Fisenko (1965).

Despite the achieved progress of many researches, the problem of stability of the pit slopes in area of the industrial sites buildings and facilities is far from being studied fully and requires further development and improvement. This is evidenced by the results of the researches in 2010-2015 of the actual condition of the slopes of the Maykainmine, executed with participation of the researcher.

There are facilities on the industrial site on the sides of the pit with a view to ensure a number of technological processes. Under the influence of the industrial and human made factors, the buildings and facilities during operation may change their position in the vertical and horizontal planes which is evident in the form of cracks, bulges, sags and roll. If these events are not detected in a timely manner and the steps for their elimination are not taken, the building may be destroyed. Therefore, the buildings and facilities should be observed during operation and the survey and geodetic measurements should be conducted (Nurpeissova, 2015; Nurpeissova and Beck, 2015).

Upon a gradual settlement, building, facility move vertically the same in all parts and do not affect significantly on their durability and stability. In cases when the soil compressibility or the load on the soil under the foundation varies, sediment is uneven and this may lead to significant deformations of the building or facility, cracks and even splits occurrence.

Deformations in the foundations of buildings and facilities cause not only roll in the framings but also the cracks which are divided into active, when there is expansion process and inactive, when this process is stopped.

Irregular settlements occur primarily as a result of a various compression of the different parts of the structure and an unequal soil compressibility under the foundations which in turn causes non-uniform displacements in over foundational constructions and facilities.

In fact, there is almost no gradual settlement on the compressible soils because the geological structure of the foundation is not similar in the vertical and horizontal planes. Gradual settlements itself do not reduce the strength and stability of structures but significant settlements may lead to changes in the physical and mechanical properties of the foundation soil which in turn can cause foundation failures. In addition, gradual settlement can cause disturbance of the utility communications of the structure. In the impact on the structures, the foundation failures are more dangerous. This danger is greater when the difference between the parts settlement is greater and the greater is the sensitivity of the construction and technological elements.

MATERIALS AND METHODS

We used an integrated research method including: analysis and synthesis of science, techniques and practice to provide the long term stability of the high walls on the Kazakhstan mining plants and abroad high precision geodetic observations improved methods of observation assessment of stability of the engineering structures and facilities practical application of the techniques for observing the stability of building and constructions of various structural features of the Maykain mine industrial site.

To conduct observations, the Kazakh National Technical Research University has developed the project (The project of the monitoring station of the side mass in 2009), according to which in 2011 the observation stations were designed to periodically perform the instrumental observations (Anonymous, 2002a-c). The observation stations are datum lines system, pledged on lines perpendicular to the high wall.

The length of the profile lines should be such that both or one end of it should be outside the expected displacement. With a shallow depth, the profile lines can be directed all through the open-cast. The datum lines were laid, so that, the safety of the observer should be provided while working on them.

There are key datum lines at the ends of the profile lines. Prior to the observation station construction at least three initial datum lines are laid in such a way to guarantee their safety. The key datum lines are attached to the initial lines.

Methods of processing and analysis of the monitoring results include integrated geodetic measurements of the facilities various parameters, taking into account their design features. Survey geodetic monitoring system is based on instrumental geodetic observations of displacement and deformations of the control observed points and the changes in the spatial position of the structures in general (Piskunov, 1980).

Instrumental geodetic monitoring of the facilities stability condition on the industrial site on the Maykain mine is held by the laid datum lines of the observation stations in the pit and industrial site facilities with the set deformation control benchmarks. Established monitoring system is carried out using modern electronic surveying equipment-electronic total station Leica TCA 1201 and high precision laser level DNA03.

Developed observing system, installed in the object, consider the monitoring aims and give the ability to forecast the intensity of the deformation processes development. Methodology and the scope of observations for monitoring ensure the accuracy and completeness of the obtained information for preparation of a valid conclusion on the current condition of the facilities. For complex processing and analysis of the monitoring results, the specialized software systems are used which handle data of the instrumental measurements and allow a comparative analysis with the maximum permissible values of the deformations and deviations.

The attained data are used to develop measures to eliminate the negative phenomena, occurred in the structures or facilities or in the shift of the ground surface and rocks.

