ANNOTATION

Dissertation for the degree of Doctor of Philosophy (Ph.D.) in the specialty «6D071100 – Geodesy»

Sarsembekova Zeinep

«Justification of the parameters of the high-altitude planned position of road bridges, taking into account the regional characteristics of the territory»

The efficient functioning and sustainable development of the transport infrastructure located across the vast territory of the Republic of Kazakhstan represent one of the key factors determining the dynamics of the national economy. However, the country's natural, geographical, and engineering – geological conditions-such as complex geological and geomorphological structures, frequent seismic activity, sharply continental and arid climate, as well as the insufficient implementation of modern logistics and road construction technologies – have a significant impact on the reliability of infrastructure facilities, particularly bridge structures.

In this context, based on the Presidential Decree of the Republic of Kazakhstan dated January 15, 2020, No. 247 On the State Program for Infrastructure Development «Nurly Zhol' for 2020–2025», and the strategic program «Master Plan of the City Transport Framework until 2030» published on the official website of the Department of Urban Mobility of the Almaty City Akimat, a series of studies was conducted. Taking into account regional characteristics, the altitude and plan parameters of highway bridges were developed and substantiated, deformation monitoring of urban bridge structures was carried out, and comprehensive geodetic schemes for their prevention and control were proposed.

Relevance of the Research. Bridge structures are complex and strategically important elements of transport networks. The processes of their design, construction, and subsequent technical condition control require specialized engineering and geodetic support. In seismically active regions, the implementation of high-precision geodetic monitoring for the detection and prediction of deformations in bridge structures is one of the most urgent tasks of modern transport construction.

In this regard, the correct organization of plan-altitude geodetic networks plays a crucial role at all stages of bridge construction. Such systems ensure the accurate determination of the position of structural elements, while installation and control-measurement operations are performed with a high degree of reliability.

Furthermore, to ensure the long-term and safe operation of bridges, the geodetic observation system must be designed considering specific regional characteristics – such as terrain relief, soil properties, climatic conditions, and seismic activity.

Accordingly, this dissertation is devoted to the scientific justification of plan-altitude parameters of highway bridges, considering regional geological and seismic conditions, as well as to the development of efficient organization methods for reference geodetic networks used in the construction and operation of bridge structures.

The conducted research is aimed at improving the reliability and technical safety of bridges and ensuring the timely detection of deformations, thereby contributing to the overall sustainability and safety of the national transport infrastructure.

Object of the research. Reinforced concrete highway bridges of various design types operating under complex geodynamic conditions.

Subject of the research. The process of substantiating plan-altitude parameters of highway bridges in determining their deformations by geodetic methods, taking into account regional seismic and geodynamic features.

Research Methods. The research employs advanced computational approaches for coordinate adjustment using the correlation method and weighting coefficients in constructing plan-altitude geodetic networks applied for monitoring bridge deformations during construction and operation of road crossings and interchanges.

A comprehensive analysis of instrumental and measurement methods used for monitoring and testing bridge deformations was conducted. The methodology also included a systematic analysis of scientific sources and practical experience in the field. The obtained statistical data were processed, theoretically substantiated, and subjected to practical analysis, leading to scientifically grounded conclusions and recommendations.

Purpose and Objectives. The purpose of the research is to develop and scientifically substantiate geodetic support methods for determining the plan-altitude position of highway bridges, taking into account regional geodynamic characteristics.

To achieve this purpose, the following research objectives were defined:

1. To analyze modern geodetic methods used in the construction of highway bridges and develop an adjustment scheme for the plan-altitude geodetic network.

2. Based on an assessment of regional geodynamic features, to justify the structure of the plan-altitude geodetic network intended for monitoring the condition of bridge structures.

3. To conduct experimental geodetic observations on selected bridge sites and develop recommendations for implementing the proposed monitoring methodology in bridge operation practices within regions of increased geodynamic activity.

Scientific Novelty. The scientific novelty of the dissertation is defined by the following results:

– A new methodology has been developed for constructing plan-altitude geodetic networks for monitoring highway bridge deformations, taking into account the seismic and geodynamic characteristics of the region.

– An integrated measuring system has been proposed to assess the technical condition of bridge structures through long-term geodetic monitoring, based on the combined use of satellite (GNSS), total station, and leveling observations.
– The coordinate adjustment algorithm was improved using the correlation method and weighting coefficients, which significantly increased the accuracy of deformation determination.
– Experimental studies examined the stress–strain state of reinforced concrete bridge spans under test loads and determined effective parameters for safe operation in complex geodynamic environments.
– Based on an analysis of the settlement dynamics of bridge piers, patterns of regional deformation processes were identified, and requirements for the periodicity of geodetic observations were substantiated.
– Using the «OPORA_X» software package, an engineering analysis of the influence of seismic loads on the stability and durability of highway bridge piers was performed.

