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Road Route Designing and Its Survey Processing with Use of the *Bentley InRoads* Software**

1. Introduction

Land means of transport are: motor, rail transport and inland navigation. The largest part of passenger and goods traffic in European Union currently has a motor transport. It is effective in the greatest outlay on motor transport infrastructure's development.

During the next several years Poland will make up for the arrears in road infrastructure construction. We are forced to do this by the country's transport situation and by European Union's requirements, when European Union covers a considerable part of costs related to transport development. Works related to construction and modernisation of roads are currently taking place in a wide-spread scale, with an effect from the most significant, such as motorways or express roads, through national roads, up to internal estate roads. This condition extorts from surveyors achieving up-to-date knowledge both in the scope of surveying equipment maintenance and transport infrastructure or modern software used in land and survey engineering.

There are many computer-aiding programs for designers and surveyors on the market, which help them to design the communication routes and landscapes. One of the biggest software developers of above mentioned scope of works destination is Bentley Systems, Inc. In its offer it has software packages labelled *InRoads*, *GEOPAK* and *MX*. Each of these consists of many applications presenting complex solutions for communication routes planning, roads and road infrastructure designing and also for repairs and management of transport infrastructure. For the sake of size limitations, the article comprises the most important *Bentley*

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InRoads application's aspects only. It represents software characteristics and presents its capabilities on an example of road design. It also describes functions suitable for surveyors in a designing phase from its terrain realisation point of view.

2. *Bentley InRoads* Application's Characteristics

The *Bentley InRoads* package is integrated applications series used in land and water engineering. It finds its application in design aiding, roads and tunnels reconstruction and modernisation, designing of road junctions, pipelines, airfields, railroads and rail transport traction, modelling of bridge constructions, groundworks, drainworks, in hydrology and management and maintenance of road infrastructure network. Applications enable creating: contour maps, spatial terrain model, cross sections and profile and also planning of investment progress or drawing up the necessary documentation.

Bentley InRoads software series does not have its own graphic interface and makes use of world most popular CAD platforms. The user can choose from *AutoCAD* or *Microstation*. Bentley Systems Inc. currently offers *InRoads Suite V8i* version cooperating both with *AutoCAD* (in 2008 and 2009 versions), and with *Microstation V8i*. The newest version of application enables multi-source data import. It is possible to load data created in competing firm's software, load and process data from survey measure equipment such as: tachometers, levellers, GPS receivers. The application enables work on data from ground-based laser scanners and LIDAR (Light Detection and Ranging) type air laser scanners, and from every ASCII file having any text data. Centralised database is a common source of data for all *InRoads* series products. This solution enables a smooth interoperability between all series applications. Thanks to a common database access, one project can be operated by many users.

The series consists of six programs. These are a complex solution for automation of design works. First of these programs, from which the whole series name comes from, is called *InRoads* (Fig. 1). It is destined for road and land design aiding. The design process aided by this program is made up of several phases. In the first order a digital terrain model should be created. To do this, the designer can use a series of advanced tools. There is a possibility of adding files with a map in raster format, vector map or numeric map. Successive, a vertical projection of a route geometry, grade line and normal section is designed. The route can be designed in various versions, and every version can be saved and read at any time. In further sequence a road corridor is created for chosen version. At this stage normal sections, superelevations and ramps are attributed to predefined route axis. It enables creating a spatial route model and calculating ground works. The last phase of the designer work is data saving in i.e. XML files containing reports, visualisation of created object and design figures printing. More comprehensive description of designing process is presented in the further part of the elaborate.