For early diagnosis of the technical condition of the buildings and localization of the variance of the stress-strain points: in the most critical nodes, the systematic control of the deformations is performed with the identification of their character. Upon detection of the critical changes in the individual elements of construction, additionally, the high precision measurements should be conducted and by these results, the final conclusions of the facilities technical conditions should be made. The causes should be determined and the measures to restore or eliminate the deformations in the structures should be established.

This technique should be applied not only to the industrial sites facilities but also to the unique buildings such as the “Kazakhstan TemirZholy Administrative building” in Astana. The benchmarks, monitoring prisms and sedimentary marks are mounted on the controlled objects by which the further observations are performed over the deformations in the buildings and constructions, providing the required accuracy in accordance with the requirements (Anonymous, 2002a-c, 2007a, b).

RESULTS AND DISCUSSION

The purpose of monitoring of the industrial site facilities is to ensure reliability, safety and functional fitness of the operated facilities analysis of the stress condition, deformations and displacements of the structures monitor the overall deformations and cracks of the operated constructions by systematic observation and instrumental control. The following tasks are solved to achieve this purpose:

- The geo-monitoring techniques are developed using modern high precision geodetic measurements for providing the stability of the mass near sides and the engineering structures on the industrial sites of Kazakhstan mines

- The evaluation of the facilities on the industrial site in example of the Maykain mine
- The researches of the geo-mechanical condition of the rock masses near the sides in the Maykain mine

Therefore, the purpose of the geodetic monitoring of the industrial site facilities is to ensure reliability, safety and functional fitness of the operated facilities analysis of the stress condition, deformations and displacements of the structures monitor the overall deformations and cracks of the operated constructions by systematic observation and instrumental control.

In solving the monitoring tasks, all engineering, geological and mining factors, types, characteristics and requirements of the protected facilities (Anonymous, 2002a-c, 2007). Recommendations for making the observation stations and observation methods are set out in VNIMI instructions.

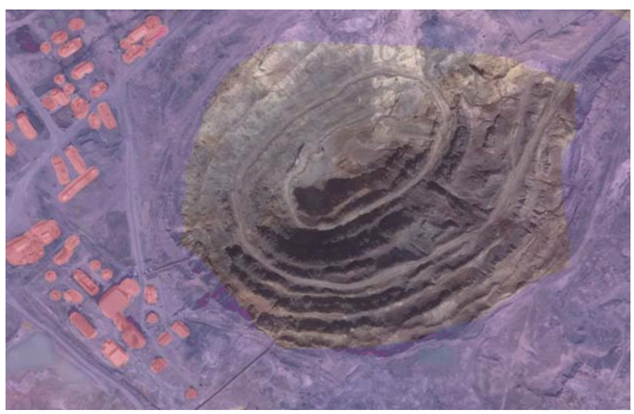
The scientific novelty of this research is to develop aintegrated method of monitoring of the industrial site facilities and geo-monitoring of the rock mass using high precision surveying instruments, allowing to establish a direct connection between mass displacements and deformations of the bearing and enclosing structures of the engineering facilities.

The selection of the observation stations for the condition of slopes ledges and the sides stability of the Maykain mine location in the form of the profile lines is performed on the basis of the mining conditions of the field development, the current state of the rock masses and dumping sites and prospects for development of mining operations (Anonymous, 2005).

Results of research and analysis of the mining and geological documentation show the following strained areas in the open-cast are identified:

- There is a caving of the upper ledges in the South Western side of the open-cast (Fig. 1a-c)
- There are a caving and a crack in the South side (Fig. 2)
- The deformations on the ground surface and on the engineering structures (Fig. 3)
- The overpass of the industrial site of the open-cast in the mining affected area (Fig. 4)

(a)



(b)

(c)

Fig. 1: a-c) The aerial view and closeups of Southwestern side of the open-cast. The deformations on the upper ledges

