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Geodetic surveying of railway objects

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Abstract

The paper includes the description of geodetic activities using computer and plotting support for the construction of the traffic objects in the railway engineering. The main principles of monumentation and adjustment of the setting-out network are presented among the most common kinds of surveying methods. The requirements for the apparatus equipment and its precision of measurement. Two step setting-out of the traffic objects and control measurement during their construction process. The measurement of deformation values during the load test of constructions. The relation of the required accuracy between deformation values and surveying accuracy. The cyclic measurement for the purposes of the diagnostics of the spatial traffic objects changes. Geodetic surveying using computer support for the construction of bridges across the river Váh in Žilina. The software utilization support for the geodetic survey and cartographic work for the railway engineering

1 Introduction

Geodetic surveying methods are the necessary components of work in the railway engineering. They include the execution of the final design documentation, the laying-out of the building objects, working out the projections of the realization of the building productions and they contribute to settlement of the requirements for the accuracy and quality

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of the spatial shape adherents during putting the building objects into operation. The experience of geodetic surveying in the railway engineering is presented by the construction of bridges, tunnels, railway track, electric traction lines, signal and communication system, retaining walls, railway yard and switches in the stations and track and another railway facilities.

Computer and plotting devices which are continuously developed are the inherent part of surveying work. New properties of the computer work stations such as high performance, multimedia technology, virtual reality, graphical user interface, high resolution monitors create conditions for increasing the performance and quality of designing and surveying work in the railway engineering.

Computer work is one part of the whole performance only and the computer is a tool for processing the geodetic surveying solutions. The most common thing of the surveying activities in the railway engineering are geodetic measurements in terrain onto the points of the construction structure, which include pre-designing preparation, creation of the numeric and graphic designing source material, establishment and surveying setting-out network, laying-out and control surveying during the construction process of the traffic objects, measurement and documentation of the resulting shape of objects, measurement during the load test of constructions, the cyclic measurements of the spatial object deformations during its putting into operation.

2 Setting-out network

Geodetic setting-out network is built in accordance with the project of the traffic object so that it would be utilized especially for the spatial laying out of the characteristic main points of the object. The network is used for the detailed laying out and control measurements during the construction of the objects. After finishing the construction of the bridge it is used for the load test and later for the cyclic surveying of the spatial construction deformations.

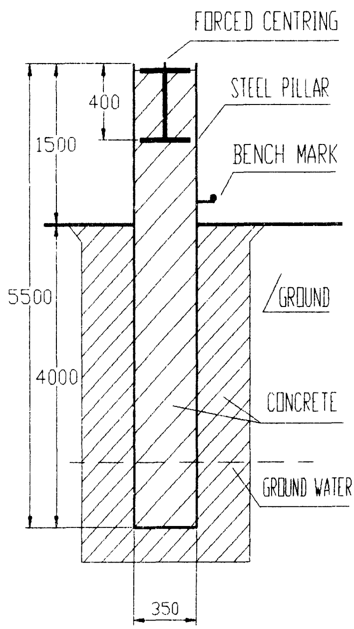

Figure 1: The observation pillar of the setting-out network.

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For this purpose, the permanent monumentation is built using the observation pillars (Fig. 1) or the monumentation using surrounding objects (crosslines onto the bridge support or bridge abutments and piers). The supplementary monumentation can be obtained by setting steel pole or bound in length of 1.0 m (with concrete foundation 0.30 x 0.30 x 0.50 m). The minimum depth of the permanent monumentation is 4,0 m. Bottom of this foundation must be at least 0.5 m under level of the ground water.

The permanent monumentation of the setting-out network is supplied with the equipment for the forced instrument centring and the target mark. The bench mark of the setting-out network is built into the structure of monumentation too. For the purpose of the homogenous precision, the points of the setting-out network, in accordance to the surveying methods, are grouped into the triangular or tetragonal surveying strings (Fig. 2), which are sometimes built as the groups of separate points too. Setting-out network for the traffic lines includes the surveying polygon.

