Organizational and technological features of geodetic observations of earth surface deformations

Valerya Bobkina¹, Vladimir Yakovlev¹

¹ Don State Technical University, Gagarin square 1, Rostov-on-Don, 344000, Russia

Abstract. The article examines a complex of organizational, technological and economic measures to ensure observations of deformations of the earth's surface. The authors provide an overview of issues of improving the safety of buildings located in seismically active and landslide zones of the Russian Federation, and offer recommendations for improving monitoring methods. The need for careful consideration of the geodynamic factor during the construction and operation of not only especially critical unique objects, but also mass housing construction projects is substantiated. To study geodynamic processes occurring in the territories of populated areas or in the territories of large industrial enterprises and engineering structures, it is proposed to create specialized observation systems - geodynamic polygons. The authors propose an organizational and technological scheme for observations at the geodynamic site. Research methods for making organizational and technological decisions are discussed. Effective organization of work will allow us to study abnormal vertical and horizontal movements and prevent possible damage to infrastructure. The authors of the article also discuss and justify recommendations for performing and processing geodetic observations of deformations of the earth's surface.

1 Introduction

Currently, the relevance of studying geodynamic processes has increased. Due to abnormal vertical and horizontal shifts, which arise due to movements and vibrations of the earth's surface, buildings and engineering structures are destroyed, which in turn can lead not only to economic and environmental damage, but also to human casualties. In the area of seismically active and landslide zones of the Russian Federation, where large engineering structures, industrial enterprises, monuments of historical, cultural and natural heritage are located, deformation and movement of the earth's surface should be studied constantly. During the construction and operation of buildings and structures (including underground), engineering communications, as well as historical and cultural monuments, the use of comprehensive information on the geodynamic state of the earth's surface will reduce the risk of emergencies and disasters. Taking into account the scale of high-rise construction, as well as intensive development of underground space, increased traffic flows, the probability of deformations in megacities is increasing.

* Corresponding author: bobkina.75@mail.ru
Monitoring of the state of soils and foundations in the construction zone will ensure safety and operational reliability of facilities. The relevance of studying the impact of geodynamic processes, which today are increasingly becoming anomalous, on the occurrence of accidents at industrial facilities or mining complexes, deserves close attention. Also monitoring the stress-strain state and stability of engineering structures (tunnels, railroads, etc.) will reduce environmental, economic and insurance risks [1-4]. Thus, taking into account the geodynamic activity will allow us to establish the true objective basis of accidents: man-made or natural. This issue requires study and elaboration.

2 Materials and methods

To study geodynamic processes that occur in the territories of populated areas or in the territories of large industrial enterprises and engineering structures, it is necessary to create specialized observation systems - geodynamic polygons, which take into account mathematical models of the movement of geological structures and their structure. The study of geodynamics of these territories will prevent the occurrence of dangerous deformations of objects located on them, as well as provide a forecast of emergencies and disasters, including those with human casualties [5-7].

Geodetic works on geodynamic polygons are part of the complex of scientific geophysical research and are aimed at obtaining quantitative characteristics of the stability of the mutual position of points of the Earth's surface in time, so the measurements, in accordance with the Order of the Federal Service of Geodesy and Cartography of Russia, should be carried out in several consecutive cycles. Along with this task, the issues of improving the methodology of high-precision measurements should be solved, so the observations in each cycle should be carried out in such volume and by such methods, which allow to judge about the magnitude of possible systematic and random errors of measurement results.

Since geodynamic polygons are located, for the most part, in mountainous areas, geodetic points are located on a large territory with different lengths and elevations between them. The specificity of high-precision geodetic measurements in complex physical-geographical and climatic conditions of mountainous terrain requires at the stage of design of high-precision engineering-geodetic networks comprehensive analysis of technical and economic nature [8-11].

When designing especially important civil and industrial facilities in unstable geotectonic areas, the design of high-precision geodetic network for cyclic observations of crustal movements is planned at the joint analysis of geological and geophysical studies.

The project of points location (plan and height) and schemes of geodetic observations on geodynamic polygons should provide solution of tasks of different purposes. For their solution three types of networks are created:

1 type - local networks - for observation and control of tectonic faults;
2 type - area networks - for study and observation of earthquakes;
3 type - regional networks - for studying geological structures.

The initial points, where the location of base stations is designed, should be located on a monolithic basis, where the stability of their position is confirmed by long-term geophysical, geodetic and other types of studies. Other points in the projected network of the geodynamic polygon should be laid taking into account their location on different sides of the geotectonic fault. Laying of geodetic point should be made taking into account the availability of a site for forced centering of geodetic instruments.

