FEATURES OF GEODETIC WORKS DURING ROAD CONSTRUCTION

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Abstract

The article considers the main aspects of geodetic works during the road construction. The importance of geodetic control for ensuring the accuracy of objects location, compliance with design parameters and the quality of construction work is determined. The analysis of regulatory legal acts governing geodetic surveys in the field of road construction is carried out. The methods of creating geodetic densification networks, constructing topographic plans and transferring the roadway to the site are described. Recommendations for improving the geodetic support of the construction process in order to increase the management efficiency and minimize the risks of road infrastructure operation are proposed.

Keywords: geodesy, road construction, geodetic control, topographic plan, densification network, executive survey.

Introduction

Geodetic works are an integral part of road construction, as they ensure accurate determination of coordinates and heights of objects, as well as control over the implementation of design decisions. Without proper geodetic support, the risks of deformation of road infrastructure increase significantly, which can lead to premature failure. The implementation of geodetic control allows minimizing risks, contributing to the quality of construction work and the durability of the facilities under construction. This article considers the basic principles of geodetic works, their regulatory and legal support and practical application during the r construction of highways. (LexStatus, 2025).

Road construction is an important element of infrastructure development that ensures efficient logistics, economic development, and population mobility. However, the lack of proper geodetic control can lead to violations of the geometric parameters of structures, which negatively affects their performance and road safety. Therefore, the performance of geodetic works is a critical factor that determines the success of construction and reliability of roads.

Research aim: analysing geodetic works performed during the construction of highways, identifying key regulatory acts governing this process, and developing recommendations for improving geodetic control at all stages of construction.

The following **objectives** have been set to achieve the aim:

1.To investigate methods of creating and improving geodetic densification networks.

2.To analyse the process of creating topographic plans and their importance for the design and construction of roads.

3.To evaluate modern methods of transferring the roadway to the site, taking into account the use of innovative geodetic instruments.

4.To consider the main aspects of geodetic quality control of work performed and to develop recommendations for its improvement.

Research object and methods

The object of the study is the M-01 Kyiv-Chernihiv-Novi Yarylovychi road. (AzVirt, 2025).

Methods. To achieve the set goal, various research methods were used. The abstract-logical approach was applied to study the concept of "types of geodetic work in road construction"; the comparative method was used to assess the effectiveness of different geodetic technologies and instruments; theoretical analysis of regulatory acts made it possible to identify the main requirements for geodetic work in road construction; the methods of analysis and synthesis were used to study the research subject and examine the issue of quality control; the graphical method was used to develop illustrations and cartographic materials that represent the object and the calculation of its elements; the use of mathematical modeling methods allowed for the analysis of measurement errors and the development of recommendations to improve the accuracy of geodetic work in highway construction.

Research results and discussion

Geodetic works are managed by a number of regulatory documents that set general requirements for geodetic surveys, design, construction and operation of highways. Among them are DBN A.2.1-1-2008, which defines the general requirements for engineering surveys, DBN B.1.3-2:2010, which establishes the standards for geodetic works in construction (DBN V.1.3-2:2010, 2010), and DBN B.2.3-4:2015, which regulates the process of designing and constructing roads. Correspondence to these regulations ensures that road construction meets modern requirements and quality standards.

Geodetic works are carried out for the purpose of constructing topographic maps and plans, as well as for solving engineering and geodetic tasks in the survey and construction of buildings. (Bilokrynytskyi, 2011).

In order to combine maps drawn for different areas of terrain into a general topographic map of a district, region or country, it is necessary that all measurements be drawn in the same coordinate system. A system of points fixed on the ground with permanent signs, for which the X, Y, H coordinates are determined with a given accuracy, forms a geodetic network. (Shaulskyi, 2012).

One of the key tasks of geodesy is to create a geodetic densification network that ensures the necessary measurement accuracy during construction.

The geodetic network is formed according to the principle of "from general to specific", which implies the initial creation of a sparse network with the highest possible accuracy, which is gradually supplemented by additional points with lower measurement accuracy. This allows detailed mapping of the area and accurate design solutions in the field. (Dmytriv, 2019).

