ABSTRACT

of the dissertation on the topic:

"DEVELOPMENT OF METHODS FOR GEODETIC MONITORING OF DEFORMATION PROCESSES AND TECHNICAL CONDITION OF HIGH-RISE AND UNIQUE BUILDINGS AND STRUCTURES" submitted for the degree of Doctor of Philosophy (PhD) in the specialty 8D07306-"Geospatial Digital Engineering"

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The purpose of the study is to develop and test methods for monitoring and assessing the technical condition of buildings, construct predictive models of displacements of load-bearing structures based on geodetic measurements, taking into account the spatio-temporal interaction of objects with the geological and seismic environment with values of the energy class of an earthquake K = 6-7.5 in the area of possible underground vibrations with an intensity of 3-4 points.

The main idea of the work is to conduct geodetic measurements of the settlements of load-bearing structures of buildings in the vertical plane, calculate the deformation parameters, build predictive models of displacements and identify patterns of change in displacements over time.

Object and subject of the study. The object of the study is a residential complex building in the Rakhat microdistrict and an underground multifunctional structure.

Subject of the study. Establishing deformation processes in the load-bearing structures of the building and structure based on geodetic monitoring.

Research objectives. To achieve this goal, the following tasks were solved:

1. Collection and analysis of materials from complex periodic engineering and geodetic measurements to determine the quantitative parameters of deformations of buildings and structures.
2. Conducting high-precision instrumental observations during the operation of buildings and structures.
3. Mathematical processing of the results of geodetic measurements, calculation of deformation parameters and construction of predictive models based on the data obtained.
4. Processing the results of geodetic observations to identify patterns of change in displacements over time and developing recommendations.

Research methods. An integrated approach is used, including the theory and methods of geodetic monitoring of deformation processes of high-rise and unique buildings and structures, probabilistic and statistical analysis, analytical forecasting methods and mathematical modeling using modern computer technologies.

Relevance of the dissertation topic.

Currently, high-rise, underground buildings and unique engineering structures are being built at a rapid pace all over the world, which stand out for their architectural forms, complex structural elements and the use of the latest

construction technologies and materials. Such buildings and engineering structures, distinguished by their originality and uniqueness, become the hallmark of megalopolises, giving them a unique, easily recognizable style.

In Almaty, at different times, unique buildings in their architectural solutions were erected, which are included in the lists of cultural heritage and are a symbol of the southern city. These include the Kazakhstan Hotel, the Kok-Tobe TV and Radio Broadcasting Tower, a multifunctional underground center, and multifunctional high-rise buildings that create additional loads on the stability of the building, which can lead to deformation shifts in the structure. A striking event affecting the stability of urban construction projects is the earthquake that occurred in Almaty on January 24, 2024, with a magnitude of 6.0. As a result of strong underground vibrations, cracks and damage were found in many residential buildings and socially important facilities. Therefore, to ensure the normal operation of the building and prevent dangerous displacements, a technical survey and geodetic observations of deformation processes in the main load-bearing and enclosing structures of the underground structure were carried out.

In this regard, the development of effective methods for identifying and predicting deformations of high-rise and unique buildings and engineering structures is an urgent problem for the successful solution and development of issues of ensuring the reliability, durability and safety of operation of critical structures. The solution to this issue contributes to the increased efficient use of high-rise and unique buildings and structures and helps to rationally plan various routine works, including geodetic observations of the deformation of structures and brings a certain social effect.

The introduction of new methods and means of geodetic measurements should be accompanied by a new methodology for processing measurement results. Only a comprehensive solution to the problem will allow achieving maximum efficiency and will meet modern requirements. Monitoring based on geodetic measurement methods is one of the most important tools for ensuring the reliability of a building and controlling deformation processes.

Scientific provisions submitted for defense:

1. Improving the methodology of geodetic monitoring of vertical displacements of building load-bearing structures taking into account complex geological conditions of the foundation, fluctuations in groundwater levels, soil compaction under static load and accumulation of damage due to frequent weak underground seismic tremors.

2. Building a predictive mathematical model of deformation displacements of a structure in the form of digital 2D and 3D models of a building taking into account the spatio-temporal interaction of the studied objects with the geological and seismic environment with values of the earthquake energy class K=6-7.5 and possible underground vibrations with an intensity of 3-4 points.

3. Identifying patterns in the development of deformation processes in individual building load-bearing structures in the vertical plane taking into account complex geological and morphological conditions of the soil foundation and

seismic vibrations causing additional dynamic loads and accelerating deformation processes.

Scientific novelty of the results of the work:

1. An analytical method for predicting possible vertical changes in individual structures of high-rise and unique buildings located in areas of active seismic displacements and complex rheological soil conditions has been developed, the novelty of which lies in increasing the accuracy of geodetic measurements through the use of modern high-precision observation technologies.