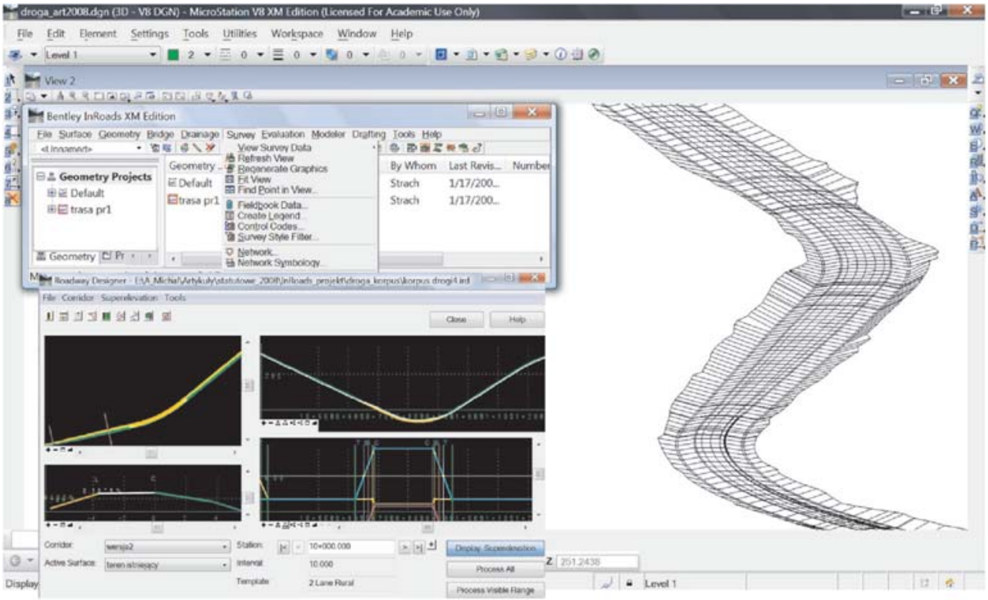

Fig. 1. The general *MicroStation* graphic interface view with *InRoads* application's windows visible

The next program is the *Bentley Rail Track*. It replaced previously available *InRail* and *MXRAIL* programs merging its best features in one product. It is one of the most popular programs in railroads design offices. *Bentley Rail Track* provides a set of tools to three-dimensional designing of a new traction, adjustment of an existing rail track axis and to manage and supervise of railroad elements' construction works. The interactive route geometry generation is possible through painting tools to create elements according to methods typical for railroads designing. Adjustment of rail track axis is possible with the use of regression analysis for single of cluster elements. The designer can choose from straight line sections, circular arcs and a series of predefined interim curves: Clothoid, Cubic Parabola, Bi-quadratic Parabola, Bloss, Sinusoid, and Cosine. The broader discussion on the potential of this application can be found in the thesis [3].

The next program is *InRoads Site*, which aids designing the spatial land management and industrial, commercial and housing sites regeneration. It enables modelling of terrain and objects in 3D space and its photorealistic visualisation and interpreting. The next program is called *InRoads Bridge*. It serves to a complex designing of geometry, constructions and modeling and analyzing of all type of Bridges. *InRoads Storm&Sanitary* application disposes of advanced 3D modeling tools, analysis and design of water, sewage and sewerage management projects.

The last series program labelled *InRoads Survey* enables field logger data transfer to *Microstation* or *AutoCAD* environment with an interactive edition. The direct import of both coordinates and surveys taken in field with use of all popular tachometers is possible. The application read files from devices developed by the following brands: Geodimeter, Leica/Wild, Nikon, Sokkia, Trimble, Topcon, Zeiss. An optional ASCII text file can be also loaded to the application. During the survey import a style of elements' projection can be defined, such as units, corrections, standard deviations essential to compensate survey results and assign surveyed points coordinates can be set up. Loaded field survey data can be edited and filtered in the electronic field book and a graphic interface enables its verification (Fig. 2). The application also provides tools to adjust geodetic control network, calculate station pole's coordinates and generate outcome reports.

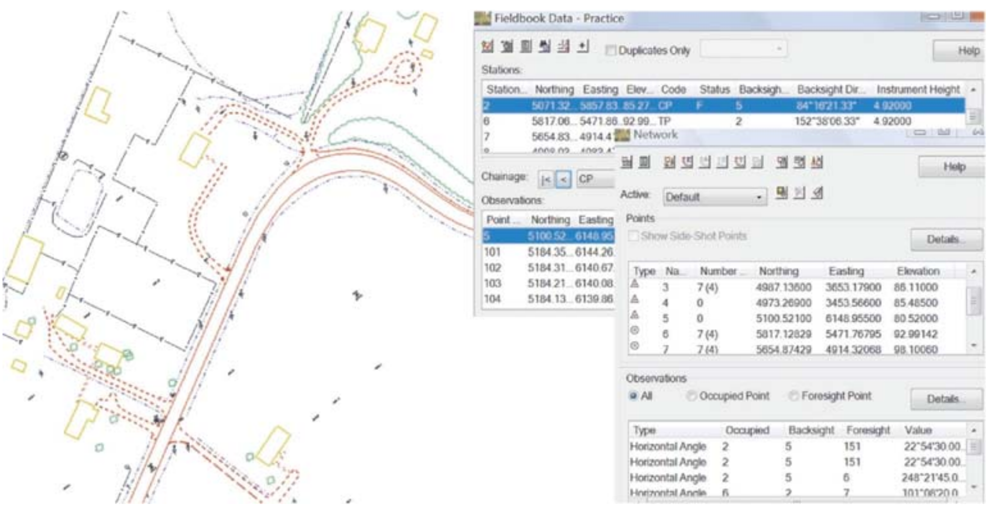

Fig. 2. Fragment of a digital map with compensation and point coordinates' calculation tools

