Causes of strain of buildings and structures in areas of abnormal stress and surveillance terrestrial laser scanners

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Abstract. The paper presents new methods of engineering-geological surveys, geodetic measurements to determine the deformations of buildings. For a long time many experts point the lack of a clear answer about the causes deformations of buildings and structures out. As a rule, within that framework are engineers mountain profile, surveyors and Geophysics - people who worked in the underground mines and quarries and familiar with the concepts of the stress state of the geological environment. Most of them are inclined to think that an emergency condition caused by many engineering objects wrong approach to engineering surveys and underestimation of modern geodynamic activity of the geological environment. Until recently, geologists believe that the Earth's crust, except in areas of active volcanism and seismic areas (ie dangerous in terms of earthquakes) is at rest, ie immobile. However, at the present stage to the commissioning of new measuring techniques, to use of satellite geodesy and development of geophysical research methods apparently, it became that the crust is always and everywhere is in motion. Roughly speaking, the earth goes right under our feet. Displacement of the earth surface and rock masses have negligible amplitude and not visible to the eye but can have a significant impact on both the rock mass and the engineering structures [1]. Object of study is the main academic building of the Kazakh National Technical University named K.I.Satpayev (KazNTU), which is situated on the street Satpaev 22 Baitursynov street corner, the city of Almaty, Kazakhstan.

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Introduction

Operational safety of engineering structures and equipment, such as accelerators, high-rise buildings, dams, bridges and reservoirs are required periodic monitoring of their conduct. Strain - is the most important parameter to be monitored. Monitoring deformations of these structures is one of the applications of high precision surveying methods and means of measurement. Therefore, monitoring of structural deformations and active responses to multiple external loads are of great importance to maintain the operation of engineering structures. Deformation of buildings, cracks in foundations and supporting structures are a major problem faced by builders, designers and surveyors in the process of their work. Most often strain engineering objects are explained as a result of soil compaction precipitation base. Undoubtedly, the process of soil compaction is the cause of many strains. However, we should note two important points. First, the process of soil compaction under the weight of the building can not last more than 2-3 years after its construction. Second, before to the construction and development of the detailed design for the site is carried out geotechnical investigations. The purpose of this research - to determine the bearing capacity of the soil and the possible impact of negative processes, including non-uniform sediment, karst- suffusion processes, landslides, silt, etc. Ie the possibility of such sediment is provided in advance and designers should avoid it. Accordingly, if the building is still the beginning of deformation it means that either someone has done his job in violation of existing rules and regulations or the rules themselves contain flaws and not fully reflect the real situation. [2]

In many cities, there are a number of facilities at which strain manifested from the beginning of their operation and continued for decades. Quite revealing in this regard is an example of the building of the main academic building of Kazakh National Technical University named after K.I.Satpayev (KazNTU) which is situated on the street Satpaev 22 Baitursynov street corner , the city of Almaty, Kazakhstan. The building was built in the mid 80 - ies of the last century by the "Giprovuz". Studies of the fault zone and the preliminary assessment of geotechnical conditions at the site of construction of various functional purposes for KazNTU which is situated southerly of Satpaev street and eastern of Baitursynov street, performed JSC "KazGIIZ". [3]

Fig. 1. The main academic building of the Kazakh National Technical University (KazNTU)

According to SN RK 2.03-07-2001, the bulk of the requested site projected construction and renovation is located in a zone Zhanaturmys's tectonic fault. Therefore, as part of work performed, the task of verifying the location of the northern boundary and study the structure of the Zhanaturmys's fault zone displays on this site. For these purposes, in accordance with the protocol decision of the Ministry of Construction of the Republic of Kazakhstan № 1 from 2.06.94g. and the order of the head of the Almaty City Administration for number 58 -p of 5.06.94g. as a mandatory method has been used in mapping active zones of anomalous voltage (Azan method). The method is patented in the Republic of Kazakhstan (RK 799 Patent).

Geomorphologically complex in KazNTU is located in the central part of the modern alluvial fan p. Minor Almatinka on the border with erosional outliers ancient alluvial fan. In this regard, in terms of soil conditions are characterized by high variability over short distances. [3]

According to SN RK 2.03-07-2001 "Development of Almaty and adjacent areas subject to seismic zoning" this area is referred to an area with seismic 9 points. This seismicity refers to the development area, located outside the fault zone.