2. A mathematical model has been proposed for predicting deformation processes in individual sections of vertical structures that differ from previously existing digital two- and three-dimensional models of the building, taking into account the complex lithological structure of the foundation and the location of the object in the zone of possible tectonic vibrations with an energy class of K = 6-7.5.

3. A pattern has been established for the development of deformation processes in individual load-bearing structures of the building in the vertical plane, taking into account the complex geological and morphological conditions of the soil foundation and seismic vibrations with an intensity of 3-4 points.

Main results of the study:

1. An improved technique for geodetic observations of vertical displacements in a monolithic wall of a residential building is proposed by placing deformation marks along the perimeter of the wall at a distance of 0.30-0.60 m from the junction of the vertical and horizontal surfaces.

2. A mathematical technique is proposed for predicting displacements in individual sections of the perimeter of the structure, taking into account the spatio-temporal interaction of objects with the geological and seismic environment with values of the energy class of an earthquake of K = 6-7.5 in the area of possible underground vibrations with an intensity of 3-4 points.

3. Geodetic observations of the underground object for deformation processes (deflection and subsidence of the roof surface of the building) were carried out. The values of subsidence before and after geodetic monitoring for a 10-year period of operation of the building ranged from 27 mm to 130 mm. After the subsidence and deflection of individual sections of the roof of the underground structure, the operation of the building was suspended.

4. An analytical method for predicting possible deformation changes during the operation of a building is proposed. In just 9 months of observations, roof subsidence will range from 9.63 mm to 103.07 mm, and the dependence of the building roof deflection on time is established, which is mathematically expressed by the regression equation $w = 0.781 \cdot t2 - 13.312 \cdot t + 56.906$.

5. Recommendations have been developed for regular monitoring and additional strengthening of structures in seismically hazardous areas to prevent critical deformations, taking into account the influence of energy indicators of earth's surface displacement during the life of buildings; further geodetic observations of possible subsidence are required. The principle of predicting the state of engineering and industrial buildings and structures is aimed at monitoring the technical condition during operation and timely warning of changes in the

conditions of homogeneity of the modeled implementations and taking measures to preserve them for a long time and ensure their safety. The author's personal contribution consists of conducting high-precision geodetic measurements of deformation processes, developing an analytical method for predicting vertical displacements of load-bearing structures of buildings and structures.

The validity and reliability of scientific provisions and conclusions are confirmed by:

- the correct use of widely tested research methods and in conducting high-precision geodetic measurements.

- sufficient convergence of theoretical and experimental studies (reliability of 0.95, the maximum value of the variation coefficient does not exceed 20%), meeting the requirements of SNiP.

Scientific significance of the work

The dissertation proposes methods for improving the current scientific and technical task of conducting geodetic monitoring of deformation processes to ensure the stability and safety of buildings and structures.

The practical significance of the work lies in establishing in the process of research the patterns of changes in vertical subsidence of load-bearing structures of the building, installed taking into account the complex structure of the soil at the base, the accumulation of statistical loads on load-bearing structures due to numerous and minor underground seismic shocks. This allows for making management decisions to ensure the safe operation of residential and underground buildings.

Testing of work.

The main ideas and results of the research work were reported at conferences: International scientific and practical conference "Satpayev Readings" (Almaty, KazNITU, 2021, 2022); International Scientific School of Young Scientists and Specialists "Problems of Subsoil Development in the 21st Century Through the Eyes of Young People" (Moscow, 2021), International Scientific School "Problems and Prospects of Integrated Development and Conservation of the Earth's Subsoil" (Moscow, 2022), International Scientific and Practical Conference dedicated to the 115th anniversary of Corresponding Member of the Kazakh SSR Academy of Sciences A.Zh. Mashanov and the 100th anniversary of Academician of the Kazakh SSR Academy of Sciences Zh.S. Erzhanov (Almaty, KazNITU, 2022); International Scientific and Technical Conference "Development of the Mining and Metallurgical Complex of Kazakhstan for the Implementation of the State Investment Project" (Almaty, KazNITU, 2022). The dissertation was completed using a robotic electronic total station with software in the Geomechanics and Geotechnology laboratory of the Innovative Engineering Center.

Publication of the work. On the topic of the dissertation, 11 scientific works have been published, including: 1 article in a journal included in the Scopus database (percentile - 51%), 3 articles in journals recommended by the Committee for Quality Assurance in Education of the Ministry of Education of the Republic of Kazakhstan, 6 articles in the materials of international scientific and practical

conferences. Structure and volume of work. The dissertation work consists of an introduction, four chapters, a conclusion and a list of references containing 107 titles, is presented on 91 pages of computer text, contains 8 tables, 61 figures.