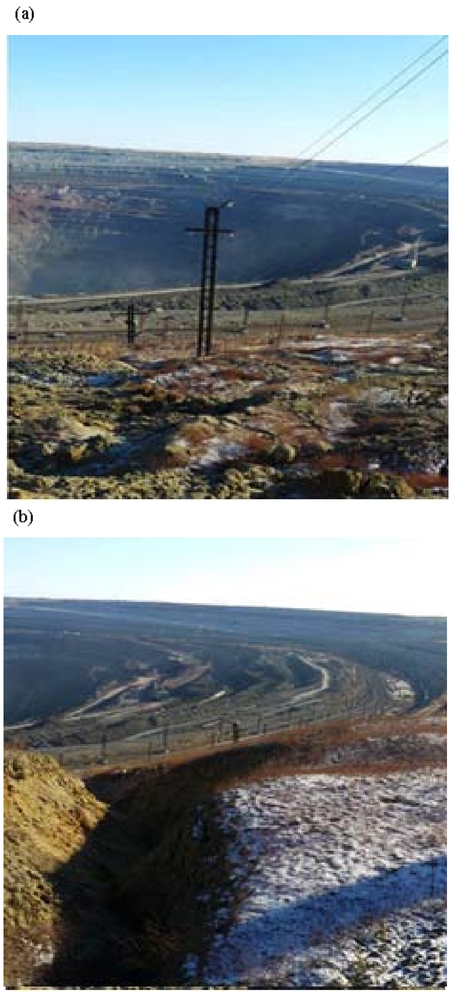


Fig. 2: a) The Southwestern side of the open-cast and b) Cracks with wide opening up to 1.5 m

Fig. 3: a) The deformations on the ground surface and b) The engineering structures

Fig. 4: The overpass of the industrial site of the open-cast in the Maykain mining affected area

Fig. 5: Location of the benchmarks on the object "KTZ Administrative building"

Fig. 6: Monitoring prism and sedimentary mark

The system of geo-mechanical monitoring of the stability condition of the side masses and the engineering constructions is developed in the project (The project of the monitoring station of the side mass in 2009). The initial and key benchmarks are laid in concrete and the operational benchmarks are laid precast for monitoring stations.

The benchmarks, monitoring prisms and sedimentary marks are secured on the protected objects for further monitoring of the buildings and facilities deformations, providing the required accuracy (Fig. 5 and 6).

Systematical instrumental observations at the geo-monitoring stations mean determination of the benchmarks position in space at a given time with the fixation of the geological factors using the total electronic station Leica TCA 1202. For each of the created monitoring station in the open-cast by SSGPO JSC, there are identified the schemes of location reports and orientation of the profile lines key and link marks, that allows quickly and accurately locate the initial points and stick to a single orientation system in different series of monitoring.

The surveying geodetic monitoring of the displacements and the deformations of the observation benchmark are performed at least 2 times a year in accordance with (Anonymous, 2002a-c, 2004, 2007). Complete series of monitoring include the following activities: the binding of the initial and key benchmarks (coordinates determining X-Z) to the nearest points of the surveying geodetic network conducting the initial observation to determine the starting position of the benchmarks and the deformation control benchmarks of the monitoring stations on the horizontal and vertical planes conducting the systematic observations of the benchmarks displacement.

The binding of the initial and key benchmarks of the profile lines to the points of the surveying geodetic network and determining the coordinates (X, Y, Z) in a single system is performed automatically by the Leica TCA 1202 total station. This Leica TCA 1202 total station is set to the initial (key) benchmark of the monitoring station and is focused on the other 1-2 points of the network.

All Leica TCA 1202 measurements to improve the accuracy and elimination of the gross errors, performed at two positions of the vertical circle in 6 manners. The measuring receiving includes one reflecting on the reflector in which the measurement is performed several times (2-3). The average measurement is taken for the final result and the difference between the individual samples should not exceed ±2 mm.

Position of the link benchmarks is determined automatically by the Leica TCA 1202 total station from the initial (key) benchmarks of the created system or from the network.

Initial observations on the station consist of two independent series of measurements within 3-5 days. Using Leica TCA 1202 electronic total station, the coordinates of the initial position of the profile lines benchmarks, coordinates of the same benchmarks in subsequent observations, horizontal traversing between the benchmarks and their displacements are being determined. By the difference of the coordinates of the benchmarks ΔX-ΔZ relative to their initial position, we can determine the direction of displacement vector in space in digital form as well as the difference of horizontal traversing ΔS between benchmarks relative to baseline values may judge on the stability (movement) of rock mass.

When using the Leica TCA 1202 total station, the processing of the surveying measurement results is performed, automatically. It should be noted that the processing of the surveying measurement results with the calculation of the movement and deformation parameters is possible only in the case of defining the displacements exceeding the instrumental accuracy.