Prior to the start of the works related to the densification networks, a set of geodetic points is created, improved and restored to ensure high accuracy of measurements during construction. According to the results of an international tender held by the State Road Agency of Ukraine "Ukravtodor", the overhaul of the highway M-01 Kyiv-Chernihiv-Novi Yarylovychi, with a total length of more than 80 km, was designed under the government program "Big Construction" (Fig.1).

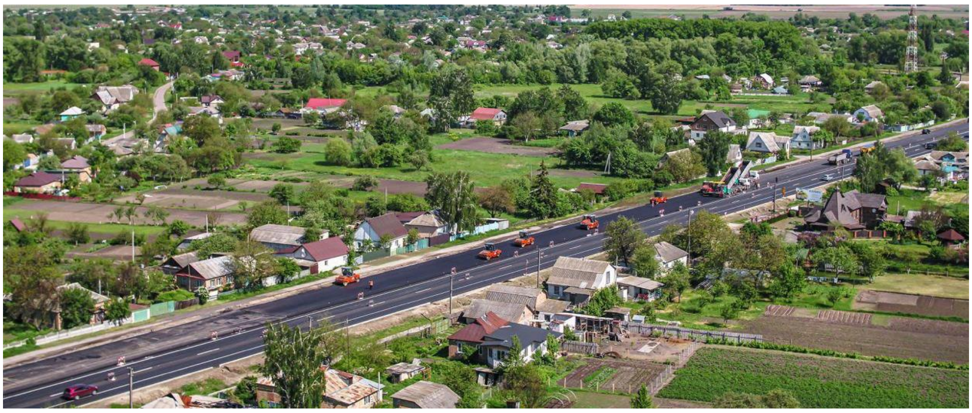

Figure 1. Construction works on the Kyiv-Chernihiv-Novi Yarylovychi road section

The main stages of these works are:

- Preparatory stage
- Field work
- Office work
- Commissioning and consolidation of points.

At the first preparatory stage, we analyse geodetic networks and the condition of points, study archival materials of cartographic and design data to determine the optimal location of new or restored points, and plan the location of densification points according to the accuracy requirements.

The next step is field work, where lost points are identified and restored. To do this, metal detectors, pitting or other methods are used to find old marks. If the old geodetic marks have been destroyed or lost, work is done to lay new marks. After the geodetic points are found and restored, they are fixed on the ground by concreting, installing markers or laying down reps, etc.

To determine the coordinates of new points, GPS tracking or classical geodetic measurements are performed, such as triangulation, polygonometry, and levelling. The last step is to measure horizontal angles and line lengths and check the accuracy of the data obtained. If necessary, geometric or trigonometric levelling of points is also performed to determine the heights of new or restored points.

Having completed the fieldwork stage, the next step is to carry out office work. This part includes processing the results of field measurements and their equalization, error analysis and data correction, and preparation of technical documentation (coordinate and elevation catalogues, point location diagrams, and progress reports).

After the necessary work is done to commission and fix the points, the points are marked and described, new points are entered into the geodetic database, and the required result is transferred to the customer or relevant institutions for further use. These works ensure the accuracy of geodetic measurements required for construction, avoid planning errors and create a reliable geodetic basis for further engineering works.

A topographic plan of an area is one of the most important results of geodetic work. Its creation is based on tacheometric survey data, which allows it to determine the terrain and the existing situation on the ground. The topographic plan is created using a coordinate grid, drawing points of theodolite course, determining the coordinates of rail points and drawing the situation according to the scale of 1:1000. (Main Administration of Geodesy, Cartography and Cadastre, 2001).

The obtained topographic materials are used for design and further control over the construction works. Before starting construction, it is necessary to transfer the design data of the roadway to the field.

The roadway consists of the following elements: roadway, roadside, slope and ditch (Fig. 2). For the removal of the roadbed in nature, transverse profiles are marked every 20-40 m along the axis (Fig. 3). A trough is excavated under the roadway, into which layers of artificial pavement are laid. In cross-section, the trough has a slope from the centre to the edges within 15-40 ppm (1.5-4.0%). Cross slopes are important for ensuring water drainage in one or two directions away from the road axis and are crucial for maintaining stability and safety when vehicles navigate curves. After road construction, a geodetic as-built survey is carried out. (Burkun, Zholobova, 2022).

