ANNOTATION

Dissertation for the Degree of Doctor of Philosophy (PhD) in the Specialty "6D071100 – Geodesy" by Diana Suleimenova on the topic: "Investigation of Deformations of High-Rise Buildings Using Geodetic Methods and Automated Equipment"

Relevance of the Research Topic

Modern construction of high-rise buildings and structures requires special attention to issues of ensuring the safety and stability of building structures during their operation. Deformation processes caused by natural and anthropogenic factors can lead to changes in the geometric parameters of buildings, a decrease in their load-bearing capacity, and the creation of potential risks to human life and health.

The relevance of this research is determined by the need for a comprehensive approach to the study and improvement of geodetic monitoring technologies, especially under conditions of urban development and high-rise construction.

Geodetic monitoring of deformations in high-rise buildings and structures located in seismic zones involves a wide range of measures aimed primarily at ensuring the safety and stability of the structures. Geodetic monitoring includes regular observations of subsidence, tilts, deformations, and other geometric parameters in order to identify possible problems in a timely manner and take preventive measures at an early stage to avoid emergency situations.

Modern anthropogenic and technogenic structures are characterized by large scale and high requirements for stability at all stages of their implementation. Solving this problem requires the introduction of automated geodetic deformation monitoring systems (AGDMS) based on advanced geodetic hardware and software complexes and technologies, such as satellite GNSS, electronic tacheometry, high-precision digital inclinometers, geotechnical accelerometer sensors, strain gauges, and other devices integrated into a unified monitoring system for structural stability.

The use of geodetic methods and automated observation systems makes it possible to significantly improve the accuracy, efficiency, and reliability of the obtained data. To ensure the stability and safety of buildings during construction and operation, it is necessary to introduce automated geodetic deformation monitoring systems (AGDMS) that employ advanced technologies such as satellite GNSS, electronic tacheometry, and high-precision inclinometers. In Almaty alone, there are more than 300 unique structures that require special attention to safety issues.

Constructed and operated facilities are subject to deformations caused by various factors such as climate, seismic activity, unplanned surface and underground urban development, static and dynamic technological loads, as well as geological and tectonic processes. The most effective approach to the timely detection of deformations in technogenic structures is the use of AGDMS. The results of monitoring obtained through such systems serve as a basis for decision-making regarding major repairs, suspension of operation or production, and even evacuation of people. Such systems should be provided at the stage of technical design development for construction, taking into account all conditions of use and

operation, including the monitoring of all types of deformations in a comprehensive manner.

Traditional geodetic monitoring methods, such as microtriangulation and hydroleveling, although highly accurate, are labor-intensive and time-consuming. Modern technologies, such as robotic total stations and digital inclinometers, allow continuous monitoring with high accuracy and efficiency. These systems ensure real-time deformation control, which significantly enhances the safety and stability of engineering structures.

Modern AGDMS technologies, such as satellite GNSS and robotic total stations, provide the necessary accuracy and responsiveness for deformation monitoring. The successful implementation of these technologies in practice highlights the relevance of this research, which aims to improve the efficiency and reliability of the operation of unique engineering structures through the use of automated geodetic monitoring systems.

Automated geodetic deformation monitoring systems play a key role in the overall system for ensuring the safety of construction and operation of buildings and structures, especially for those classified as particularly hazardous, technically complex, and unique.

To ensure the systematization, storage, and analysis of information obtained during geodetic observations of the Al-Farabi Kazakh National University (KazNU) building, a specialized database was developed. This database serves as a foundation for monitoring, subsequent analysis of deformation processes, and preparation of reporting documentation.

The introduction of modern measurement technologies, including GLONASS/GPS satellite receivers, automated electronic total stations, and digital inclinometers, provides high monitoring accuracy while significantly optimizing labor resources. Automation of data collection, processing, and analysis allows for obtaining up-to-date deformation information in near real-time.

Purpose of the Dissertation Research

The purpose of this dissertation is to substantiate methods for monitoring deformation processes during the operation of high-rise buildings and structures based on the use of modern automated geodetic instruments.

Object of the Research

The object of the research is the high-rise building of the Rectorate of Al-Farabi Kazakh National University (KazNU) located in Almaty.

