

# **SURVEYING WORKS IN ROAD DESIGNING AND CONSTRUCTION**

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*The paper presents an outline of geodetic works related to the development of technical documentation during construction of roads (highways, trunk roads, etc.). Special emphasis is placed on the needs, goals and significance of geodetic works, as well as on the extent or level of detail of necessary technical documentation.*

*Key words: design of geodetic marking, geodetic maps, design of geodetic observations, land acquisition design*

## **INTRODUCTION (1)**

The up-to-date practice has proved that the geodetic profession and its practitioners failed to affirm their role in a multidisciplinary team, that is to say, that their participation and significant responsibility during developing of technical design documentation for the needs of construction of various roads, participation in construction and the procedure itself of technical acceptance and subsequent use of built structures is usually underestimated by other professions.

Reasons for such a status of geodetic profession may be sought in insufficient understanding of the structure and importance of the activities of this profession by representatives of other engineering fields. However, the blame should be first of all looked for within the profession itself. Namely, geodetic professionals should primarily make sure that their staff receive quality professional development (both in terms of theory and practice) as well as that adequate IT infrastructure (equipment and software) is ensured, which should help create pre-conditions for responsible and reliable participation in the process of preparation, designing and implementation of surveying tasks, more specifically:

- from the moment of identification of the concerned land parcels on which construction is planned,
- collection of numerical and graphical data from cadastral and other public records,
- establishing geodetic network of the concerned object and its connection to state geodetic base,
- geodetic surveying and developing updated geodetic base for all stages of design documentation, in required accuracy, in the state coordinate system, in digital form, and correct printing in appropriate-required scale,
- integrating topographical map with cadastral plan,
- forming geodetic survey,
- participation in all stages of development of design documentation, development of necessary surveying designs,
- translation of the designed structure on the ground from all design stages of the concerned structure,
- forming the construction lot for the needs of construction of the concerned structure,
- participation in the building of the structure from the moment of onset of works by the Contractor,
- permanent detailed marking and monitoring the construction process,
- until the moment of providing proofs that the structure was built in accordance with and based on design documentation and building permit, in spatial form
- development of as-built design
- and geodetic surveying and gathering all necessary data on newly-built structure and development of necessary surveying analy-

sis and its submission to the competent service for real estate cadastre, for its review and verification and for registration in real estate records,

- and further monitoring and observation of the ground and structures during use,
- independent geodetic supervision of conducting all surveying works as they are performed and during measurement and development of design analysis and building of the concerned structures;
- technical control and verification of acceptance of design technical documentation.

### **PROBLEMS RELATED TO DEVELOPMENT OF DESIGN DOCUMENTATION (2)**

Geodetic works, that is to say, development of concerned technical documentation, although clearly defined by relevant legislation, [01], [02] and by-laws, most frequently do not have a prescribed form.

Habits inherited from the past period when this field was not clearly defined in terms of legislation, inconsistencies in observance of law, investors' incompetence during the stage of development of Design Task, inertia of supervision bodies, indolence or lack of competence of persons in charge of technical check, are only some of the reasons for such a situation.

On the other hand, one of the peculiarities of geodetic profession is the fact that during the implementation of multi-disciplinary projects, such as infrastructure projects in civil engineering, the segments of designing and carrying out of surveying work overlap within the surveying stage itself.

Namely, the basic task of geodetic professionals as far as those designs are concerned, includes development of a geodetic map, with the digital model of the ground, as a basis for designing, as well as development of the design of geodetic marking and observation of structures during construction and exploitation, and the land acquisition (expropriation) design (if a completely new structure is involved). That is to say, the main task implies designing, immediately followed by carrying out of surveying works, i.e. gathering data and performing works on the ground. Only after completion of the construction design of the structure, can the designs of geodetic marking, observation of ground and structures during

building and use of the structure, and the land acquisition design be made, which is then followed by submission of the design documentation to technical control by an authorized independent institution.