On different sections of the road, it is possible to arrange embankments or excavations. Their marking on flat terrain is quite simple, while on slopes, it is necessary to take into account the natural slope. When designing a road, these slopes are taken into account by software. The main method of marking is using a free station with an electronic total station, which is used to measure horizontal and vertical angles, as well as distances. This is the most effective option for ensuring accuracy and speed compared to other technical instruments, which are more prone to errors in complex areas.

The use of automated geodetic control systems for construction equipment significantly reduces the amount of marking work, eliminates the traditional use of pegs and speeds up field work. (Bachyshyn, 2020).

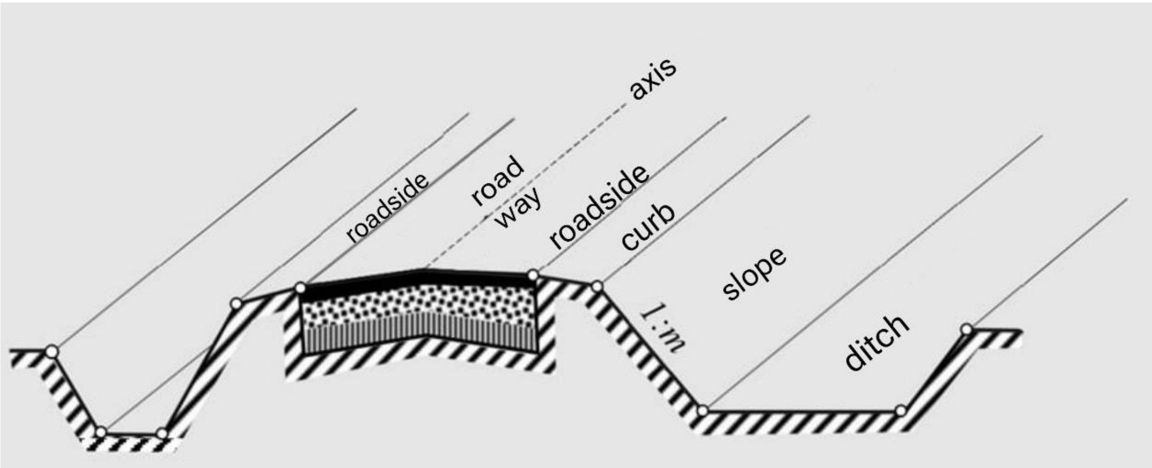

Figure 2. Roadbed

After completion of excavation works, the executive survey of each profile is carried out. Permissible deviations are:
- height of the edges of the subgrade ±5 cm;
- trough width ± 5 cm;
- transverse deflection slope ±0,005;
- longitudinal slope of the pits ±0,001.