Therefore, when receiving the displacement values within the instrumental accuracy, it is convenient to determine deviations in the horizontal and vertical planes through the benchmarks coordinates between the initial and subsequent measurements ΔX-ΔZ.

An additional control of the benchmarks displacement in the horizontal and vertical planes is the calculation of dS-changing of the interval length, ΔL-benchmark displacement as well as amount of dS and ΔZ for the observation period.

The result of the two series of the surveying observations processing is making the tables which show the changes in elevation marks of the profile lines as well as changes in the interval length between the benchmarks and the intervals total length from the key benchmark to the operating one.

When the deformations are in the active stage, using the proposed method allows the quick (within one day) getting a full picture of displacements and to develop in timely manner the measures to ensure stability.

To perform monitoring and integrated evaluation of the industrial site facilities, the modern high precision electronic equipment produced by Leica Geosystems (Switzerland): high precision electronic total station TCA 1201series (Fig. 7a) and digital high precision laser level DNA03 (Fig. 7b), a laser scanner Scanstation and specialized software which allows to produce data computer processing (Baygurin, 2011).

The facilities displacements in the vertical plane (immersion) are determined by geometric leveling using the digital laser level DNA 03 and the digital invar-surveying rod.

Data from TCA 1201 Leica total station may be incorporated into any process flow of the geodetic data handling. The field measurements can be easily transferred to various processing and equalizing programs of the geodetic measurements: Liscad, CREDO-DAT, RGS, AutoDesk survey. Next, the equalized three dimensional point coordinates are transferred into programs: CREDO-MIX, CAD-relief, TOPOCAD, AutoDesk Land Development Desktop.

The memory capacity of the total station is up to 10000 dB and a task management system makes it possible to streamline the field data. The laser level DNA 03is designed to measure the elevation and transmission of the elevation marks. The level emits visible light beam with respect to which the elevation measurements are being conducted (Anonymous, 2007; Yambayev, 2014; Zaitsev, 1991).

(a)

(b)

Fig. 7: a) Electronic total station Leica TCA 1201 and b) Laser level DNA 03

Laser electronic level has an electronic compensator-self alignment system of the laser beam, a laser emitter, a collimator, a mechanism of setting the inclined planes and other additional devices. The lasers of this type are perfect automatic devices, equipped with computer programs of electronic record of measurement results and solving various surveying tasks.

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While monitoring the settlement of the industrial site facilities by geometric leveling using digital laser level DNA 03 and digital surveying rod, the need to address the issue of the performed work accuracy occurs.

The mistake of a viewpoint is the main in the geometric leveling. It means a set of elementary errors caused by the influence of instrumentation (a level and a rod), construction of the benchmarks and the link points, external environment, instability of the object being measured, the measurement processing procedure and personal errors that surely shall enter into the equalized ratio.

According to the schedule of the research, the following researches have been conducted in 2012-2015: based on the analysis of the side and dump rock masses of the open-cast, according to the developed projects in 2010, the profiles benchmarks of the geo-mechanic monitoring stations of the pit slopes stability were laid.

There is one constructed monitoring station on the pit, consisting of three profile lines. Two series of surveying geodetic observations by the laid benchmarks of the profile lines have been performed.

The first series of the surveying geodetic observations were conducted in the period from October 30, 2013 until November 8, 2013. The second series of the surveying geodetic observations of the side masses condition were conducted in the period from April 11, 2013 until April 19, 2013. Monitoring results are presented in the tables and figures, the results of monitoring of the industrial site buildings and facilities are presented in Table 1-3.

To evaluate the technical condition of the facilities, the complex of high precision surveying geodetic measurements of the bearing and enclosing structures of the industrial site facilities using developed surveying observations is united in a single system of side mass condition and structural elements of the buildings and civil engineering of the industrial site (Nurpeissova, 2015).