Taking into account all the above-mentioned, it is not difficult to conclude that the process itself of developing design documentation, although it is done in accordance with the law, contains some logical inconsistencies. It is certainly not logical or useful that the technical control of the design of geodetic works (which includes the design of geodetic base – the main traverse) is done after completion of geodetic works and making geodetic map. On the other hand it is not adequate or technically correct to present the results of such works within the design of geodetic works, that is to say, that the elements of the analysis of performed geodetic works be a part of design documentation.

All the mentioned peculiarities and problems indubitably point out at the need of a clearer and more systematic regulation of this issue, both from the normative and the good engineering practice points of view.

### **FUNCTIONAL AND TECHNICAL CHARACTERISTIC (3)**

Surveying works and interpretation of geo-spatial data should, both by their size and contents, respond to real multidisciplinary needs of all stages and all segments of the construction design of the concerned structure, and conform, by both their volume and contents, to the level of detail of the design itself.

### **DESIGNING BASES (4)**

Subject to the level of the design itself, basis for the development of design documentation of a geodetic design, may comprise the following:

- Previous plan and design (project) documentation;
- Report by the competent review committee (expert control), of previously existing technical documentation, along with the proposal of measures that the investors are required to apply during development of technical documentation;
- Geodetic base information relating to the area of the concerned location, obtained from the

competent service for real estate cadastre;

- Information related to the cadastral status of lots within the perimeters of the location of the concerned structure.

### **SIZE AND CONTENTS OF DESIGN DOCUMENTATION (5)**

Design documentation of surveying works for the concerned structure should be developed on the basis of the Design Task and in accordance with specific requirements for responsible designers of a certain stage pertaining to a part of design documentation, and pursuant to legal regulations.

Design documentation of surveying works is comprised of the following [03], [04], [05], [06]:

- Geodetic network of the structure (main traverse)
- Analysis of surveying and making geodetic map for designing
- Main design of geodetic marking
- As-built design
- Design of geodetic observation of the ground and the structures during building and exploitation
- Land acquisition design

#### **5.1 GEODETIC NETWORK OF A STRUCTURE (MAIN TRAVERSE)**

Points of geodetic network of a structure, i.e. of main traverse represent a spatial basis for developing geodetic bases and for carrying out surveying works.

Trigonometry points (as well as reference points) of state network, on which the points of the geodetic network of a structure will rely in order to be incorporated in the state coordinate system, comprise the positional basis for determining the coordinates of points of geodetic network of that structure.

Practical application of positioning in 3-D space was made possible by use of development of Information Technologies, Geodetic Information systems, computer systems, global positioning system, total stations, digital levels as well as other digital technologies.

Design documentation of the geodetic network of a structure, i.e. main traverse comprises the following:

#### **5.1.1. General documentation**

- 5.1.1.1. Excerpt from the registration of economic subject (Contractor for the Concerned Works)
- 5.1.1.2. Decision on fulfillment of conditions for issuing the license to the Contractor
- 5.1.1.3. Decision of the Republic Geodetic Institute on Contractor's fulfillment of conditions
- 5.1.1.4. Certificate of Compliance with Quality System
- 5.1.1.5. List of participants taking part in developing technical documentation
- 5.1.1.6. Decision on appointment of responsible designers
- 5.1.1.7. Responsible designer's license
- 5.1.1.8. Certificate on validity period of the responsible designer's license
- 5.1.1.9. Certificate confirming that responsible designers fulfill the conditions referred to in the Law on Planning and Construction
- 5.1.1.10. Decision on Appointment of the Person in charge of internal control
- 5.1.1.11. License of the person in charge of internal control
- 5.1.1.12. Certificate on validity period of the persons in charge of internal control
- 5.1.1.13. Statement by responsible designers on conformity of technical documentation
- 5.1.1.14. Statement by responsible designers on application of the Laws, regulations and standards
- 5.1.1.15. statement by a person in charge of internal control
- 5.1.1.16. Statement by the responsible designer that all the copies of technical documentation are identical