Source: formed by the author

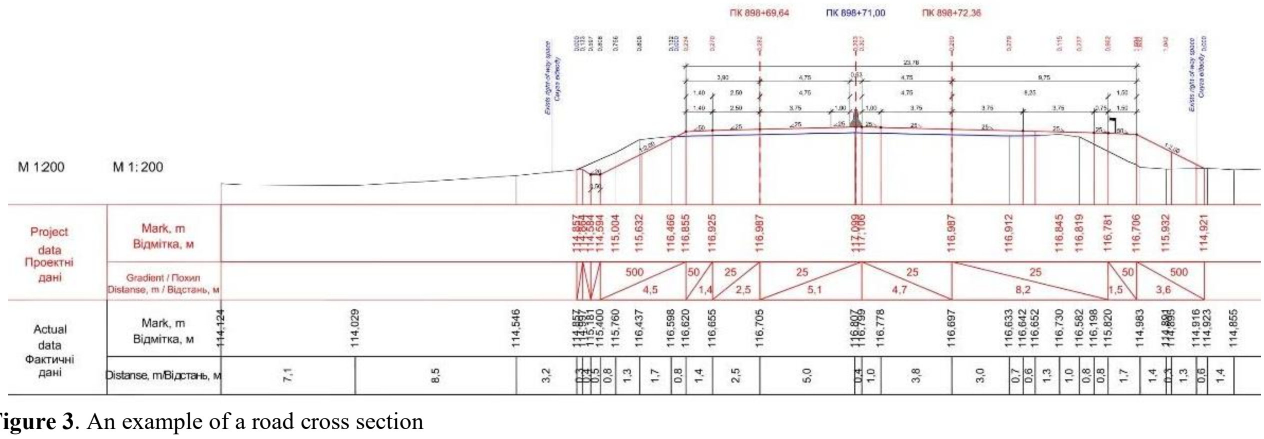

Figure 3. An example of a road cross section

This process involves the alignment of the road axis, marking of the main structural elements and control measurements. (Topograph, 2025). To ensure high accuracy of marking, modern geodetic instruments such as electronic total stations and GPS satellite systems are used. The use of automated geodetic control systems for construction equipment can reduce the labour intensity of the process and increase the accuracy of earthworks.

Timely quality control is key to successful construction, especially when it comes to infrastructure. Every stage of the building process must be thoroughly monitored to ensure structural reliability and long-term performance. Quality control in construction is carried out throughout the entire workflow. According to DBN V.2.3-4:2015, incoming inspection before starting earthwork construction requires verification of both the design and actual characteristics of soil types (grain composition, plasticity) and their condition (moisture, density) against national standards. This applies to materials from quarries, borrow pits, excavations, natural embankment bases, and transport structures.

During roadbed preparation, control parameters are applied to structural elements and work types as follows:

- Geodetic layout of the route – performed at intervals of no more than 100 meters and at the locations of transport structures. Up to 10% of measurements may deviate from the design values within ±50 mm; the rest must be within ±20 mm.
- Thickness of removed topsoil – at least three measurements per cross-section every 100 meters. Up to 10% of measurements may deviate by up to ±20% from design values; the rest must be within ±10%.
- Base soil density – at least one measurement per 1,000 m² of base, and at least one per shift, as well as after precipitation. Up to 10% of measurements may show a compaction coefficient lower than the design value by up to 0.02; the rest must meet or exceed the design standard.
- Base surface condition – monitored continuously; any deviation from regulatory requirements is not allowed.
- Cross slope of embankment base surface in non-draining soils – measured every 100 meters. Up to 10% of results may deviate from the design values by ±5‰; the rest must be within ±2‰. (DBN V.2.3-4:2015, 2015).

Geodetic control of an object can be carried out in two ways. The first involves measuring the parameters of individual elements and buildings using geodetic instruments, such as levels. The second way is to conduct an executive survey at each stage of construction.

During road construction, geodetic control covers the following aspects:

- Alignment of the roadbed in plan, which is checked through selective measurements of certain sections and angles, including the marking and verification of horizontal curves.
- Longitudinal profile of the route, monitored through leveling at all profile breakpoints.
- Cross-sections, determined by leveling along cross lines to verify the design elevations of the roadbed axis, road edges, carriageway edges, shoulders, ditch bottoms, channels, and borrow pits, as well as for setting the slopes of the roadbed.
- Width of the roadbed and carriageway, as well as the dimensions of ditches and berms.

Control at the stages of roadbed layout in plan and profile, as well as the geometric parameters of embankments and cuts, is carried out during both operational and acceptance inspections in accordance with the requirements of DSTU-NB V.2.3-32 “Guidelines for the Construction of Roadbed for Highways” (Dorozhko, Yankin, 2022).

The main control methods include measuring the parameters of road pavement elements, performing site surveys, checking correspondence to design data and recording the results in special logs. The as-built survey is carried out after each stage of construction and before the road is put into operation, which allows to assess the compliance of the work performed with the design solutions.