3. The Design of a Road Route Section and Its Geodesic Survey with Use of the *InRoads* Package

The first design phase is creating a digital terrain model (DTM) [2]. There are many methods allowing the creation of DTM. Designers hold a digital map prepared basing on direct field surveys in particular esteem. It is a detailed and accurate material comprising data on a terrain structure, territorial development networks, elements of land and buildings' record. On the grounds of a digital map a route's situation design is created. Residual design's elements are created basing on DTM. A digital map can be imported from other applications or can be created with the use of *InRoads Survey* application (fig. 2). In the process of DTM creation an application labelled *Text Import Wizard* is particularly suitable, which allows to load any ASCII text file. Tools available in the application enable defining the tag of any element in the file. Read elements can be defined as: diffused points (*Random*), discontinuity lines (*Breakline*), isohypses (*Contour*), points defining the area, in which the DTM is not created by application (*Interior*), DTM area's borders (*Exterior*). In imported files additional elements, such as spatial axis system of technical infrastructure can be presented. Next, objects of this type are loaded in the same way as break lines. Other methods of DTM creation is graphical data import, i.e. vector map's elements and geometry data import, i.e. axis arranging the designed route. In both cases the application makes use of graphic displayed in CAD application. Loading proper elements to the application is followed by DTM creation with use of triangulation (fig. 3). In the subsequent order user can display, modify and design the DTM taking advantage of dozens of options.

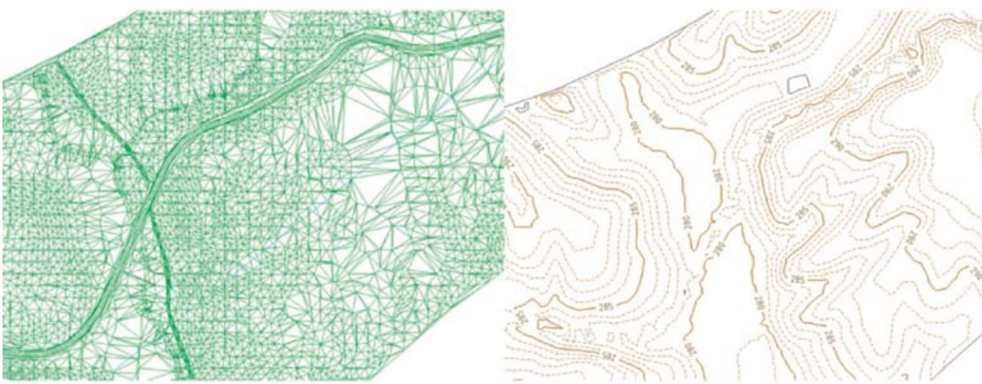

Fig. 3. Phases of DTM creation: terrain triangulation, generated contours

The following phase of designing is creation of road's geometry. This phase is broken down into two successive sub phases. Firstly, the axis of road in a horizontal view (Horizontal Alignment) is designed, and then a grade line is designed (Vertical Alignment). There are a couple of route display methods in the application. First one is a vertex method, where the following straight sections are defined by assigning vertexes. These points can be chosen in a different way: by its coordinates input with keyboard or by pointing it with a mouse on a scheme. Consequently, curvilinear sections are inscribed in straight lines' bends. The other method of designing is a method of elements' composing. This way is used to design roads of constant curvature, i.e. motorways, or routes, where its geometry does not changes much, i.e. modernization. Each of the elements of the designed route has a degree of freedom attributed. Fixed element is based on 2 map points. Floating element is fixed on 1 map point and is usually controlled to previously defined fixed element. The last are free elements not fixed to a map. Designing starts with setting stable sections, then floating elements controlled to them, and finally free elements.