The observations are based on a common system of reference points which eliminates the initial errors of

Table 1: Monitoring results of the deformation control benchmarks on the ETL supports

Number of the control point	The first observation (m) November 8, 2011			The second observation (m) April12, 2012			Horizontal and vertical control benchmarks displacements of the deformation between the cycles (mm)		
1	Y	X	Z	Y	X	Z	ΔY	ΔX	ΔZ
2	6465.571	4628.48	157.419	Destroyed					
3	6318.395	4347.09	159.114	Destroyed					
4	6333.535	4347.09	159.114	6333.58	4347.109	159.1050	43	19	-9
5	6452.786	4351.89	177.507	6452.81	4351.921	177.4877	22	36	-19
6	6354.327	4418.59	157,105	Destroyed					
7	6320.206	4390.76	157,105	6320.25	4390.787	157.0620	43	28	-43
8	6372.178	4357.96	159.745	6372.19	4357.974	159.7305	14	13	-14
9	6313.535	4347.09	159.252	Destroyed					
10	6324.953	4609.26	158.614	6324.99	4609.302	158.5740	36	38	-40
11	6324.595	4542.69	159.743	6324.65	4542.728	159.6790	58	41	-64
12	6427.811	4120.70	172.146	6427.85	4120.765	172.1230	38	66	-23

Table 2: The surveying results of the ETL substation building columns

Marking	Coordinates of the alignment feature points		The columns displacement from the vertical plane along the axis		The absolute value of the roll
Axis, Column #	Y (m)	X (m)	ΔY (mm)	ΔX (mm)	(L (mm))
1	2.000	3.000	4	5	6.00
K-5/1c, E/1c	97.381	100.134	8	-3	8.54
	97.373	100.137			
K-5/1c, D/1c	96.220	104.477	-14	-2	14.14
	96.234	104.479			
K-3/1c, D/1c	101.686	105.293	7	3	7.62
	101.679	105.290			
K-3/1c, D/1c K-3/1c, D/1c	101.787	101.314	-15	-9	17.49
	101.802	101.323			
K-1/1c, E/1c	106.632	101.625	-5	-4	6.40
	106.637	101.629			
K-3/2c, D/2c	104.156	100.444	0	10	10.00
	104.156	100.434			
K-3/2c, E/2c	101.083	97.855	1	9	9.06
	101.082	97.846			
K-5/2c, D/2c	100.916	104.249	-3	-14	14.32

Table 3: The determination surveying results of the COG displacement alignment of the overpass round support

Nos. mark of support, point	The actual diameter of the axial column (m)	The radius of the axial column (m)	The reference sight in diameter direction (°)	Coordinates of the column center Y (m)	X (m)
A 1, lower	0.595	0.298	25.147447	151.934	69.369
A 1, lower					
A 1, upper	0.601	0.301	79.503316	151.855	69.397
A 1, upper					
Axis displacement of the central support				0.079	-0.027
B 1, lower	0.607	0.304	88.012839	624.193	974.030
B 1, lower					
B 1, upper	0.606	0.303	3.128582	624.212	973.944
B 1, upper					
Axis displacement of the central support				-0.019	0.086
C 1, lower	0.600	0.300	4.876663	455.393	1081.833
C 1, lower					
C 1, upper	0.604	0.302	19.020959	455.420	1081.832
C 1, upper					
Axis displacement of the central support				-0.027	0.001
D 1, lower	0.602	0.301	15.685199	137.439	164.221
D 1, lower					
D 1, upper	0.612	0.306	78.246975	137.414	164.253
D 1, upper					
Axis displacement of the central support				0.025	-0.032
E 1, lower	0.606	0.303	17.625486	536.007	1029.709
E 1, lower					
E 1, upper	0.603	0.302	53.558207	535.997	1029.779
E 1, upper					
Axis displacement of the central support				0.010	-0.070

(a)

(b)

Fig. 8: a) The deformation control benchmarks were installed in September, 2011 on the ETL supports and b) Caving coil in the monitoring station No. 1 area

binding and orientation and establish a direct connection between the rock displacement and deformation of the bearing structures to ensure the reliability and safety of their operation. According to the above procedure, the deformation control benchmarks were installed inthe investigated objects (Fig. 8).

According to the results of the industrial site facilities monitoring, the following is detected: in the upper horizons of the southwestern side of the open-cast there are the power pylons which are in area of dangerous deformations. Upon the results of the deformation control benchmarks, it can be concluded that the ETL supports are vertically displacement up to (-) 36 mm, 4 benchmarks are in the caving area. The maximum displacement of the ETL supports in direction of the open-cast is 58 mm and the results are presented in Table 2.

