ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD) in the field of training: 8D071 – “Engineering and Engineering Sciences” educational program: 8D07102 – “Transport, Transport Equipment and Technologies”

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DESIGN AND CALCULATION OF THE RUNNING GEAR OF A MOBILE OVERPASS

Relevance of the dissertation. The dissertation was carried out within the framework of the implementation of the state priorities of the Republic of Kazakhstan reflected in the National Project "Strong Regions - Driver of the Country’s Development" (Resolution of the Government of the Republic of Kazakhstan No. 729 dated 12.10.2021), the Concept for the Development of the Transport and Logistics Potential of the Republic of Kazakhstan until 2030 (Resolution of the Government of the Republic of Kazakhstan No. 1116 dated 30.12.2022), and the Concept for the Development of Housing and Communal Infrastructure of the Republic of Kazakhstan for 2023–2029 (Resolution of the Government of the Republic of Kazakhstan No. 736 dated September 23, 2022). These program documents provide for the modernization of urban utility networks, improvement of the capacity of the street and road network, reduction of traffic congestion, and implementation of engineering solutions that ensure the stability of urban infrastructure during repair works.

The research was also carried out within the framework of grant project AP23487832 "Development of the Design and Calculation of a Mobile Overpass" under Agreement No. 258/GF24-26 dated 09.09.2024.

In dense urban development, the laying, repair, and replacement of underground utility lines (heating mains, water pipelines, sewerage systems, and electrical networks) are inevitably associated with opening the carriageway and partially or fully closing traffic. Such works lead to a significant decrease in the capacity of the street and road network, the formation of congestion, increased travel time, higher fuel consumption, increased exhaust emissions, and a higher accident rate in the roadwork zone.

This problem is especially acute in central urban areas, where transport infrastructure operates at the limit of its capacity and there are no reserve routes for redistributing traffic flows.

Traditional methods of traffic management during repair works, such as arranging detours, reversible traffic lanes, optimizing traffic light control, and using intelligent transport systems, only partially compensate for the consequences of road closures. These measures do not eliminate the main problem of the physical limitation of road capacity and the inability to ensure continuity of the traffic flow.

Under these conditions, the use of temporary overpasses installed directly above the work zone becomes particularly relevant. Such structures make it possible to maintain traffic without changing routes and without reducing road capacity, which significantly reduces negative transport, economic, and environmental consequences.

Thus, the development and study of mobile overpasses intended for operation during utility and road works is a relevant scientific and technical task aimed at improving the resilience of urban transport infrastructure.

In previous studies by A.A. Ganyukov (dissertation "Development of the Design and Calculation of a Mobile Overpass Used in the Repair of Urban Utility Networks"), a mobile overpass design was proposed, representing a single-span metal truss structure intended for the temporary organization of traffic over emergency and repair sections of roads.

The overpass structure is designed as a spatial frame consisting of longitudinal and diagonal bracing elements that provide high spatial rigidity, uniform distribution of loads over the span structure, and structural stability under moving loads.

A key feature of the design, which fundamentally distinguishes it from known temporary bridges and overpasses, is the presence of its own wheeled undercarriage, by means of which the overpass is transported to the installation site on its own axle base using a towing vehicle. After delivery, it is moved over the trench and transferred from the "transport mode" to the "bridge mode" by lifting the wheels and lowering the load-bearing structure onto the supports.

Thus, the mobile overpass was considered as an integrated engineering system in which the undercarriage was studied in terms of the strength, stiffness, and dynamics of the front and rear axle frames as elements of the overall metal structure. Static and dynamic calculations were performed, the influence of natural frequencies was studied, and the design parameters of the frames were justified.

However, in these studies, the undercarriage design was not considered as an independent engineering subsystem that determines the mobility, deployability, operational safety, and adaptability of the overpass to dense urban conditions. In particular, the issues of the kinematics of axle and carriage movement during launching, fixation and self-positioning mechanisms, maneuverability in confined spaces, the influence of dimensions and moving elements on driver visibility, as well as a methodology for selecting a rational undercarriage scheme taking into account real operating requirements, were not considered. A systematic analysis of possible undercarriage development options was also not conducted, and there is no engineering methodology for calculating an undercarriage of this type. In this regard, studies aimed at developing the design and calculation methodology for the undercarriage of a mobile overpass are relevant.

The design of the proposed overpass is novel and sets increased requirements not only for the span structure but also for the undercarriage design.

The main idea is the possibility of improving the operational efficiency of a mobile overpass through the development of a movable structure and the design calculation of the mobile overpass undercarriage.

