A promising system of geodetic and coordinate ensuring for transport construction

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Abstract. Increasing the requirements for the quality and timing of transport construction, as well as ensuring the quality of the work carried out, requires the unified approaches to the information-control systems’ creation for coordinate support of construction and extended objects’ geometric parameters monitoring over a large territory with high accuracy. The article presents the development evolution of the transport construction technologies with the conclusions concerning the need for the integrated application of satellite navigation and remote sensing methods. The concept of building a four-level high-precision system of geodetic and coordinate support for the long transport facilities railway transport construction is presented. The presented monitoring system will ensure the compliance with the necessary requirements for the constructed objects’ accuracy in a single coordinate system.

Introduction
The transport infrastructure of the Russian Federation is a key link in the economy, ensuring the unity of its regions and industrial production in almost all spheres and industries. Railway transport is currently its main component.

The increase in traffic intensity, mass and speed of trains leads to increased loads on the railway transport infrastructure (railway, bridges, tunnels, etc.). Over the past 100 years, the average mass of a freight train has grown by almost 10 times (up to 4,000 tons gross). In addition, it should be noted that most of the existing railway lines and the lines under construction are located in the regions with difficult climatic conditions. The existing lines built at different times differ, both in construction methods and in the requirements for them. In particular, until 1900, railways were built in the absence of a single regulatory framework; later, the regulatory documents in the field of transport construction have changed more than 10 times.

The development and implementation of new technologies for the railway construction in Russia took place in several stages:
- manual labor stage (until the 1930s);
- stage of mechanization and machinization of work (since the 1930s);
- stage of the production processes automation (since the 1960s);
- the control systems’ computerization stage (since the 1980s);
- stage of geo-informatization of design, construction, reconstruction and repair processes (since the 1990s).
The stage of the high information technologies’ development and implementation in railway construction, which started in the 1990s, has so far developed according to the following cycle:
- the geographic information systems’ implementation (since the 1990s);
- space technologies of satellite navigation and remote sensing (since the 2000s);
- information modeling and digital models of the railway tracks (since the mid-2000s);
- creation of an integrated spatial data system for the railway transport (since 2010).

An integrated spatial data system implies the widespread use of modern information tools for managing and monitoring the transport construction processes based on high-precision coordinate methods for measuring the geometric parameters of the transport objects under construction.

The relevance of the research.
Globalization and informatization trends in the transport construction development show the need for mutual integration of information modeling technologies and aerospace monitoring tools in the geodetic and coordinate support systems of transport construction. A sufficient number of scientific publications has been devoted to this issue, both in Russia and abroad [1–9, etc.].

The aim of this work is to develop a promising information technology support system for the construction of long transport facilities (highways) using the advanced technologies for aerospace remote sensing and high-precision satellite navigation systems GLONASS / GPS.

To achieve this goal, the following main tasks are formulated:
1. To conduct a comprehensive analysis of the technical equipment existing system for geodetic and coordinate support for the tasks of transport construction, reconstruction and repair of long railway infrastructure.
2. To identify the main technical and technological problems in the construction, reconstruction and repair of the railway using the existing means of geodetic and coordinate support.
3. To form a multilevel model of geodetic and coordinate support for the construction, reconstruction and repair of the railway tracks using the advanced aerospace monitoring tools and high-precision satellite navigation systems GLONASS / GPS.

Methods and Methodology
Analyzing the emergencies circumstances on various sections of the railway (including the potentially hazardous ones), it can be concluded that the current system of geodetic and coordinate support for construction, reconstruction and repair cannot implement a number of functionalities that directly affect safety, such as:
- to evaluate the position and geometric parameters of the railway track and artificial structures in the complex;
- to operatively evaluate the managing construction object’s state (railway track and artificial structures) at all stages of its life cycle;
- to determine the place of a possible emergency on the basis of dynamic changes in geometric parameters.

The situation is complicated by the fact that the railway during construction is not a separate point, but an extended object that affects the entire ecosystem of the area where it is located. Large-scale interference in the natural nature of the landscape leads to the emergencies, both during construction and during the subsequent operation. The articles [10-12 and others] are devoted to a comprehensive solution of safety issues in construction. A unified scientific and technical approach to the formation of geodetic and coordinate support systems for the construction, reconstruction and repair of the railway track is required [10]. This approach consists in solving the complex technical and technological problems of the transport construction geodetic and coordinate support system by eliminating the causes of their occurrence (Table 1).

Table 1. Key technological problems of monitoring
| The key technological problems of the construction, reconstruction and repair of the railway | The main reasons for the lack of the construction technologies’ effectiveness for the long transport infrastructure facilities (railways) |
|---|---|
| Lack of a single integrating system for collecting and automated processing of the spatial information coming from the construction equipment, track building machines, travel measuring and diagnostic tools | - the impossibility of promptly detecting the discrepancies in the geometric parameters of the railway track to the design parameters in a single global coordinate system during construction, reconstruction and repair;  
- high error of coordinate reference of track building machines and track measuring complexes in the picket (linear) coordinate system;  
- the impossibility of using a single high-precision information model updated by the automated measuring and diagnostic tools at all stages of the railway track’s life cycle |
| Lack of a unified control system for the design parameters of the railway under construction, under reconstruction, under repair and maintenance | - current technologies and operating technical means do not allow to cover and control the geometric parameters of the railway track along the entire route with the necessary accuracy;  
- Assessment of the railway track’s condition and the adjacent infrastructure facilities (artificial structures) is carried out separately according to the individual design tasks and parameters |
| Lack of a single integrated operational system for monitoring and preventing emergencies at the stages of the life cycle (construction, reconstruction, repair and operation) of the railway | - monitoring of the potentially dangerous sections of the railway track is carried out locally by tracking the individual point parameters without integrating measurements into a single information system;  
- the impossibility of assessing the railway track’s condition and its adjacent territories in the complex for the highway length. |

The existing system of geodetic and coordinate support for the construction, reconstruction, repair and operation of the railway includes only two technological levels (Fig. 1) [10].
Figure 1. The current system of geodetic and coordinate support transport construction

The first level is comprised of reference networks and geodetic instruments, which are the means of local point control. The second level consists of track measuring complexes (track cars and track measuring trolleys of various designs) - the means of linear automated control. The technical means that make up the first and second levels do not allow building and updating a unified informational spatial model of the railway track due to the heterogeneity and discreteness of the information collected and processed.

To solve the technical, technological problems and functional limitations presented above, it is proposed to modernize the existing system of geodetic and coordinate support for the transport construction and expand its functionality by means of global monitoring and control - aerospace and ground-based remote sensing (Fig. 2) [10]. To ensure the unity and accuracy of coordinate information, high-precision satellite equipment for binding remote sensing data is used.
Summary
The geodetic and coordinate support developed (modernized) system’s implementation in transport construction will allow solving the key technical and technological problems of construction, reconstruction and repair of the railway track by implementing the following main technological capabilities:
1. Adaptive management of construction, reconstruction, repair and operation based on a single information model of the railway track for all the stages of its life cycle;
2. Comprehensive assessment of the railway track and artificial structures’ condition for compliance with the design parameters from the construction moment;
3. The ability to identify the emerging potentially dangerous phenomena during the construction phase of the railway track throughout the territory.

Figure 2. Perspective system of geodetic and coordinate support transport construction
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