#### **5.1.2. Design task**

#### **5.1.3. Textual documentation**

- 5.1.3.1. Technical report
- 5.1.3.2. Introduction
- 5.1.3.3. Basic data on designed structure
- 5.1.3.4. Subject of geodetic works
- 5.1.3.5. Inclusion of the geodetic network of the structure in the state coordinate system
- 5.1.3.6. Designing and reconnaissance of geodetic network points for a structure
- 5.1.3.7. Stabilizing the points of geodetic network of the structure
- 5.1.3.8. Geodetic measurements aimed at

determining coordinates of points of geodetic network of a structure

- 5.1.3.9. Data processing related to measurement of geodetic network of a structure
- 5.1.3.10. Determining rectangular coordinates of points of geodetic network of a structure
- 5.1.3.11. Determining the heights of points of geodetic network of a structure
- 5.1.3.12. Forming technical documentation of geodetic network of a structure
- 5.1.3.13. Conclusion

#### **5.1.4. Numerical documentation**

- 5.1.4.1. List of coordinate points and newly-determined geodetic networks (TO 25a)
- 5.1.4.2. Minutes of ground measurements and numerical processing

#### **5.1.5. Graphical documentation**

- 5.1.5.1. General map of a concerned site
- 5.1.5.2. Geodetic network sketch
- 5.1.5.3. Description of position of points (TO 27)

#### **5.1.6. Appendixes**

- 5.1.6.1. Applying for works at the Service for Real Estate Cadastre
- 5.1.6.2. Certificate of correctness of measuring devices
- 5.1.6.3. Data on geodetic base obtained from the Republic Geodetic Institute
- 5.1.6.4. Contract on development of concerned documentation

### **5.2. ANALYSIS (STUDY) OF GEODETTIC SURVEYING AND OF MAKING GEODETTIC BASE FOR DESIGNING**

In order to provide a spatial basis for designing, it is necessary to perform geodetic surveying of the existing situation on the ground, both horizontally and vertically, in accordance with the required precision. The width of the surveying area should be such to ensure the required spatial basis for designing all the contents of the concerned structure.

The basis for developing design technical documentation (all stages of construction design) implies the data from the ground, collected through standard geodetic methods, and on topographical maps, made on the basis of such data, along with digital models of the ground, adjusted for printing at a required scale 1:1000, 1:1500, etc.

The contents of design documentation of the analysis of geodetic surveying and making the geodetic base for designing includes the following:

#### **5.2.1. General documentation**

The contents of general documentation is the same as in 5.1.1. of this paper.

#### **5.2.2. Design task**

#### **5.2.3. Textual documentation**

- 5.2.3.1. Technical report
  - 5.2.3.1.1. General information about design
  - 5.2.3.1.2. Basic data on designed structure
  - 5.2.3.1.3. Subject of geodetic works
  - 5.2.3.1.4. Plan of geodetic surveying
  - 5.2.3.1.5. Geodetic base
  - 5.2.3.1.6. Geodetic surveying method
  - 5.2.3.1.7. Instruments and tools for geodetic surveying
  - 5.2.3.1.8. Geodetic surveying and collecting data for making geodetic base
  - 5.2.3.1.9. Geodetic surveying data processing
  - 5.2.3.1.10. Making geodetic map
  - 5.2.3.1.11. Geodetic analysis development for making design documentation
  - 5.2.3.1.12. Conclusion

#### **5.2.4. Numerical documentation**

- 5.2.4.1. List of coordinate points of geodetic network
- 5.2.4.2. List of coordinates and levels of detailed points

#### **5.2.5. Graphical documentation**

- 5.2.5.1. General map – layout at scale 1:25000
- 5.2.5.2. Geodetic network sketch
- 5.2.5.3. Topographical plan at scale 1:1000 (1:500)
- 5.2.5.4. Digital form of topographical plan (designing base)

#### **5.2.6. Appendixes**

- 5.2.6.1. Applying for works with the Service for Real Estate Cadastre
- 5.2.6.2. Certificate of correctness of measuring instruments
- 5.2.6.3. Data on Geodetic base collected from the Republic Geodetic Institute

### 5.3. MAIN DESIGN OF GEODETIC MARKING

The main purpose of this design is to ensure exact translation of the design of the concerned structure in real space, in conformity with pre-determined accuracy and marking methods.