Observed that accident, destruction and deformation of engineering constructions, industrial and civil buildings, ceteris paribus, in most cases occur in these so-called anomalous zones stress, especially when seismic tremors, repeatedly reinforcing the damaging effects. The nature of these areas is explained by the perturbation of the background stress field caused by the presence of various irregularities and dangerous manifestation of exogenous processes in the soil array of features such as tectonic faults. [3]

At high power unconsolidated sediments appearance of radioactive gases in the soil air can be attributed to the release of the emanations of themselves deposits and anomalies of radioactive and other gases in the soil increase emanations when they created stresses migration gases and their accumulation over the weakened areas.

Results of profile works by Azan made in the last five years to study the zones of tectonic faults, indicate the prospect of a new method for evaluating the applicability of these zones an urban development areas. These measurements were carried out on Metolit individual fragments zones of tectonic faults, while associated Map integrated microzoning Almaty and the surrounding area. These measurements indicate that the actual tectonic fault zone width of about 300 m is an alternation of blocks with varying degrees of disturbance of soil mass. Especially dangerous is the broken blocks and their articulation zone, where there are abnormal voltage. These tectonic elements within the time scrap mapped as separate zones of higher order for elevated concentrations of the gas components contained in the soil air. Undisturbed blocks characterized by background gas readings components. [3]

Thus, within the areas of manifestation of tectonic fractures on the surface, shown on a map of seismic mikrorayonirova of Almaty, favorable and unfavorable allocated land for construction.

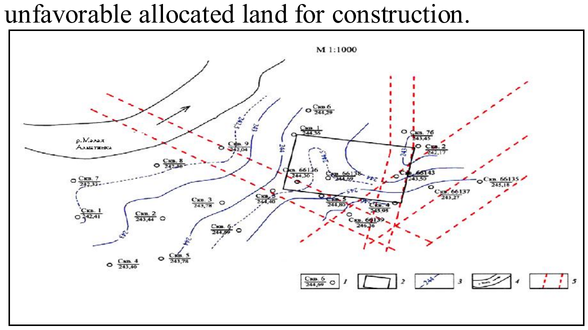
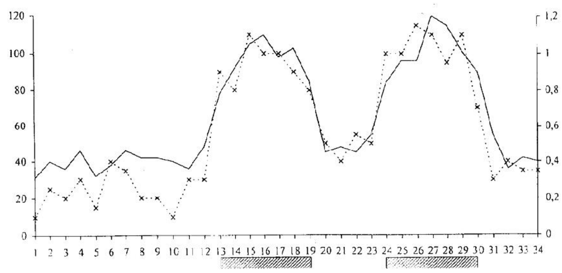


Fig. 2. Map hydroisohypses

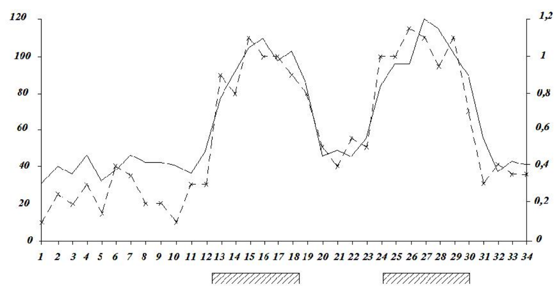
1 - Well, ist's number, 2 - Loop building KazNTU, 3 – hydroisohypses, 4 – The river Small Almaty, 5 - active tectonic faults

Requested on site measurements were made by Azan 3 profiles oriented in submeridional direction crossing the northern border zone Zhanaturmysskogo tectonic fault. Profile number 1330 meters in length stretches from the western one hand KazNTU territory on the street Baitursynov. Profile number 2 length of 330 meters passed the street Satpaev and further down the street Askakov through university, and the profile number 3310 meters in length was made on the east side of the requested area. In addition, to clarify the northern boundary fault Zhanaturmys's results were used stock profile measurements on the street Markov. [3]

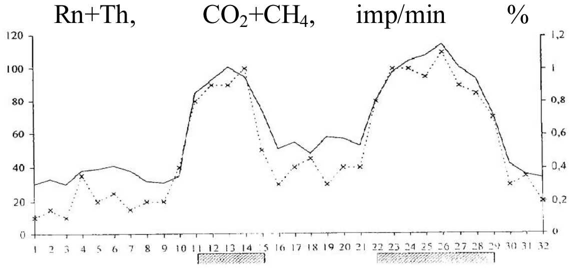
Measurement schedule by AZAN
Profile number 1
Rn+Th, CO_2+CH_4, imp/min %



