COMPATIBLE PROCESSING OF RESULTS OF HIGH PRECISION GEOMETRIC LEVELING AND INCLINATION MEASUREMENTS

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Problem. Safe operation of engineering structures and process equipment objects fuel - energy complex such as nuclear power plants (NPP), requires periodic monitoring of their conduct, and the definition of deformations [1, 6]. Deformation - is the most significant parameter that is subject to control. Monitoring of deformations of these structures is one of the applications of high precision surveying methods and means of measurement. During monitoring means monitoring the environment, which is a dynamic system, ie a system that is constantly changing with the aim of monitoring, research and prediction.

Analysis of recent research and publications. Used to monitor devices that allow for measuring spatial information continuously and in automatic mode (satellite geodetic receivers, robotic total stations, electronic). In addition to these classical geodetic instruments used precision inclinometers [8, 9, 11]. Their work - opto-electronic registration signal inside the unit, while the performance of similar devices based on the detection of electrical resistance between the contacts primary converter, which vary in proportion to the slope. The benefits just opto-electronic principle should include the fact that it provides continuous recording angles in two planes with a resolution of 0.001 mrad.

Currently inclinometers are widely use in the practice of engineering - geodetic works. They are used for continuous or periodic observations of the spatial position of bridge structures, tall buildings, dams and waterworks pylons GNSS base stations [2, 4, 10]. Also inclinometers are used to study seismic and volcanic areas and areas of mining [3, 5, 13]. Use in conjunction with inclinometers accelerometers and thermocouples allows to study the behavior of high-rise structures (wind turbines, masts, antenna towers, etc.) during dynamic loads [7, 12].

Despite the obvious achievements, it is worth noting the following difficulties in the application of systems for monitoring deformation structures using inclinometers. Firstly, at present there are no detailed documented methods for creating such systems, which prevents their further development. Secondly, existing monitoring systems provide only the definition of critical deformation structures, while the information supplied is sufficient to conduct an in-depth analysis of structures.

Problem. In observing the deformation of engineering structures and process equipment objects fuel - energy complex is mainly used precision geometric leveling method. The disadvantage of this method is discrete information received. Application inclinometer measurements during and between cycles observations may give a complete picture of the dynamic processes occurring in the territory of work. It should be noted that a combination of these methods is only possible when the study area represents a rigid framework. This can be a foundation of process equipment engineering, or surface within the continuous tectonic plates.

The main material. To this end, we have developed a rigid model sample basis for research accuracy of heights obtained by precision geometric leveling inclinometer measurements and nahylomirnyh and to develop methods of joint processing of results. For this was an experiment that was to determine exceedances defined by precision geometric leveling, and by nahylomirnyh measurements.

For the experiment was mounted metal frame-section (4 x 4 cm) in a rectangle measuring 5.92 x 6.00 meters. Rama was installed on the four brackets that were fixed in the walls and columns of the room (Figure 1). Two brackets were fixed in the wall hard, and the other two were equipped with micrometer screws

displacement (raising or lowering) the entire design within 3cm (pic2). Deflection asked by an indicator clock type (m_h = 0.01mm).

Fig. 1. Location frames in the room

On two opposite sides of the frame inclinometers were installed (Figure 3), so that the tilt axis X parallel to the side of the frame. Inclinometers through communication "COM" port and a cable was connected to the computer and to the power supply 12 (Figure 3). To transfer data and processing software used «NIVEL 210 Data Reader», which allows not only to view, record and display the results in real time, but also to process and present them in a convenient form to the observer. For the leveling of the corners of the frame rails fixed length of 0.7 m pasted scan code rails (Figure 2), and used four digital Trimble DiNi levels 03 (m_h = 0.3mm / km) (Fig1). Due to synchronize clocks of computers and digital data levels and leveling measurements nahylomirnyh oderzhuvalysya us at one time in the entire period of the experiment.

The experiment was conducted from 18.04. 2014 to 04.25.2014 year. During the experiment, digital inclinometers worked continuously, and measure the levels performed automatically every day 3 - 4 hours. Every day with micrometer screw brackets with clock and indicators type tilt wondered designs with various step (1 mm, 0.5 mm, 0.25 mm), and various time intervals (15 min., 10 min., 5 min).