The definition of the columns roll of the processing plant was performed by the procedure of the non-reflective coordinates method using TSR 1201 electronic total station. According to the obtained values and coordinates increment of the points in the same vertical plane, the linear value of the roll by Eq. 1:

$$L = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \quad (1)$$

where, X_1, X_2, Y_1, Y_2 coordinates of the facility feature points, respectively in the lower and upper sections. The results are shown in Table 1, determination of the COG displacement alignment of the overpass round support from the points of the industrial site geodetic network with reference to the surveying network was performed by a similar method and the results are presented in Table 3 determination of the beams sag of the Processing Plant cover (PP) was performed using digital high precision level DNA 03 (Fig. 9a and b) and a digital invar rod. To solve this task, the invar rod was installed in the points of the beginning, middle and end of each beam span. The results are presented in Table 4. To determine the sag of span f_{abs} and the deflection f_{def} the formulas were used:

$$f_{abs} = \frac{2Z_2 - (Z_1 + Z_3)}{2} \quad (2)$$

$$f_{def} = \frac{f_{abs}}{L} \quad (3)$$

where, Z_1 and Z_3 is elevations of extreme points of the structure in this section of the straight line. To determine the sag of span f_{abs} and the deflection f_{def} the Eq. 4 and 5 were used:

$$f_{abs} = \frac{2Z_2 - (Z_1 + Z_3)}{2} \quad (4)$$

$$f_{def} = \frac{f_{abs}}{L} \quad (5)$$

where, Z_1 and Z_3 is elevations of extreme points of the structure in this section of the straight line. The obtained results of the industrial site facilities technical condition evaluation by the method described above were compared with the permissible values in SniP SN RK 1.04.04-2002-"Examination and evaluation of technical condition of buildings and structur4es", SniP RK 5.04-18-2002 "Metal constructions" (Anonymous, 2002a-c; Zhukov and Karpik, 2003; Klyushin, 2002).

The permissible beams sag is 1/300 L where L, m-length of the beam (Fig. 10). Permissible

Table 4: The surveying results of the ETL substation building covering beams

Covering beams marks	Results by the digital rod	The absolute value of the beams sag f (m)
	0.5187	-0.00140
B-337-7	0.5205	
	0.5195	
	0.3749	-0.01525
B-336-8	0.3858	
	0.3662	
	0.3810	-0.00955
B-335-8	0.3833	
	0.3665	
	0.3819	-0.00510
B-334-8	0.3873	
	0.3825	
	0.5117	0.00085
B-325-6	0.5113	
	0.5126	
	0.3651	-0.00520
B-323-6	0.3763	
	0.3771	
	0.3680	-0.00655
B-322-8	0.3817	
	0.3823	
	0.3683	-0.00855
B-321-8	0.3854	
	0.3854	
	0.3742	-0.00500
B-320-8	0.3805	
	0.3768	
	0.5069	-0.00420
B-281-6	0.5114	
	0.5075	
	0.5001	-0.01965
B-208-8	0.5215	
	0.5036	
	0.4979	-0.02185
B-207-8	0.5228	
	0.5040	
	0.4986	-0.01765
B-206-8	0.5148	
	0.4957	

displacement value of the processing plant is 15 mm, if the height is up to 4 m (Konopaltsev, 1981). In some cases of the slope deformations determination, it is necessary to use laser scanning to create 3D Models of open-cast side. The magnitude and direction of the deformations are calculated by superimposing of the object models for each measurement cycle. The difference between the models should not exceed 10 mm which refers to the laser scanner observation error. Processing and comparing of the models is produced in the special software I-site Maptek studio Leica where the process of modeling and superimposing is performed. The developed integrated monitoring program of the stability condition of the side rock masses and the industrial site facilities allows to establish a direct link between the mass displacements and the facilities displacements, excluding the errors of the binding and orientation, allowing to identify on the early stage the stressed and strained condition of the mass and the most dangerous areas of the industrial site engineering structures.