Profile number 2
Rn+Th, CO_2+CH_4, imp/min %



Profile number 3
Rn+Th, CO_2+CH_4, imp/min %



Symbols

- A zone of anomalous stress

The total content of radon and Goroka, CP / min

X --- X --X The total content of methane and carbon dioxide,%

At each point, the measurements with sampling soil air holes of depth 0.6 - 0.8 m by pump follower but the camera and emanometra analyzer. As the measuring apparatus used tours plant comprising manometer "Radon" and mine interferometer "SHI-10". Content of radioactive gas radon and thoron determined in arbitrary units, which taken as counts per minute (cpm/min) electromechanical meter, and the content of the gas components methane and carbon dioxide - a percentage (%) optimal number of strokes of the pump for air sampling technique of work defined by the Azan. At each point of measurement in accordance with thosenology production work provided an average of three measurements. After producing a measurement instrument pumped airbags, and installation was moved to another point of measurement, where repeated measurement cycle. [3]

According to the results of profile measurements were constructed graphs of the total content of radioactive gas radon and thoron in pulses per minute (counts/min) and gaseous components - methane and carbon dioxide - in percent max (%).

All graphs are marked by two sites with anomalous values of the measured gas content of soil air components. Profile on the chart number one abnormal value of the content of the gas components allocated isolated from 13 to picket 19 and 24 to 30 picket. Profile on the chart number 2 abnormal values were observed at two sites - with picket 13 to 18 and 25 to picket picket 31 and graph profile number 3 anomalous sectors hook in between pickets 11 -15 and 22 - 29.

Abnormal areas are characterized by high values of the contents in soil air radon and thoron in the range 70 - 110 pulses/min and the total content of methane and carbon dioxide 0.6 - 1.1%. Background values of radioactive gases account for 30 - 60 pulses/min, and the other measured ha call -0.1 -0.5%. [3]

When combined abnormal areas on the profiles are the two linear zones Zhanaturmysskogo tectonic fault extends in sub latitudinal direction. The plot with anomalous value located in the middle part of the fault is identified with the "axial" stress zone, and in the northern part of the tectonic fault - with "the contact" area of abnormal voltages, which corresponds to the northern boundary of the updated location of the fault zone. Between these zones stands favorable for the construction site with background values measured gas components.

Thus, at the site of construction of various functional purposes for KazNTU which is situated southern of Satpaev street and eastern of Baitursynov street in Almaty, the results of profile measurements by Azan updated location on the surface manifestations northern boundary Zhanaturmys's fault zone and identified two anomalous zones latitudinal direction unfavorable to the construction, among which is favorable for the development of the construction site within the zone Zhanaturmysskogo fracture. [3]

When designing and building on unfavorable sites within the fault zone in the calculation of seismic loads must enter the multiplying factors on the amount of displacement and acceleration, pleasant for similar soil conditions outside the fault zone. These coefficients can be determined only by taking into account the geological conditions for specific construction projects according to detailed research. [3]

The concept of the safe operation of engineering structures are the basis of modern systems of their design. Details of structural deformations can help determine the overall condition of these structures, as well as calculate the maximum allowable values of possible deformations.

The main purpose of monitoring the condition of buildings and engineering structures is [7, 8]:

- Determination of absolute and relative values of the precipitate and strains;
- Identify the causes and severity of deformities;
- Characterization of the stability and reliability reasons the foundations of buildings;
- Setting emission limit values of deformations;
- Forecasting the development of deformation processes during construction and operation, as well as changes in these impacts;
- Prevention of possible risks.

In solving these problems with the help of modern instruments and equipment are set sizes, types and quality of the installation of foundations, deformation structures, as well as state and moving soil. In developing the observational network geotechnical monitoring features are taken into account facilities. Through this approach, the location and number of elements of the observation network for each object can be developed individually. [9]

Determination of the deformation is necessary in order to ensure normal operation of the facility. Monitoring and surveillance of buildings deformations operate on specially designed project, which includes the following basic information are shown in the generalized scheme (Fig. 3).