It’s important to consider that roads are constantly exposed to the damaging effects of precipitation, and their strength and quality can truly be assessed only after the first winter, when prolonged moisture may damage the surface (Geodesy, geology, topography from certified specialists Guild Engineering, 2025). This highlights the need for quality control not only during construction but also after completion—throughout a defined period of operation—to evaluate the durability of the pavement and address any defects in time.

Deviations of actual results from the design data should be within acceptable limits, according to the recommendations. Permissible errors when comparing data should be minimal - no more than 0.2, regardless of the unit of measurement.

The best option is to have the surveying and control performed by one company, which ensures accuracy and consistency. The control procedures should correspond to the marks made during the main geodetic works. The results of the geodetic control are recorded in a special journal, and based on the results of the survey, executive schemes or drawings are developed. This is especially important for underground utilities and other engineering buildings. (Geodez, 2025).

According to the article by A.H. Batrakov, Ye.V. Dorozhko, E.V. Zakharov, and O.M. Klyuka (2022), special attention should be paid to instruments and the requirements for them during engineering and geodetic work, as the accuracy and quality of the results directly affect the correctness of the task execution. Engineering and geodetic tasks must be carried out using modern surveying equipment and instruments that have passed metrological verification in accordance with the Law of Ukraine "On Metrology and Metrological Activity" and other regulatory and technical documents in force in Ukraine. Surveying equipment and instruments used during field investigations must be checked for errors at all stages of the work. They must ensure high measurement accuracy in line with the client’s technical specifications.

For conducting geodetic work, the following equipment is typically used:

- Linear measurements are performed using string, optical, and laser rangefinders, electronic distance meters (EDMs), radio rangefinders, as well as steel tapes, measuring tapes, and wires.
- Angle measurements are carried out using theodolites, electronic theodolites, and total stations, with the choice depending on the required measurement accuracy.
- Height measurements (levelling) are performed using optical, electronic, or laser levels.
- Point cloud data is collected using scanning total stations and laser scanners.

One of the main challenges in modern road construction is the use of outdated software, which has significant shortcomings:

1.Most traditional programs used for geodetic control (such as AutoCAD, Credo, GeoniCS) support only basic calculations.

2.Low accuracy and a high risk of human error, combined with the lack of automated checks and error correction mechanisms in older software, lead to deviations in measurements.

3.Traditional systems do not support 3D data representation, making it harder to understand terrain and design solutions.

4.Outdated systems require more time to analyze data and prepare project documentation, slowing down the pace of work and affecting deadlines.

Today, implementing BIM (Building Information Modeling) technologies has become highly relevant. BIM allows for more effective management of a structure's life cycle, including planning for maintenance, repair, and renovation. BIM is a system of digital 3D models that includes a wide range of data, enabling users to plan, design, construct, and manage a project digitally. With this system, users can create a personalized project by adding all necessary objects and elements and click on any object to get full details about its characteristics, including standards and manufacturer info. This is especially useful in the planning and construction phases.(Zholobova, Brumm, 2022)

Using BIM in construction offers the following benefits:

- creation of detailed digital replicas of structures;
- improved accuracy and construction efficiency;
- avoidance of errors in budget planning;
- shorter project design and construction times;
- reduced costs through accurate forecasting of required resources.(Arsenieva, 2022; Zholobova, Brumm, 2022).

In geodetic work, BIM brings additional advantages:

- the ability to perform multiple tasks simultaneously, such as documentation, analysis, and calculations;
- automatic calculation of the necessary quantity of building materials;
- quick implementation of project changes without the need to fully redesign it.

In conclusion, the benefits of BIM technologies in geodetic control for road construction are significant. The use of modern geodetic control integrated with BIM and surveying tools (laser scanners, drones, GPS stations) ensures high-precision digital terrain models. Interactive 3D visualization allows the creation of real-scale digital models of terrain, road structures, and utility systems, which simplifies project control and adjustments. The system can detect discrepancies between design data and actual geodetic measurements, accelerates work, and optimizes costs, enabling deadlines to be met and unnecessary expenses avoided. Real-time monitoring helps track the condition of the structure and its potential deformations, which is essential for long-term road maintenance.