In the experiment received daily files nahylomirnyh observations intervals measuring 0.2 sec., Which represent the value of inclination on the X axis, the axis Y, and temperature during measurement (during the experiment the temperature changed within 15 - 16 C0). Also received daily files measuring height change each of the points by leveling.

Results

Initial data for combined study results nahylomirnyh leveling and height measurement points were defined with geometric leveling, construction angles of the axes X and Y, as well

Method

As inclinometer measures angles, not exceeding a leveler, before developing methods compatible balance must be found between dependence and excess angles. Let point 1 (Figure 5) installed inclinometer, which recorded angles for axes X and Y respectively i_x and i_y.

as the coordinates of points 1 - 4 and locations inclinometer. The methods and calculation algorithm implemented in the package MATHCAD.

As noted above the importance of balancing compatible with the correct selection of the weight measured values, and especially the results obtained inclinometer. Table 1 shows the value changes in height and mean square error of its determination in one cycle after balancing observations at different values of mean square error of measurement of the angle of slope inclinometers m_i.

m_i, мрад	The change points height mm				UPC determining the change points height mm
	1	2	3	4	
0,005	0.387	0.679	-0.336	0.270	0.603
0,007	0.308	0.753	-0.272	0.211	0.462
0,009	0.242	0.812	-0.217	0.163	0.385
0,01	0.215	0.836	-0.194	0.143	0.358
0,05	*0.014*	*1.000*	*-0.014*	*-0.000*	*0.098*
0,1	0.004	1.007	-0.003	-0.007	0.050

As seen from the results obtained optimal value of mean square error of measurement of the angle of slope inclinometers for experimental conditions are m_i = 0,05 mrad.

Table 2 shows the changes in elevation points after joint balancing the results of several measurements in three days of observations with different step heights and their changes mean-square error determination. Also in Table 3 shows the change in altitude deviation from the reference value. Analyzing the data in Table 3, we can conclude that the deviation height change points after joint balancing ranges from 0.02 - 0.06 mm (except for a few cycles of observations where these values are 0.1 - 0.2 mm for technical reasons). This indicates that our model sample represents not quite a rigid framework. Mean square error determination position inclinometer that ranges 0.1 - 0.3 mm, as evidence of this assumption.

Дата та час вимірів	Зміна висоти точок, мм				СКП визначення зміни висоти точок, мм
	1	2	3	4	
1	2	3	4	5	6
18.04.2014	**крок зміни висоти 1 мм**				
9:45:00	0.014	1.000	-0.014	-0.000	0.098
10:00:00	0.992	0.006	0.010	0.082	0.110
10:15:00	0.023	0.991	-0.027	-0.087	0.096
10:30:00	0.912	0.004	0.011	0.103	0.103
10:45:00	0.152	0.992	-0.015	0.012	0.104
11:00:00	1.067	-0.005	0.011	-0.003	0.106
11:15:00	-0.217	1.009	-0.017	0.006	0.099
11:30:00	1.058	-0.005	0.001	-0.005	0.107
11:45:00	0.016	1.000	-0.015	0.009	0.099
12:00:00	0.921	0.004	0.009	-0.013	0.092
22.04.2014	**крок зміни висоти 0,5 мм**				
8:29:00	0.002	-0.505	0.008	-0.005	0.052
8:39:00	-0.562	0.022	-0.007	0.007	0.056
8:49:00	-0.008	-0.496	0.008	-0.004	0.051

8:59:00	-0.485	0.003	0.004	-0.002	0.050
9:09:00	0.011	-0.515	-0.002	-0.005	0.051
9:19:00	-0.466	-0.007	0.004	-0.061	0.052
9:29:00	-0.006	-0.495	0.009	0.063	0.047
9:39:00	-0.524	0.012	-0.006	-0.002	0.055
9:49:00	-0.008	-0.505	0.017	-0.005	0.050
9:59:00	-0.475	0.003	-0.005	0.017	0.047
23.04.2014	**крок зміни висоти 0,25 мм**				
8:09:00	-0.023	-0.248	0.014	0.007	0.025
8:14:00	-0.199	-0.003	-0.003	-0.065	0.026
8:19:00	0.006	-0.247	0.005	0.066	0.024
8:24:00	-0.198	-0.003	-0.002	0.003	0.020
8:29:00	-0.025	0.267	-0.005	0.002	0.027
8:34:00	0.247	0.003	0.003	-0.013	0.023
8:39:00	-0.006	0.238	-0.004	0.002	0.025
8:44:00	0.198	0.003	0.002	0.017	0.021
8:49:00	0.004	0.248	-0.004	-0.017	0.024
8:54:00	0.247	-0.006	0.003	0.006	0.026