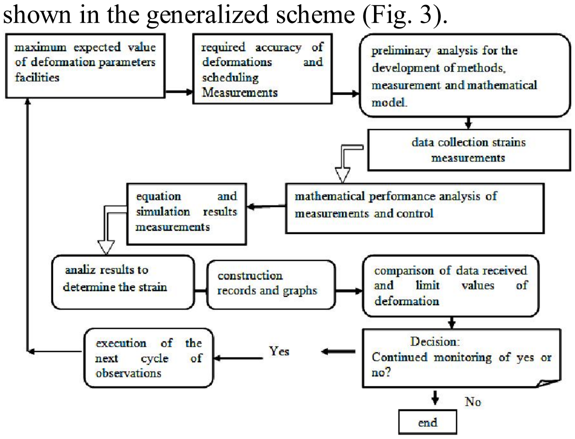


Figure 3. Schematic plan of monitoring and observation of deformation of engineering structures

Based on the analysis results of the deformation is a technical opinion on the state of development and prognosis identified strains developed recommendations for the continuation of monitoring and geodetic observations, or vice versa - increasing the number of measurement cycles of deformation and their suitability for further use.

The procedure for monitoring deformation of engineering structures includes a two-stage [10, 11]:

1. Monitoring facility deformation by performing a series of measurements made over time to determine changes in geometric parameters (dimensions) of the structures in one, two or three dimensions relative to the initial size of the derivative as a function of displacement;

2 . Monitoring of operating loads and internal pressure, which can be measured directly or obtained by special measurements.

Development of geodetic instrument making has led to the emergence of new devices for the measurement to determine the deformation structures, particularly ground-based laser scanners. The main advantages of laser measuring equipment to the analog are: speed measurement, high accuracy, ease of obtaining primary data and their automatic processing, as well as the almost complete exclusion of the "human factor " until a final result of work.

Terrestrial laser scanning - by far the most rapid and efficient way of obtaining accurate and most complete information on the spatial object. The laser scanner is the latest technology, and, despite the relatively short period of its existence, has been used in many surveying applications. Terrestrial laser scanning allows for greater density and accuracy of laser reflection points, and therefore a higher level of detail shots. Terrestrial laser shot used in the need to obtain detailed plans and three-dimensional models to the local area in a few dozen hectares.[4]

3D scanning is used in many applications: architectural, industrial, civil survey, urban topography, survey linear structures, mining, archeology, engineering and mechanical control measurements, etc. [4]

The technology of laser scanning is to determine the spatial coordinates of points on the surface of the object. This is done by measuring the distance to all points determined by laser reflectorless EDM. By type of received information the device is largely similar to the instrument. Same as the last, the scanner using a laser rangefinder calculates the distance to the object and measuring the vertical and horizontal angles, getting XYZ- coordinates. Unlike the instrument lies in the fact that the daily snapshot by using the laser scanner - the tens of millions of measurements. The initial result of the scanner is a cloud of points. In the process of shooting for each recorded three coordinates (XYZ), and a numerical indicator of the intensity of the reflected signal. It depends on the properties of the surface on which the laser beam. Cloud points highlighted depending on the intensity and after scanning looks like a three-dimensional digital photos. Most modern laser scanners have built-in camera or camcorder, allowing a cloud of points can also be painted in realistic colors.

In general diagram of the instrument is as follows. Laser scanner mounted in front of the subject on a tripod. The user specifies the desired density of the cloud of points (resolution) and shooting range, and then starts the scanning process . For complete data of an object, as a rule, it is necessary to perform these operations from several stations (products). [12]

At each measurement beam rangefinder deviates from its previous position so as to pass through the assembly of some imaginary normal grid, also called the scanning matrix. The number of rows and columns of the matrix can be adjusted. The higher density of points of the matrix, the higher the density of points on the object surface. Measurements are made with a very high speed - thousands of measurements per second. The result of the scanner is the set of points with the calculated three-dimensional coordinates. These sets of points are called point clouds or scans. Typically, the number of dots in one cloud may vary from tens of thousands to several millions.

It is known that these coordinates scanner include systematic measurement errors [7]. For example, the distance measurement errors of terrestrial laser rangefinder scanner error angle measurements and measurement errors in terms of disturbances. With this in mind, we propose a technique for the general approach calibration of terrestrial laser scanner and determining the values of the systematic errors of measurement of distance and angles obtained scanner next.

We write the original equation (1) the transition from the coordinate system to an external system scan following well-known expression in mathematics. [9]

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{Tax.} = \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix} + R(\omega_X, \omega_Y, \omega_Z). \begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{C\kappa.} ,$$

where $\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{Tax.}$ - the coordinates of the i-th point, $\begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix}$ - received a total station displacement vector rotation matrix, $\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{C\kappa.}$ - coordinates of the same points, $R(\omega_X, \omega_Y, \omega_Z)$ - obtained by the scanner.