The cyclic nature of the measurements depends on the purpose of the site. If, for example, to obtain high-precision data for the study of tectonic phenomena by satellite methods, based on the period of rotation of satellites $\approx 11h58m$, it is optimal to perform 1
cycle per year for one date and time, then the observations in the locations of underground gas storages depends on the frequency of the process of "injection-pumping". And further, in zones with increased seismic activity, continuous observations should be carried out, which confirms the idea of individual approach to each organized polygon.

The final data for analysis and forecast are obtained from the processing of the whole set of measured elements. The processing should be performed in a conventional coordinate and height system. In order to ensure easy reduction of the measured elements, a conditional relativity surface is chosen. If at repeated measurements instability of the chosen initial points is found out, then, according to Recommendations on geodetic works on geodynamic polygons, calculations of coordinates and heights on all cycles are carried out again from new initial points.

When creating high-precision local geodetic networks, which include points of geodynamic polygon, static mode of satellite observations is the main one. Observations in this mode at each separate point with the mandatory use of dual-frequency receivers can be about an hour or more, which is explained by the need to exclude a number of cyclic systematic errors of observations at different locations of the initial satellites of the radionavigation system, the possibility of selecting for a given, rather long period of time, the most favorable factor of spatial geometric notching, the accumulation of redundant information of field observations to resolve the ambiguity of the phase of the geodetic system. An obligatory condition is the necessity to observe the same ISRs at the reference (base) and rover (mobile) stations. The transfer of differential corrections during measurements from the reference station to the rover station is not provided [12-13].

Since coordinate determinations at geodynamic polygons in rather complicated mountain conditions are usually referred to the highest class of accuracy, the observations should be designed using simultaneously several dual-frequency receivers of satellite signals. It is now possible to add receivers of signals at three frequencies to the observation process.

In addition, in mountainous terrain to solve the problems of reducing the conducted measurements and constructions on the local surface of relativity and, most importantly, to determine the excesses between points by high-precision trigonometric leveling (two-sided), a set of gravimetric determinations and studies of the phenomena of vertical refraction is necessary. If the correction for refraction by atmospheric models we can calculate with sufficient accuracy up to 1 [12-13], then the deviations of plumb lines should be determined directly from measurements of acceleration of gravity at each point, and the gravimetric point is considered to be combined with the geodetic center, if the gravimetric devices are installed from the center no further than 25 cm in height and 5 m in plan in accordance with the Instruction for the development of high-precision state gravimetric network of Russia. Markings of the points along with their planned position form the basis for creating a digital model of the polygon. Further methodology to determine the vertical displacements of each point includes the use of satellite leveling with ensuring the principle of "unity of measurements", i.e., receivers, time, forced centering.

If the excess from trigonometric leveling can be obtained with an accuracy of 1-2 cm, then when using multi-frequency satellite receivers at the same distance between the points of about 10-15 km, the accuracy of base determinations in plan and vertical displacements can be several millimeters.

3 Results

For making organizational and technological decisions and drawing up the technical project (Fig. 1.) of geodetic works at the geodynamic polygon the results of geophysical, geological and geomorphological studies in the area are necessary.
**Terms of Reference**
(characterization of geological structure, characterization of tectonic phenomena, gravimetric and seismic observations, study plan and schedule, scheme of geophysical observation points)

**Detailed field reconnaissance.**
Survey of the condition of all points of the geodetic network

**Topographic and geodetic support.**
Materials of all previously performed geodetic observations in the polygon area

**Organizational and technological solutions**
(density of observation points, location design, equipment (accuracy, efficiency, automation), periodicity, control measurements, duration of measurements)

**Monitoring of vertical and horizontal movements at the geodynamic test site.**
VAT of geological environment

**Monitoring of vertical and horizontal movements of built-up areas**

**Instrumental observations:**
- high-precision leveling
- satellite measurements (GNSS)
- line-angle measurements
- gravimetric measurements
- laser scanning

**Monitoring of deformations of buildings and structures**
(structures and technological equipment)

**Processing of measurement results**
- field logs, calculation logs, charts, coordinates and heights catalogs
- technical report

**Management decisions**
- comprehensive analysis
- conformity assessment of design solutions
- forecast of spatial and temporal characteristics

**Geophysical, geological and geomorphological studies**

**Fig. 1.** Organizational and technological scheme of geodetic observations
Before compiling the technical project the following materials should be collected:
- technical assignment from the territorial research institute or organization, containing a characteristic of geological structure and tectonic phenomena in the area of the designed polygon, a set of planned geophysical observations (gravimetric, seismic, etc.) and tasks to be solved, a plan of the schedule of the main stages of research and a scheme of geophysical observation points;
- results of all geodetic works previously performed in the area of the polygon with characteristics of their quality and method of fixing the points;
- materials of analysis of all types of observations, allowing to reveal the nature and magnitude of possible deformations of the earth surface in the area of the polygon and their connection with tectonic processes;
- results of a field survey of the preservation of existing geodetic networks and geomorphologic conditions.

References