Conclusions

Geodetic surveying plays a key role in road construction, as it ensures the accurate location of objects, controls compliance with design parameters and guarantees the quality of construction work. During the work, the methods of creating densification geodetic networks, the construction of topographic plans and their significance for design were considered and analyzed, the methods of transferring the roadbed to the field were described, and the main aspects of geodetic quality control of work execution with the development of recommendations for them were considered. The analysis of the current state of work quality control made it clear that it requires the introduction of new technologies to achieve better results. Based on the main problems, recommendations were made regarding the need for diagnostics and verification of instruments, and the importance of implementing BIM technologies for creating accurate, reliable, and cost-effective projects was determined. Thus, compliance with regulatory and legal requirements and the use of modern geodetic technologies allow minimizing risks during construction, increasing the efficiency of process management, and ensuring the durability of road infrastructure, and a systematic approach to the management of geodetic works is the key to successful and high-quality construction of highways.

References

1. Arsenieva N. (2022). Features of bim technologies in geodetic works. Theory and practice of science: key aspects.

2. AzVirt. (2025). Highway M01 Kyiv, Chernihiv, Novi Yarylovychi, Ukraine 2019 – 2025. Available at: https://azvirt.com/en/node/113 (accessed 03.02.25)

3. Bachyshyn B.D. (2020). *Engineering Geodesy*: textbook [Electronic publication]. Rivne: NUWEE, 196 p.

4. Batrakova A.H., Dorozhko Ye.V., Zakharova E.V., Kliuka O.M. (2022). Features of the composition of engineering and geodetic surveys in road construction. *Engineering science and architecture,* 6(173), 81-85 [in Ukrainian]

5. Bilokrynytskyi S.M.. (2011). *Geodesy*: textbook. Chernivtsi: Chernivtsi National University, 576 p.

6. Burkun I.V., Zholobova D.D. (2022). Modern technologies of geodetic works in the construction of highways. *Kharkiv National Automobile and Highway University*.

7. DBN V.2.3-4:2015. (2015). Automobile Roads. Part I. Design. Part II. Construction.

8. DBN V.1.3-2:2010. (2010). Geodetic works in construction.

9. Dmytriv. O. P. (2019). *Geodesy. Part I*: textbook [Electronic publication]. Rivne: NUWEE, 166 p.

10. Dorozhko Ye.V., Yankin O.Ye. (2022). Features of the composition and content of geodetic works in road construction. Municipal Economy of Citie of the O.M. Beketov Kharkiv National University of Urban Economy.

11. Geodez. (2025). Geodetic works. Available at: https://geodez.com.ua/geodezichniy-kontrol (accessed 03.02.25)
12. Geodesy, geology, topography from certified specialists Guild Engineering. (2025). Geodesy in road construction. Available at: https://geotop.com.ua/geodezicheskie-raboti-pri-stroitelstve-avtomobilnix-dorog_en.php (accessed 01.04.25)
13. LexStatus. (2025). Geodetic works in construction. Available at: https://lexstatus.ua/ua/heodezychni-roboty/ (accessed 03.02.25)
14. Order of Main Administration of Geodesy, Cartography and Cadastre under the Cabinet of Ministers of Ukraine. (2001). Instruction for topographic surveying at scales of 1:5000, 1:2000, 1:1000 and 1:500, GKNTA-2.04-02-98, K., 2001; Available at: https://zakon.rada.gov.ua/laws/show/z0393-98#Text (accessed 03.02.25)
15. Shaulskyi D.V. (2012). *Lecture notes on the discipline "Fundamentals of geodesy"* (for 1st and 3rd year full-time students, field of study 6.060102 "Architecture", specialty "Urban Planning"). Kharkiv National Municipal Economy University, 55 p.
16. Topograph. (2025). Geodetic works during road construction. (2025). Available at: https://topograph.com.ua/uk/blog/geodezychni-roboty-pid-chas-budivnycztva-dorig/ (accessed 03.02.25)
17. Zholobova D.D., Brumm D.V. (2022). The use of BIM technologies in geodesy. *Kharkiv National Automobile and Highway University*.