The networks are measured by terrestrial methods or GPS methods (Global Positioning System using satellites). By the terrestrial methods using the surveying strings we usually measure all angles and distances, which are adjusted by the method of the least squares with depended measurements.

We can ensure the positional accuracy of points m_p = 3 – 4 mm within the range of distances 300 – 400 m, for example[1]. Using the static GPS surveying in the range of less than 3 km the middle position deviation m_p = 3 – 6 mm can be achieved, for example[2].

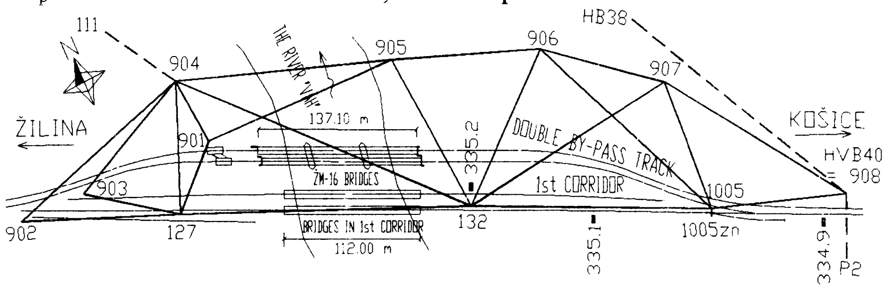

Figure 2: Setting-out network for construction of the railway bridges.

The positional setting-out networks are built in relation to the national coordinate reference system. Because higher precision than this one is required, we determine the networks in the local coordinate system. In the interest of simplification of the distance laying-out without the consideration of the length distortion, the reference plane is put into the middle plain of laying-out object.

Elevations of the bench marks of the elevation setting-out network are measured by the precise levelling.

3 Surveying instruments and systems

Geodetic measurement of bridges, tunnels and railway track requires the instruments with high standard of quality. Today, we can take advantages of the electronic total stations for surveying methods, which include the recorder with direct or indirect computer connection. Data is directly exchanged between CAD and survey system.

Among the most modern surveying instruments we include the hybrid systems, which have GPS technology of measuring (Real Time Kinematic GPS) interconnecting by universal electronic surveying instruments. The surveying instruments, which are used in common practice and require the fulfilment of the standard deviations in interval, are presented in Tab. 1.

Tab.1. Standard deviations of surveying instruments (electronic measurement).

Surveying of	Low limit of accuracy	Upper limit of accuracy
Angles Hz, V	1.5 mgon (5“)	0.15 mgon (0.5“)
Distances	3 mm + 3 ppm	1 mm + 2 ppm
Elevations	0.7 mm / 1 km	0.3 mm / 1 km
GPS-system	10 mm + 2 ppm	5 mm + 1 ppm

The producers of the surveying instruments supply software, which supports the instrument service, processing of surveying or laying-out data, graphic and numeric final outputs[8].

4 Setting-out of objects and control of surveying

The setting-out of traffic objects is executed in two stages in the terrain. The characteristic main points of the object are laying-out by using setting-out network. The detailed laying-out of the structure depends on the characteristic main points.

Limit longitudinal, transversal, linear and vertical deviation are the accuracy criteria of the position setting-out of the characteristic axis points of bridges or tunnels. The values of the limited deviations are defined by

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the standard[3].

The accuracy of the spatial setting-out is reviewed according to the criteria for laying-out of the individual kinds of work: earth work, lower construction, frame construction, etc. The designer defines the values of limited deviations for each traffic object individually. At the same time the construction and the spatial shape of the object is taken into account.

From terrestrial surveying methods of setting-out the polar method is used mainly by utilizing the universal surveying total stations in the mode of appropriate setting method. At present the application in the Real Time Kinematic GPS mode is developed.

The tunnelling direction of the underground objects, prospecting galleries, railway or motorway tunnels, is set by laser (Fig. 3). From the points of the setting-out network in the tunnel, the position of the laser instrument and the point position, where the laser beam is directed, is defined.

Using computers (PC), for example software AutoCAD[6], the designed tunnel axis, the laser standpoint are graphically displayed and then we can plot the laser beam direction across the fixed point as to the designed axis.