The purpose of the research is to obtain relationships that enable the development of the structure and an engineering methodology for calculating the undercarriage of a mobile overpass.

To achieve the stated purpose, the following **tasks:**

- analysis of the application of modular and mobile overpasses and their designs.
- justification of the need to develop a new undercarriage for the overpass;

- analysis of undercarriage designs of vehicles;
- morphological analysis and synthesis of possible undercarriage designs and selection of the most promising option from the obtained set according to the weighted criteria of reliability, cross-country capability, mass, and cost;
- modeling of the overpass operation in the SolidWorks software environment;
- development of overpass drawings and creation of 3D models;
- analysis of deformations, stresses, and the structural strength margin of the overpass;
- development of a structural solution for the overpass based on modeling results;
- development and manufacture of an experimental stand, conducting experiments, and processing the obtained results;
- establishment, using the methods of similarity theory and dimensional analysis, of dimensionless criteria that allow the obtained results to be transferred to structures of other sizes;
- development of a methodology for calculating the overpass undercarriage and implementation of the research results.

Research methods. The study employed methods of morphological analysis and synthesis of undercarriage design variants, finite element modeling in the SolidWorks software environment, methods of similarity theory and dimensional analysis, engineering calculations, experimental research, and result processing methods.

Experimental studies were carried out on the developed mobile overpass stand using methods of model experimentation and measurement of loads and deformations. The results were processed using regression analysis, similarity theory and dimensional analysis, as well as methods for the technical and economic assessment of the effectiveness of using a mobile overpass.

The scientific novelty of the research lies in obtaining dependencies that describe the operation of a mobile overpass with a movable undercarriage and provide for its calculation and design taking into account transportation, positioning, and stability conditions in the working position.

The scientific novelty is specified as follows:

- For the first time, dimensionless relationships have been derived in the form of a system of similarity criteria that establish a relationship between the inertial, elastic, damping, and load parameters of a mobile overpass, making it possible to quantitatively assess its operating modes and ensuring the transfer of research results to a full-scale structure;
- a set of dependencies has been obtained which makes it possible to calculate the undercarriage of a mobile overpass in transport, working, and fixation modes.

Scientific provisions submitted for defense:

- a mobile overpass structure with a movable undercarriage providing transportation, positioning, and stability in the operating position;
- the results of morphological analysis and synthesis of undercarriage variants, which made it possible to justify a rational structural solution according to the criteria of reliability, cross-country capability, mass, and operational suitability;
- calculation dependencies and finite element models describing the stress-strain state and stability of the mobile overpass structure and its undercarriage;

- regression relationships establishing the connection between loading conditions and deflections of the overpass structure, obtained through processing the results of experimental studies and calculations;

- dimensionless similarity criteria that allow the research results and experiments to be transferred to full-scale mobile overpass structures of various sizes and operating conditions;

- a methodology for the calculation and design of the undercarriage of a mobile overpass;

- the results of experimental studies on the operability of the mobile overpass structure, confirming the possibility of its practical application.

The author defends:

- the design of a mobile overpass with a new undercarriage scheme;
- dimensionless similarity criteria that determine the operating conditions of the structure;
- regression dependencies linking undercarriage parameters and loads in the structure;
- the results of experimental studies and the assessment of economic efficiency;
- a practical methodology for calculating and designing the undercarriage.

Objects of research - temporary bridge structures and overpasses.

Subject of research – the movable running gear of a mobile overpass.

Practical significance lies in the development of the mobile overpass design and an engineering methodology for calculating its undercarriage, which make it possible to ensure transportation, rapid deployment, and reliable operation of the structure under road and utility work conditions.

The research results can be used in the design and implementation of temporary overpasses to maintain continuous traffic flow, reduce congestion, decrease delay time and fuel consumption, and improve road traffic safety.

The developed structural solutions, calculation dependencies, and operational recommendations may be applied in the practice of design organizations, transport infrastructure management bodies, as well as enterprises carrying out utility, road repair, and construction and installation works.

The research results were transferred to GRADIENT PROJECT INSTITUTE LLP and introduced into the educational process of the course "Classification and Structure of Transport Equipment" for first-year bachelor’s students of the educational program 6B07106 – "Transport, Transport Equipment and Technologies".

The validity of the dissertation results is ensured by the results of modeling the overpass structure, the reproducibility of experimental results, the use of methods for processing experimental data, and the application of similarity criteria for transferring results to full-scale operating conditions.