Marking methods should be brought in line with the current possibilities of surveying instruments and contemporary computer technology, bearing in mind the fact that the design of surveying works will not only serve the purpose of successful building of a structure but also of making of as-built design.

The content of design documentation of the Main Design of Geodetic Surveying is comprised of:

#### 5.3.1. General documentation

The contents of general documentation is the same as in 5.1.1 of this paper.

#### 5.3.2. Design task

#### 5.3.3. Textual documentation

5.3.3.1. Technical report

5.3.3.2. Design solution

5.3.3.2.1. General data on the design

5.3.3.2.2. Basic data on designed structure

5.3.3.2.3. Esting the points of the existing networks

5.3.3.2.4. Assessment of stabilization status of the existing geodetic networks

5.3.3.2.5. Form (geometry) of geodetic network of the structure

5.3.3.2.6. Connecting the structure with the geodetic network of the structure

5.3.3.2.7. Analytical elaboration on the geometry of designed structure (calculating coordinates of characteristic points of the structure)

5.3.3.2.8. Subject of geodetic marking

5.3.3.2.9. Selection of the method of marking of the geometry of the structure

5.3.3.2.10. Calculation of accuracy (accuracy optimization) of marking the geometry of the structure

5.3.3.2.11. Calculating the elements for marking characteristic points of geometry of structures

5.3.3.2.12. Selection of the measuring method and of the instruments for marking and control measuring

5.3.3.2.13. Analysis of the measuring method

5.3.3.2.14. Measuring plan for the needs of the control geometry of marked structure

5.3.3.2.15. Model of testing the results of control measurings according to the requirements in the design of marking the geometry of structure

5.3.3.2.16. Mathematical model of equalization and evaluation of accuracy of measuring results

5.3.3.2.17. Model of testing compatibility of marked vs. designed geometry of structure

5.3.3.2.18. Model of testing of belonging of controlled points to appropriate geometrical element of the structure

5.3.3.2.19. Method of fixing (materialization) of characteristic points of the structure

5.3.3.2.20. Concept and organization of surveying works during the implementation of the design of making geometry of the structure

5.3.3.2.21. Safety at work measures

5.3.3.2.22. Contents of the analysis of the implementation of the design of marking the geometry of structure

5.3.3.2.23. Priced bill of quantity

5.3.3.2.24. Technical requirements for performing works

#### 5.3.4. Numerical documentation

5.3.4.1. The list of coordinates of geodetic network points (basis for marking the geometry of structure)

5.3.4.2. List of coordinates of characteristic points of the structure (main and detailed points according to the design task and the subject of marking)

5.3.4.3. Elements for marking characteristic points of structures for the proposed method of marking and measuring instruments.

#### 5.3.5. Graphical documentation

5.3.5.1. General map of geodetic network

5.3.5.2. Positional description of points of main traverse TO 27

5.3.5.3. Drawing of the base of construction design with characteristic points of the structure for marking along with necessary details

5.3.5.4. Marking plan

#### 5.3.6. Appendixes

5.3.6.1. Transformational parameters of the concerned site

5.3.6.2. Minutes of performed control measuring of geodetic marking

## 5.4. AS-BUILT DESIGN

Technical documentation for technical acceptance of newly-built structure should be prepared, to the end of putting the newly-built structure to the intended function (issuing of exploitation permit) and its further maintenance during its exploitation-utilization, in accordance with legal regulations. The said technical documentation includes, but is not limited to:

- As-built design of the concerned structure (including proofs that the structure was built in all details according to the Main Design, i.e. according to possible changes that are in conformity with the Building Permit)
- Excerpt from the real estate cadastre (numerical and spatial data about the cadastral lot on which the structure was built, and ownership rights on that lot along with other rights and their extent)
- A proof that geodetic survey of newly-built structure has been performed (i.e. collecting all field data related to geodetic survey and making full analysis of bill of quantity of concerned real estate, in accordance with legal regulations) and that the analysis of geodetic survey-bill of quantity has been received, acknowledged and verified by a competent service for real estate cadastre, to the end of registering changes during maintenance of real estate cadastre.