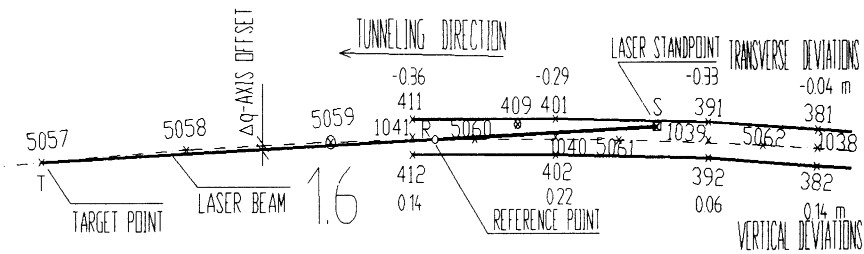

Figure 3: Control surveying and setting-out of tunnelling direction.

On the computer screen by chosen step of kilometre division, the relation between the position of the laser beam and the designed axis in transversal and vertical direction is defined. During the permanent laser radiation it is possible to adhere to the most complicated straightening and levelling process of the tunnelling axis with a cm precision. If we have a barrier in direction of the laser beam, or we overload the laser range then we must define from the setting-out network new laser standpoint and new laser direction under the designed axis.

The significant components of the surveying activities are control measurements of the spatial shape of the traffic object such as suspension bridges, lattice-girder bridges, reinforced concrete bridges, tunnels, etc. The control measurements compare the actual geometric shape with designed one. The purpose is the earlier setting of the structural corrections of the object.

During the construction of tunnels we must set the control measurements to compare the actual spatial tunnel shape with the designed shape (Fig. 3).

5 Geodetic surveying at load test of the objects

At a particular time during the load test of objects we measure all types of deformations and force values, which are necessary for the impartial static appreciation of the bridge object before putting into operation.

The measurements of deflections and deformations are realized by physical or geodetical methods, at which some parameters are measured by different methods in the concurrent process. The measurement is realised at the characteristic points of the bridge construction (Fig. 4).

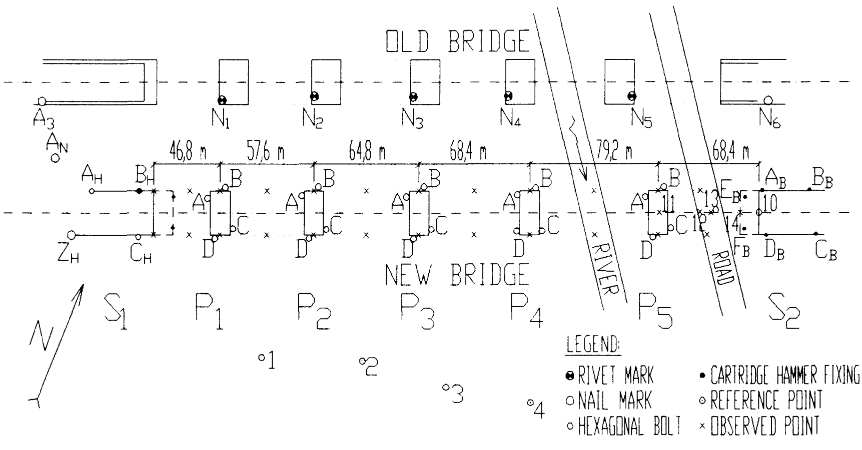

Figure 4: Layout chart of reference and observed points at the load test of Ivančice viaduct.

Geodetic surveys usually define the original shape of construction before the load test of object, subsidence of object foundation of the bridge abutments and piers, depressing of the object bearings, sags of bridge separate constructions, horizontal deformations and vertical sags under compressive load.

The most current surveying methods for these purposes are precise levelling, trigonometric surveying of elevations and measuring method by reference line.

The motorized instruments with automatic alignment from the measured target have found the technologic invocation with higher efficiency in this area, for example Automatic Target Recognition (TCA Leica)[8].