Scientific Significance. The scientific significance of the research lies in the development and justification of a prospective approach to constructing plan-altitude geodetic networks adapted to the operational conditions of reinforced concrete highway bridges located in regions with high geodynamic activity. The study provides a theoretical and methodological basis for improving geodetic monitoring systems of bridge structures, considering regional features.

Practical Significance. The practical significance of the study lies in the applicability of the developed methods and technologies for the construction and maintenance of highway bridges in geodynamically active regions. The obtained results can be used for organizing geodetic monitoring, designing reference networks, and ensuring the reliability of bridge structures in seismically hazardous zones.

Main Scientific Provisions Submitted for Defense:

– The accuracy of geodetic support for highway bridge construction depends on the quality and integration of electronic and satellite measurement methods and the precision of data processing.
– The evaluation of regional geodynamic processes directly affects the accuracy and structure of the plan-altitude geodetic network intended for bridge condition monitoring.
– Based on experimental geodetic observations, a technological methodology for geodetic monitoring during bridge operation has been developed and supported by scientifically grounded recommendations for its practical implementation.

Validity and Reliability of the Research Results.

The reliability and scientific validity of the results are confirmed by an extensive set of theoretical and experimental studies conducted under field conditions since 2019. The research is based on modern scientific and technological achievements in the fields of geodesy and geodynamics, focused on geodetic support for the operation of highway bridges.

The study covers the design and analysis of geodetic networks, the assessment of measurement errors, and the substantiation of deformation control methods. Furthermore, the integration of satellite and local coordinate systems was developed, and the geodynamic stability of a specific bridge structure was evaluated.

The obtained results confirm the applied and practical significance of the research, ensuring the reliability and accuracy of the scientific conclusions.

Practical Implementation of the Results. The results of the research are recommended for application in the operation and technical condition monitoring of highway bridges in the Republic of Kazakhstan, considering regional geodynamic characteristics.

Author's Contribution. The author personally formulated the research goals and objectives, developed the theoretical foundations for assessing the geodynamic safety of bridge structures, and independently summarized and analyzed the results across all sections of the dissertation.

The author selected source materials and developed the methodology for constructing plan-altitude geodetic reference networks for the construction and operation of reinforced concrete highway bridges. Field geodetic observations were carried out under real operational conditions on the bridge crossing at the intersection of Raiymbek Avenue and Momyshuly Street in Almaty. The author collected, processed, and analyzed the obtained data, organized experimental geodetic observations, developed a computational algorithm, and determined geodynamic safety indicators. The results formed the basis for assessing the structural stability of bridges under regional geodynamic activity and were implemented in the monitoring system.

Approbation of the Research Results. 14 scientific papers have been published on the topic of the dissertation, including: 4 articles in peer-reviewed journals indexed in Scopus and Web of Science databases; 5 articles in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan; 5 papers in the proceedings of international scientific and practical conferences.

An act confirming the implementation of the research results into practice has been obtained.

Structure and Volume of the Dissertation

The dissertation consists of an introduction, four chapters, a conclusion, a list of references, and appendices.

Chapter 1 presents an overview of the history of bridge construction development worldwide and in the Republic of Kazakhstan, analyzing the evolution of engineering achievements and structural innovations. It also characterizes the structural and operational properties of highway bridges, their classification, and provides the results of studies on the technical condition of bridges in Almaty.

Chapter 2 examines the performance of modern bridge structures under intense anthropogenic loads and geological influences, substantiating the need for applying engineering geodynamics principles and systematic technical monitoring. Particular attention is given to high-precision geodetic methods, satellite (GNSS) measurements, laser scanning, and automated sensor systems enabling real-time monitoring of stress-strain states and early detection of damage indicators.

Chapter 3 presents the results of technical and dynamic observations of bridge crossings, including load-bearing capacity tests, deformation analysis of reinforced concrete elements, and their temporal behavior during operation.

Chapter 4 develops and substantiates a methodology for constructing plan-altitude geodetic networks for bridge monitoring. It demonstrates that the combined use of satellite and traditional geodetic methods yields optimal results under complex geodynamic conditions. The coordinate adjustment algorithm was enhanced using correlation methods and weighting coefficients, significantly improving the accuracy and reliability of results. Geodetic observations confirmed the efficiency and stability of the proposed methodology in seismically active regions such as Almaty.

The dissertation comprises 124 pages of computer-typed text, including 57 figures, 23 tables, a conclusion, 169 references and 6 appendices.