The contents of technical documentation contained in the analysis of geodetic survey of newly-built structure, as the main and the most important proof as to how the concerned structure was built and positioned in appropriate space, and whether it was built in accordance with the technical documentation from the Main As-Built Design, which is therefore an important part of As-Built Design (while the other parts are related to the documentation of construction design, and of other related stages of design documentation of the new structure) includes the following:

### 5.4.1. General documentation

The contents of general documentation is the same as in 5.1.1. of this paper.

### 5.4.2. Design task

### 5.4.3. Textual documentation

#### 5.4.3.1. Technical report

- 5.4.3.1.1. General data on design
- 5.4.3.1.2. Main data on designed structure
- 5.4.3.1.3. Subject of surveying works
- 5.4.3.1.4. Plan of geodetic survey
- 5.4.3.1.5. Geodetic base
- 5.4.3.1.6. Geodetic survey methods
- 5.4.3.1.7. Instruments and tools for geodetic survey
- 5.4.3.1.8. Geodetic survey and gathering data for making the analysis of bill of quantity
- 5.4.3.1.9. Processing geodetic survey data
- 5.4.3.1.10. Developing geodetic analysis of bill of quantity of newly-built structure
- 5.4.3.1.11. Forming geodetic analysis for making design documentation
- 5.4.3.1.12. Conclusion

### 5.4.4. Numerical documentation

- 5.4.4.1. List of coordinates of points of geodetic network
- 5.4.4.2. List of coordinates and levels of detailed points

### 5.4.5. Graphical documentation

- 5.4.5.1. General map-layout of scale 1:25000
- 5.4.5.2. Geodetic network sketch
- 5.4.5.3. Topographic plan of scale 1:1000 (1:500)
- 5.4.5.4. Geodetic survey (bill of quantity) sketches - manuals

### 5.4.6. Appendixes

- 5.4.6.1. Application of papers at the Service for Real Estate Cadastre
- 5.4.6.2. Certificate of Validity of Measuring Devices
- 5.4.6.3. Data on geodetic base collected from the Republic Geodetic Institute
- 5.4.6.4. Excerpt from the real estate cadastre (numerical and spatial data on cadastral plot on which the concerned structure was built, and ownership rights on that lot along with other types of rights and their extent)

## 5.5. DESIGN OF GEODETIC OBSERVATION OF THE GROUND AND THE STRUCTURES DURING CONSTRUCTION AND USE

The purpose of this design is to define the subject, accuracy, method of work, instruments, dynamics and (priced) bill of quantities necessary for successful implementation of geodetic observation of ground and the structure during construction and use. The contents of the Design

of geodetic observation is required to have the following contents:

#### **5.5.1. General documentation**

The contents of general documentation is the same as in 5.1.1. of this paper.

#### **5.5.2. Design task**

#### **5.5.3. Textual documentation**

5.5.3.1. Technical report

5.5.3.2. Design solution

5.5.3.2.1. General data on the design

5.5.3.2.2. Goal and task of observation

5.5.3.2.3. Design of geodetic observation works

5.5.3.2.4. Measuring places, measuring instruments, plan and program of measuring

5.5.3.2.5. Series of observations and time schedule of observations

5.5.3.2.6. Visual observation of construction elements

5.5.3.2.7. Measuring processing method, presentation of results and forming documentation on observation

5.5.3.2.8. Criteria for comparing the results of measuring against the permitted values

5.5.3.2.9. Requirements for maintenance of measuring places and instruments during the period of observation

5.5.3.2.10. Method of monitoring and interpretation of the results of object observation

5.5.3.2.11. Technical conditions for the implementation of the main design of observation

5.5.3.2.12. Subjects and way of informing about the obtained observation results

5.5.3.2.13. Measures to be taken in case that the results of observation reach or exceed the prescribed or allowed parameters