Subject of the Research

The subject of the research is an integrated system for collecting and processing spatial information in order to identify deformations of high-rise buildings during operation using automated high-precision geodetic instruments.

Main Research Objectives:

• to analyze existing methods for monitoring deformations of high-rise buildings and structures based on automated geodetic systems;

• to study the current deformation state of the research object — the Rectorate building of Al-Farabi Kazakh National University (KazNU);

• to apply geodetic deformation control methods in field conditions using GPS technologies, the Rigel scanner, as well as electronic and high-precision digital instruments;

• to substantiate and develop an algorithm for evaluating the results of geodetic measurements of building and structure deformations.

Research Methods:

• Analysis of theoretical data on deformations of high-rise buildings using modern geodetic instruments;

• Field surveys considering climatic conditions and the operational capabilities of geodetic equipment for deformation detection;

• Creation of 3D graphical models of the objects to identify deformation accuracy;

• Processing of geodetic measurement results using mathematical statistics and computer technologies.

Scientific statements submitted for defense:

- the spatial–temporal deformations of the high-rise building of Al-Farabi Kazakh National University are manifested as a linear dependence on the structural parameters and foundation properties, recorded by an automated geodetic monitoring system based on a complex of modern observation methods.

- the algorithm for processing the results of deformation measurements of the high-rise building is developed based on a comparison of laser scanning data, UAV surveying, and ground-based geodetic measurements using the differences in averaged coordinates, ensuring a quantitative assessment of the measurement results.

- the assessment of deformations of the high-rise structure is formed based on the algorithm for processing measurement results, ensuring the reliability and efficiency of determining the stress–strain state of the structure.

Scientific Significance of the Research

The scientific significance of this work lies in the development and implementation of a comprehensive geodetic monitoring system for deformations in high-rise buildings and structures using modern technologies for collecting and processing spatiotemporal measurement data.

Theoretical and Practical Significance of the Research

The main results of the research and practical work consist in substantiating an optimal algorithm for designing the structure, content, and implementation process of an automated geodetic deformation monitoring system for high-rise engineering   structures.
The implementation of the obtained results ensures the safe operation of high-rise buildings and structures, while the use of AGDMS (Automated Geodetic Deformation Monitoring Systems) enhances the accuracy and efficiency of monitoring studies in real-time mode.

Scientific Provisions Submitted for Defense

• The spatial–temporal deformations of the Al-Farabi Kazakh National University high-rise building identified through the use of an automated geodetic

monitoring system, consisting of a set of methods, allow the detection of systematic measurement errors in structural elements and provide timely forecasts of structural stability;

- The developed algorithm for processing measurement results provides a quantitative assessment of deformations in high-rise structures by comparing laser scanning data, UAV measurements, and ground-based methods using averaged coordinate differences;

- The evaluation of deformations in high-rise structures is feasible and effective when developing an algorithm for processing measurement results based on high-precision instrumental and geodetic surveys.

Validity and Reliability of the Results

The validity and reliability of the results are confirmed by field observations of the deformation processes of high-rise buildings, a large volume of field measurements, the consistency between theoretical and practical studies, and the successful implementation of the proposed recommendations in real operational conditions.

Implementation of the Research Results

The main provisions of the dissertation can be recommended for use in geodetic monitoring of deformations in buildings and structures located in seismic and technogenic zones.

Author's Personal Contribution

The author personally analyzed existing deformation monitoring methods in high-rise buildings and structures using automated systems, studied the current state of deformations in the high-rise building of Al-Farabi Kazakh National University (KazNU), developed an algorithm for evaluating geodetic deformation measurement results, and created a database of the research outcomes.

Publications and Approbation of the Research

Two papers related to the dissertation topic have been published in peer-reviewed journals indexed in the Scopus and Web of Science databases:

- *"The Geodetic Monitoring of Deformations of a High-Rise Building Using Ground-Based Laser Scanning Technology," Journal of Applied Engineering Science*, Institute for Research and Design in Industry, Belgrade, Serbia;

- *"Advanced Topographic-Geodetic Surveys and GNSS Methodologies in Urban Planning," Journal of Applied Geodesy*, University of New South Wales, Australia.

Additionally, four papers have been published in journals recommended by the Committee for Quality Assurance in Science and Higher Education, and four papers have been published in international conference proceedings.

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