Rotation matrix between the two systems is calculated by formulas

$$\text{where } R(\omega_X, \omega_Y, \omega_Z) = \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}, \quad (2)$$

$$\left.\begin{aligned} R_{11} &= \cos\omega_Y \cos\omega_Z; \\ R_{12} &= \cos\omega_Y \sin\omega_Z; \\ R_{13} &= -\sin\omega_Y; \\ R_{21} &= \sin\omega_X \sin\omega_Y \cos\omega_Z - \cos\omega_X \sin\omega_Z; \\ R_{22} &= \sin\omega_X \sin\omega_Y \sin\omega_Z + \cos\omega_X \cos\omega_Z; \\ R_{23} &= \sin\omega_X \cos\omega_Y; \\ R_{31} &= \cos\omega_X \sin\omega_Y \cos\omega_Z + \sin\omega_X \sin\omega_Z; \\ R_{32} &= \cos\omega_X \sin\omega_Y \sin\omega_Z - \sin\omega_X \cos\omega_Z; \\ R_{33} &= \cos\omega_X \cos\omega_Y, \end{aligned}\right\} \quad (3)$$

where ωX, ωY, ωZ - angles with the direction of rotation X, Y and Z, respectively,

Therefore the vector proper coordinates of any point received terrestrial laser scanner will look

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{C\kappa.} = \begin{bmatrix} (s_i + \Delta s).\cos(\alpha_i + \Delta\alpha).\cos(\gamma_i + \Delta\gamma) \\ (s_i + \Delta s).\sin(\alpha_i + \Delta\alpha).\cos(\gamma_i + \Delta\gamma) \\ (s_i + \Delta s).\sin(\gamma_i + \Delta\gamma) \end{bmatrix}, \quad (4)$$

where si - measured slope distance between the scanner and the observed point; αi and γi - measure horizontal and vertical angles of the direction of observation points defined; Δs, Δα, Δγ - collimation systematic DL errors, respectively, for the slope distance, horizontal and vertical angles.

Measured slope distance, horizontal and vertical angles from the scanner to any point may be determined by the formulas

$$\left.\begin{aligned} S_i &= \sqrt{X_i^2 + Y_i^2 + Z_i^2}; \\ tg\ \gamma &= \frac{Y_i}{X_i}; \\ tg\ \alpha &= \frac{Z_i}{\sqrt{X_i^2 + Y_i^2}}. \end{aligned}\right\} \quad (5)$$

When substituting the equation (4) coordinate values obtained by using the scanner, the expression (1) can be written as follows:

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}_{Tax.} = \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix} + R(\omega_X, \omega_Y, \omega_Z). \begin{bmatrix} (s_i + \Delta s\ ).\cos(\alpha_i + \Delta\alpha).\cos(\gamma_i + \Delta\gamma) \\ (s_i + \Delta s\ ).\sin(\alpha_i + \Delta\alpha).\cos(\gamma_i + \Delta\gamma) \\ (s_i + \Delta s\ ).\sin(\gamma_i + \Delta\gamma\ ) \end{bmatrix}. \quad (6)$$

Expression (6) incorporates a non-linear functional equation observed angles, distances and nine parameters. Thus, the system of equations can be written to coordinate all reflective marks obtained by measurement of the scanner and total station. When using the method of least squares nine unknown parameters can be restored.

Then performed the initial processing of the data received from the scanner, and the preparation of measurement results in the form in which they are required to the customer. This step is not less important than the field work, and often more time-consuming and complicated. Profiles and sections, flat plans, three-dimensional model for calculating the areas and volumes of surfaces - all this, as well as other relevant information can be obtained as the final result of the scanner.

Thus, the problem of identifying and exploring moving tectonic faults is relevant and an increased interest on the part of many professionals. High rates of construction, widespread construction of tall objects and active underground space development requires a more thorough analysis of geotechnical conditions and accounting geodynamic activity of the geological environment. A significant amount of information about the dynamic action of tectonic zones for engineering objects accumulated by a number of independent researchers, requires careful analysis in order to develop an effective system of protection from the negative effects of modern tectonics. In this regard, in the central part of the main building of the Kazakh National Technical University named KISatpayev passes crack, because zones of anomalous faults. Currently investigated cracks and other reasons predicted deformation of the building .

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