5.5.3.2.14. Conclusion

#### **5.5.4. Priced bill of quantities**

#### **5.5.5. Graphical documentation**

5.5.5.1. Plan of network of observation from stable points

5.5.5.2. Position of benchmarks (permanent points being observed)

5.5.5.3. Details of permanent points being observed

5.5.5.4. Other documentation

#### **5.5.6. Appendixes**

5.5.6.1. Summary table of monitoring observation (Form)

### **5.6. LAND ACQUISITION DESIGN**

The main goal of making the land acquisition design is to define optimum area (forming of the construction parcel) of the future structure as well as of all the accompanying structures that should be both in the function of construction and maintenance of future facility.

In land acquisition design the data are transferred necessary to translate the land acquisition area from design to the ground, mark it on the ground, with all the characteristic points that fully define the land acquisition area for the designed structure, that is to say for it be positioned in space, within the borders of determined or prescribed tolerances.

The contents of the land acquisition design comprises the following:

#### **5.6.1. General documentation**

The contents of general documentation is the same as in 5.1.1. of this paper.

#### **5.6.2. Design task**

#### **5.6.3. Textual documentation**

5.6.3.1. Technical report

5.6.3.2. Design solution

5.6.3.2.1. General data on the design

5.6.3.2.2. Basic data on designed structure

5.6.3.2.3. Form (geometry) of geodetic network of the structure

5.6.3.2.4. Analytic elaboration on the geometry of designed land acquisition area (calculating coordinates of characteristic points)

5.6.3.2.5. Subject of geodetic marking

5.6.3.2.6. Selection of marking method of land acquisition area

5.6.3.2.7. Calculation of accuracy (accuracy optimization) for marking geometry of the concerned area

5.6.3.2.8. Calculating elements for marking characteristic points of geometry of the concerned area

5.6.3.2.9. Selection of measuring methods and instruments for marking and for control measuring

- 5.6.3.2.10. Analysis of measuring method
- 5.6.3.2.11. Plan of measuring for the needs of the control of geometry of marked land acquisition area
- 5.6.3.2.12. Method of fixing (materialization) of characteristic point of the land acquisition area
- 5.6.3.2.13. Concept and organization of geodetic works during realization of the design
- 5.6.3.2.14. Safety at work measures
- 5.6.3.2.15. Contents of the analysis of design realization
- 5.6.3.2.16. Priced bill of quantities
- 5.6.3.2.17. Technical requirements for performing works

#### **5.6.4. Numerical documentation**

- 5.6.4.1. List of coordinate points of geodetic network (basis for marking the land acquisition area)
- 5.6.4.2. List of coordinates of characteristic points defining the land acquisition area (taken from the construction part of the design)
- 5.6.4.3. Elements for marking characteristic points of land acquisition for the proposed method of marking and measuring instruments
- 5.6.4.4. List of lots or parts of lots with their sizes that make part of the land acquisition area.

#### **5.6.5. Graphical documentation**

- 5.6.5.1. General map of geodetic network
- 5.6.5.2. Drawing of the base of construction design with characteristic points for marking the land acquisition area and with necessary details
- 5.6.5.3. Plan of marking (integrated with cadastral status of concerned lots)

#### **5.6.6. Appendixes**

- 5.6.6.1. Possession and title deeds (real estate deeds) for lots or parts of lots that make part of the land acquisition area.

## **CONCLUSION (6)**

Surveying works and interpretation of geo-spatial data, by their size and contents, should respond to real multidisciplinary needs of all stages and all segments of the construction design of the concerned structure, while conforming by their volume and contents to the level of detail of the design itself.

It is a task of geodetic experts, in cooperation with other professions and in a multidisciplinary activity, to make constant efforts on improvement and modernization, through the activities on improving the legal regulation and other standards, by establishing a quality system and by further upgrading of the system.

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