Дата та час вимірів	Відхилення зміни висоти, мм			
	1	2	3	4
1	2	3	4	5
18.04.2014	**еталонне значення 1 мм**			
9:45:00	-0,014	0,000	0,014	0,000
10:00:00	0,008	-0,006	-0,010	-0,082
10:15:00	-0,023	0,009	0,027	0,087
10:30:00	0,088	-0,004	-0,011	-0,103
10:45:00	-0,152	0,008	0,015	-0,012
11:00:00	-0,067	0,005	-0,011	0,003
11:15:00	0,217	-0,009	0,017	-0,006
11:30:00	-0,058	0,005	-0,001	0,005
11:45:00	-0,016	0,000	0,015	-0,009
12:00:00	0,079	-0,004	-0,009	0,013
22.04.2014	**еталонне значення 0,5 мм**			
8:29:00	-0,002	0,005	-0,008	0,005
8:39:00	0,062	-0,022	0,007	-0,007
8:49:00	0,008	-0,004	-0,008	0,004
8:59:00	-0,015	-0,003	-0,004	0,002
9:09:00	-0,011	0,015	0,002	0,005
9:19:00	-0,034	0,007	-0,004	0,061

9:29:00	0,006	-0,005	-0,009	-0,063
9:39:00	0,024	-0,012	0,006	0,002
9:49:00	0,008	0,005	-0,017	0,005
9:59:00	-0,025	-0,003	0,005	-0,017
23.04.2014	**еталонне значення 0,25 мм**			
8:09:00	0,023	-0,002	-0,014	-0,007
8:14:00	-0,051	0,003	0,003	0,065
8:19:00	-0,006	-0,003	-0,005	-0,066
8:24:00	-0,052	0,003	0,002	-0,003
8:29:00	0,025	-0,017	0,005	-0,002
8:34:00	0,003	-0,003	-0,003	0,013
8:39:00	0,006	0,012	0,004	-0,002
8:44:00	0,052	-0,003	-0,002	-0,017
8:49:00	-0,004	0,002	0,004	0,017
8:54:00	0,003	0,006	-0,003	-0,006

Scientific novelty and practical significance

The results of the experiment confirmed the possibility of using nahylomirnyh measurements to determine changes in elevation points of a rigid base. Use nahylomirnyh measurements during high-geometric leveling will complement the information on dynamic processes occurring in the territory of the work between cycles observations.

The method allows consistent process results and high-precision geometric leveling measurements nahylomirnyh and to find the accuracy of elevation points obtained by these methods. Using this method you can make the choice of optimal scales of measurement results, for improvement of the results of measurements.

This method of processing the results of observations can be used to further monitor the deformation of engineering structures and process equipment.

Conclusions.

Analyzing the results of research the following conclusions:

The experimental results confirmed the possibility of using measurements of angles of inclination of a surface obtained by inclinometers coupled with the results of geometric precision leveling.

The technique that allows you to conduct a joint study of geometric precision leveling results and nahylomirnyh inclinometer measurements.

Deviations height change points after joint balancing of reference value ranges 0.02 - 0.06 mm, which is commensurate with the size accuracy of the reference value of 0.01 mm.

According to the results of processing of measurement results found optimal value mean square error of measurement of the angle of slope inclinometers to experimental conditions (m_i = 0,05 mrad).

This technique can be applied when establishing and monitoring provisions foundations of process equipment engineering structures, or the study of movements of the earth surface within the continuous tectonic plates.

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The questions of research of the accuracy of height determination obtained by precision geometric leveling and inclinometer measurements and development of technique of joint processing of these results are considered in the paper. Based on implemented experiment the technique of joint study is proposed, results of joint adjustment are shown and conclusions about the possibility of future use of this technique are made.

Keywords: deformations, inclinometer, a joint study of inclination and leveling measurements, weight of measured valu