All sections of the dissertation are presented in a methodological sequence and are logically interconnected. All tasks set by the dissertator have been solved, and the research objective has been achieved. The practical significance and scientific novelty correspond to the stated objective, tasks, and title of the dissertation.

Brief content.

In the first chapter of the dissertation, the current state of the problem of traffic congestion under road and utility work conditions is analyzed, and the relevance of developing mobile overpasses to ensure continuous traffic flow is substantiated. Existing organizational and technical solutions (reversible traffic, temporary detours, intelligent transport systems) are considered, and their advantages and limitations are identified. International experience in the use of temporary bridges and overpasses, as well as domestic developments in this area, is analyzed. The structural solutions of mobile and modular overpasses are analyzed, and the selection of a mobile overpass as the research object requiring further improvement, including the development and calculation of its undercarriage, is justified.

In the second chapter of the dissertation, undercarriage designs of vehicles are analyzed and the requirements for the undercarriage of a mobile overpass are determined. A morphological analysis and synthesis of possible structural solutions are carried out, on the basis of which the optimal configuration of the undercarriage is justified. A conceptual scheme of the mobile overpass undercarriage is developed, ensuring transportation, precise positioning, and fixation of the structure in the working position.

In the third chapter of the dissertation, the mobile overpass and its undercarriage are modeled in the SolidWorks software environment, and working drawings and a 3D model of the structure are developed. A finite element analysis of the stress-strain state, stability, and operability of the platform and load-bearing elements of the undercarriage under operational loads is performed. Based on the modeling results, the structural solution of the mobile overpass is justified, the strength, stiffness, and reliability of the structure are confirmed, as well as the correct operation of the movement and fixation mechanisms.

In the fourth chapter of the dissertation, an experimental stand of the mobile overpass at a scale of 1:4 is developed, intended to verify the operability and effectiveness of the undercarriage structural solutions. A methodology for conducting experimental studies is developed, and experiments are carried out on the experimental overpass stand with variation in the mass of the loaded trolley.

Based on the experimental data, regression dependencies are established, the adequacy of the calculation model and the operability of the overpass under operational loads are confirmed.

In the fifth chapter of the dissertation, issues of practical implementation of the research results are considered, and the transport, economic, and environmental efficiency of using a mobile overpass in an urban street and road network is assessed. A methodology for calculating the undercarriage is developed taking into account transport and working modes, as well as a system of similarity criteria that ensures the transfer of modeling and experimental results to full-scale operating conditions. Technical requirements and operating conditions for the undercarriage are formulated, and the possibility of introducing the developed mobile overpass into the practice of utility and road works is substantiated.

Personal contribution of the dissertator. The author analyzed existing designs of overpasses and undercarriages, justified the need to develop a new undercarriage design, and selected a rational variant based on morphological analysis and synthesis.

Modeling of the mobile overpass structure and its undercarriage was performed, 3D models and working drawings were developed, and the stress-strain state and stability of structural elements were analyzed. An experimental stand was developed and experimental studies were carried out, followed by processing of the results and regression analysis. Together with the scientific supervisors, an engineering calculation methodology and a system of similarity criteria were developed. A methodology for assessing transport and economic efficiency was also proposed, and practical recommendations for the design and operation of a mobile overpass were formulated.

Publication and approbation of the work. The main provisions of the dissertation have been published in two articles included in the Web of Science and Scopus databases, in two articles 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, in one certificate of state registration of rights to copyrighted objects, as well as in two abstracts of international scientific and practical conferences.

In the article "Optimization of Mobile Overpass Support Placement Considering the Nonlinear Properties of the Soil Foundation", published in the journal "Applied Sciences", indexed in the Scopus database (percentile 79, quartile Q2; 2026. Vol. 16, No. 4. Article 2075. https://doi.org/10.3390/app16042075), the author's contribution consisted of analyzing scientific publications on the problems and causes of traffic congestion, studying international experience in the application of mobile overpasses and existing analogues, as well as writing and preparing the initial version of the article.

In the article "Development of the undercarriage of a Mobile Overpass for Operation During Repair Works in Dense Urban Areas", published in the journal "Applied Sciences", indexed in the Scopus database (percentile 79, quartile Q2; 2026. Vol. 16, No. 8. Article 3879. https://doi.org/10.3390/app16083879), the author's contribution included performing morphological analysis and synthesis of the mobile overpass undercarriage, developing the experimental stand of the mobile overpass, and preparing the plan and procedure for conducting experimental studies.