(a)

(b)

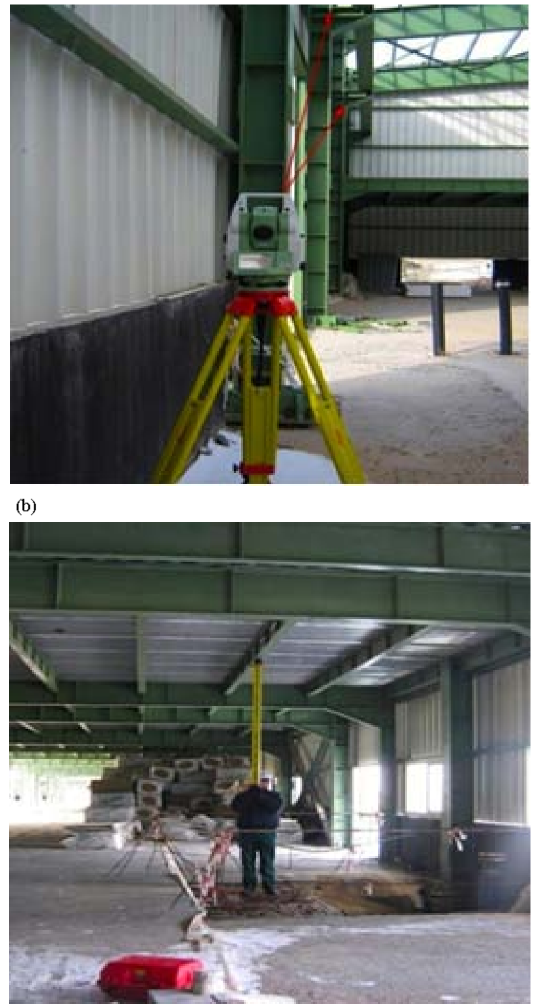

Fig. 9: a) Determination of the deformations of the ETL substation and b) Determination of the beams sag of the PP building covering

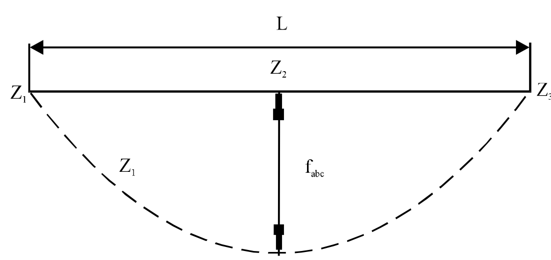

Fig. 10: The geometric layout of the beams sag

CONCLUSION

The integrated geo-monitoring program of the stability condition of the side rock masses and the industrial site facilities is developed.

The monitoring results of the side masses displacements and the industrial site facilities deformations: the ETL substation columns, it may be concluded that the column K-3/1c, Д/1c has an axis displacement of 17.49 mm. The obtained value exceeds the permissible value by the SNiP RK 5.04-18-02, (permissible value is 12 mm). Upon the ETL facilities deformation control benchmarks, it may be concluded that the ETL supports have the vertical displacement is up to (-) 36 mm, the maximum horizontal displacement of the ETL in direction of the open-cast is 58 mm.

Upon the beams of the ETL substation building a covering, it may be concluded, that the beams B-208-8, B-207-8 have a sag of 0.01965, 0.02185 mm, respectively. The obtained results do not exceed the values from the SNiP 2.0107-85*.

The developed integrated monitoring program of the stability condition of the side rock masses and the industrial site facilities allows to establish a direct link between the mass displacements and the facilities displacements, excluding the errors of the binding and orientation, allowing to identify on the early stage the stressed and strained condition of the mass and the most dangerous areas of the industrial site engineering structures.

According to the SNiP high requirements to the buildings and facilities to ensure their functional fitness, the obtained results upon the monitoring may be used to forecast the process of the side rock masses displacement.

The results of investigations in this study and the monitoring of the side rock mass and evaluation of the facilities technical condition have been introduced at the mining plants in Kazakhstan and unique facilities of the construction corporations in Almaty and Astana.

The level of the performed research is in line with the best achievements in this field. We managed to combine high accuracy and relative cheapness. The algorithm and corresponding software for the applicable surveying tasks using modern and computer technologies has been developed.

Thus, the integrated procedure of the surveying monitoring is developed for the first time, based on a common system of the reference points, that eliminates the initial errors of binding and orientation and establish the direct link between the mass displacement and the engineering constructions.

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