The surveying method selection and instrument accessories are given in accordance with the surveying accuracy of deformation values. Before surveying we verify the formula $2\sigma \leq m_{\Delta}$ using the accuracy analysis, where σ - stands for standard deviation, m_{Δ} - stands for required accuracy of the deformation values. The relation between σ and deformation value Δ is: $2\sigma < |\Delta|$, which is interpreted as the proved change in shape at the risk of wrong decision with the significance level $\alpha = 5$ %.

6 Cyclic surveying of spatial shape of traffic objects

The movement of traffic vehicles and other external factors (for example effect of undermining) cause spatial rearrangement of bridge structure. Where we expected these deformations, the construction are adapted for the object rectification.

For this purpose we carry out the cyclic measuring of: clutching of the expansion joint, the height deformation of the expansion joint, the tilting of piers, leaving the object line and the total subsidence.

The goal of surveying is the early diagnostic of the spatial object deformation and thus to prepare the source material for taking building-technical steps in order to interrupt the spatial deformation development.

7 Railway bridges across the river Váh in Žilina

The bridges across the river "Váh" in Žilina in 335.312 km of double track "Košice – Žilina – Bratislava" in the 1st main corridor of the Slovak railways (ŽSR) rank among the largest constructions built in the course of years 1996-1998 in the Slovak republic in railway engineering..

Geodetic surveying included: the establishment of the setting-out network (Fig. 1), the laying-out of two small bridges in length of 14.0 m across the city sewerage, the laying-out of two temporary railway bridges ŽM-16 with three fields per 45.0 m in length (in total length of 135.0 m), doubled track by-pass in front of, across and behind these temporary bridges, the laying-out of the traction electric wiring, the laying-out of the separate turnouts for branching of double track, measurement of railway

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track before the track removal in the 1^{st} corridor, surveying activities of the auxiliary steel bridge across the river Váh for bridge ejecting in length 112.0 m (nine piers in the river), measurement of the two new one-span bridges in length of 112.0 m, measurement of the real state of the built objects and other surveying tasks, occurring during construction.

The construction was enforced investment owing to the construction of the dam in Žilina “Vodné dielo Žilina”. The setting-out network was established in the shape of the triangular string and in relation to the state triangulation network. The setting-out network had to be adjusted as to the reference points of the dam construction. The coordinate closures of the triangular string were Δy = 0.012 m, Δx = -0.017 m, which represent the total positional closure Δp = 0.021 m, which meets the standard requirements for bridges and railway track constructions[7].

The important part of job was laying out precision position for the bearing setting of steel bridge onto the land abutment and the river piers. The steel structure was locked across the river as a whole body and then the construction was divided into three parts in length of 45.0 m. After the surveying the position of separate bridge fields was adjusted and the construct bearings were set into the designed position and elevation. Before the load test of these bridges the final surveying of the bridge setting and surveying of the parabolic shape of the rising track grade line at 1.5 m interval was executed.

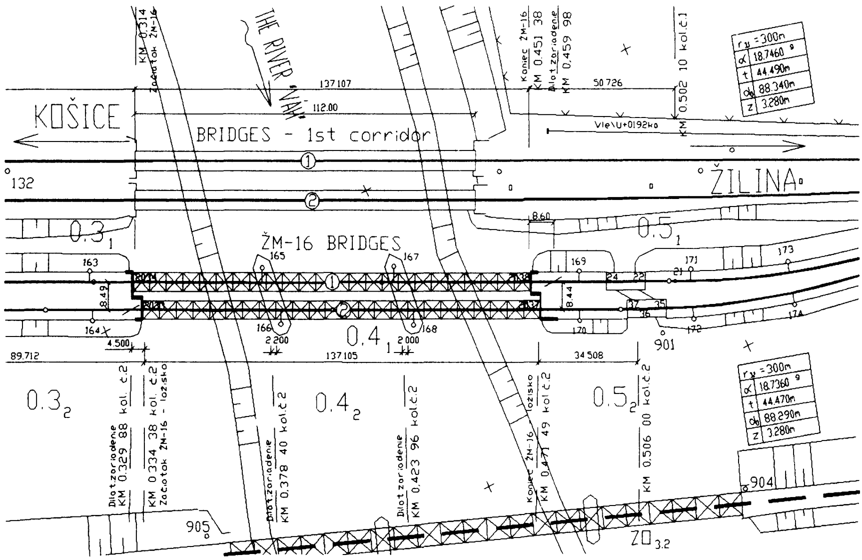

Figure 5: Final design of real processing of railway bridges.