In the article "Justification of the effectiveness of developing and using a mobile overpass", published in the journal "Material and Mechanical Engineering Technology" (2026, No. 1. http://mmet.kstu.kz/download/articles/02042026022750_digest.pdf), the author's contribution consisted of substantiating the methodology for assessing transport, economic, and operational efficiency, performing calculations of the economic effect from implementing the mobile overpass, as well as discussing the obtained results and formulating the research conclusions.

In the article "Тарихтан қазіргі заманға дейін: көлік инфрақұрылымындағы мобильді жол өтпелерінің рөлі", published in the journal "Университет Еңбектері" (No. 2 (99), 2025, Section 3 "Construction. Transport". DOI: 10.52209/1609-1825_2025_2_196), the author's contribution consisted of analyzing scientific sources on the topic of mobile overpasses, considering the history of their development, classification, structural features, and modern application, systematizing international experience in their use, as well as substantiating the importance of mobile overpasses in the rapid restoration of traffic during emergencies and road repair works.

Structure and scope of the dissertation. The dissertation is presented on 197 pages of typed text, consists of designations and abbreviations, an introduction, 5 chapters, and a conclusion, and includes 113 figures, 27 tables, a list of 122 references, and 3 appendices.

The dissertation contains new scientifically substantiated results, the use of which ensures the solution of an important applied task - the development of the structure and calculation methodology for the undercarriage of a mobile overpass. Based on the results of the dissertation research, the following conclusions were obtained:

-an analysis of the causes of traffic congestion in large cities was conducted, showing that a significant part of congestion is formed in areas where road, коммунal, and emergency repair works are carried out.

-an analysis of global experience in the application of modular and mobile overpasses demonstrated the effectiveness of mobile overpasses under conditions of communal, road, and emergency repair works on the urban street and road network.

-the previously proposed design of the mobile overpass was analyzed. It was established that, despite the overall operability of the structure, the undercarriage does not fully ensure the required indicators of mobility, positioning accuracy, stability, and safety during transportation and operation, which justifies the need to develop its new structural solution.

-the analysis of vehicle undercarriage designs confirmed the expediency of using dependent suspensions, multi-axle and tandem schemes, as well as specialized fixation and positioning units adapted to the operating conditions of a mobile overpass;

-morphological analysis and synthesis of possible undercarriage designs of the mobile overpass were carried out, which made it possible to select the most promising structural solution based on a set of key operational and design criteria;

-a conceptual scheme of the overpass undercarriage was developed on the basis of a low-frame two-axle structure with movable axles, carriages, a movement mechanism along I-beam guides, a fixation system, and integrated subsystems that ensure the transfer of the overpass from the transport position to the working position and its stability during operation;

-drawings of the main elements of the overpass and undercarriage were developed in the SolidWorks software environment, and a complete three-dimensional model of the structure was created, including the load-bearing platform, frame, axles, suspension, carriages, and transformation mechanisms;

-the operation of the mobile overpass was modeled in the SolidWorks software environment, and the results showed that a truss scheme of the load-bearing platform is rational, providing high strength at a relatively low mass. The virtual assembly confirmed the absence of mutual intersections between structural elements and the correct operation of the movement and fixation mechanisms;

-analysis of the stress-strain state and strength margin showed sufficient strength and stiffness of the structure; it was established that the arising stresses and deformations do not exceed the permissible values, which confirms the validity of the adopted structural solution;

-based on the modeling results, a structural solution for the mobile overpass was developed, ensuring the necessary combination of strength, mobility, and manufacturability during operation in urban development conditions.

-an experimental stand of the mobile overpass was developed and manufactured. The stand includes a load-bearing platform, undercarriage, movable carriages, fixation mechanism, control system, light signaling, and elements of the braking system, which made it possible to ensure the transition from the calculation and modeling stage to experimental verification.

-the results of experimental studies on the stand confirmed the operability of the structure: uniform load distribution, absence of overloads, and elastic nature of deformations;

-based on similarity theory and dimensional analysis, a system of dimensionless criteria was developed, ensuring the transfer of results to structures of other sizes and scales;

-a methodology for calculating the overpass undercarriage was developed, taking into account transport and working operating modes, including the calculation of loads, main structural elements, drives, and fixators; it was shown that the proposed structural solution corresponds to transportation and operation conditions and can be used in the creation of mobile overpasses.

Thus, the tasks set in this dissertation have been fully achieved. The developed design of the mobile overpass undercarriage, the results of its modeling and experimental verification, the system of similarity criteria, and the proposed calculation methodology form a scientific and practical basis for the design, manufacture, and implementation of mobile overpasses intended to ensure continuous traffic flow under conditions of road, utility, and emergency restoration works.