Before putting into operation the by-pass double track and two temporary bridges in length of 135.0 m the final design of the real processing of the building production for 1st period of construction had to be executed (Fig. 5). The redirection of the train route was carried out gradually on each track according to the time working schedule to the new by-pass double track.

During the deflection of 1st corridor along by-pass track was realized the construction of two new railway bridges in length of 112.0 m – 2nd period of construction. Geodetic surveying continued with laying out the temporary structure across the river Váh, on which two bridges will be pushed out across the river. After all types of surveyings we had to process the final project of these traffic objects.

8 Conclusion

Software support increases the productivity of geodetic surveying. The developed software systems with new technologies improve the quality of project documentation, data processing of surveying in the terrain and finally the processing of the real building project.

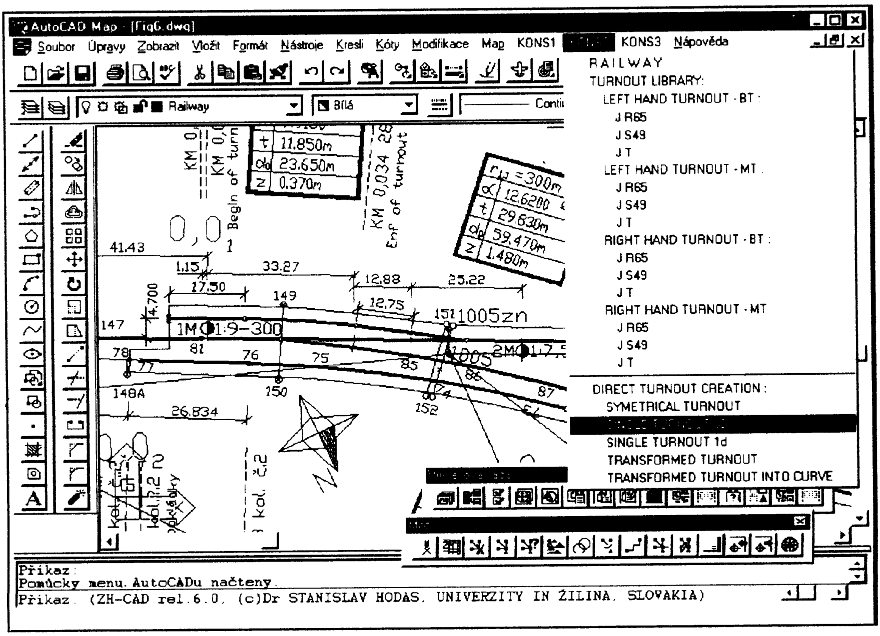

Figure 6: ZH-CAD – design and reconstruction in railway engineering.

During geodetic surveying and cartographic work in railway engineering we took software advantages for data processing and for the computations of setting elements from: AutoCAD rel.14. - main graphic software[6], AutoCAD MAP rel.2. – software for mapping and GIS[6], ZH-CAD rel.5 – design, reconstruction of gridiron in the railway engineering[3] (Fig. 6) using AutoCAD[6], GEOD rel.2 – optimalization of the track line, geometry of track and geodetic calculation[2], GSS/pp rel.2 – drawing-up of gradient profiles and cross-sections of the railway line[4].

The software technology, quality computer and plotting configurations are the certain assistants for the construction process of traffic objects. The main point of view is the mastering of the projection activities of construct technologies and finally the geodetic surveying procedures using precision electronic total station.

Surveying and cartographic work, with the computer support, are the component of each construction activities. Without them we cannot reach the required quality of traffic objects at putting into operation.

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