During designing auxiliary tools can be used. One of them is a calculator to compute parameters of circular arcs, clothoids and combinations of these curves (Fig. 4). The other useful tool set is a possibility of displaying route elements' parameters in a text window, defining station poles of designed road and displaying it with a proper description (Figs 5, 6).

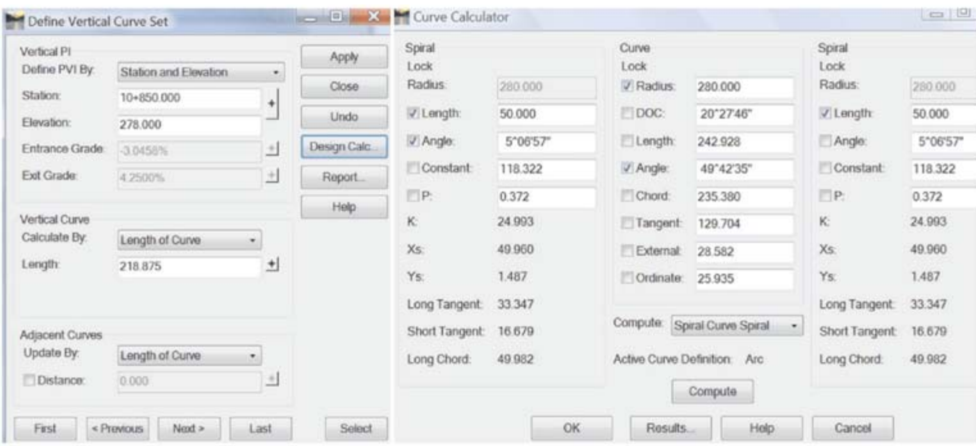

Fig. 4. Tools enabling route geometry's definition

In the next order a grade line is designed. Operation starts with drawing a terrain section. Basing on it the designer determines a course of particular grade line's sections. Defining of the orientation takes place with the use of one of above described methods: vertex or elements' composing. Successive grade line's designing phases are analogical to activities performed in road designing in a horizontal view; its final effect is shown on figure 6.

Having three-dimensional route axis' course defined, a creation of spatial road modeling can be commenced [1]. Process of its creation consists of several activities. The following activities can be distinguished: normal (crosswise) intersections defining, assignment of normal intersections to particular road sections, defining of superelevations and broadenings on curves and defining of ramp configuration manner, creating road's DTM (fig. 1) and generating of crosswise intersections with designed road's frame marked [4].

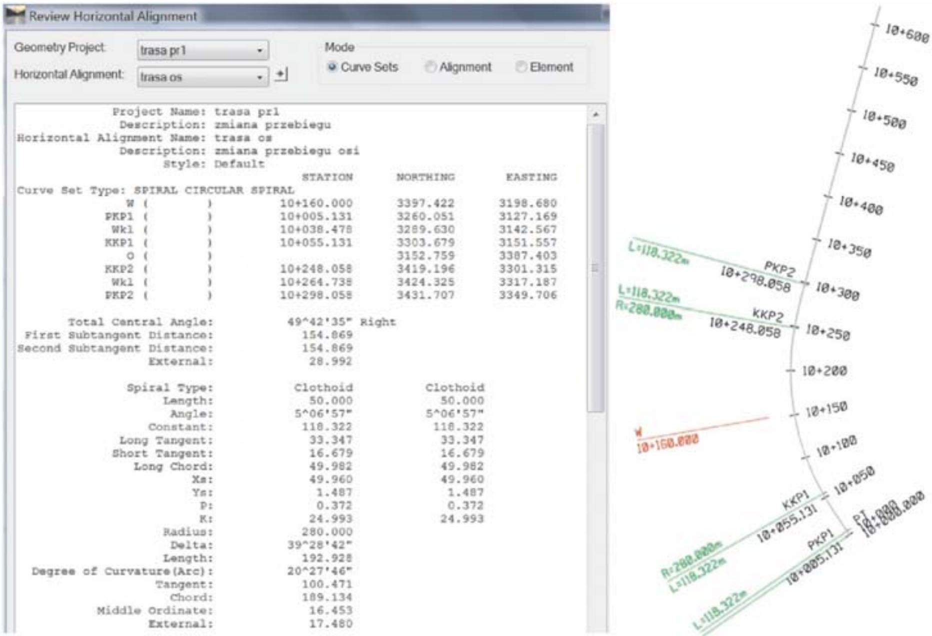

Fig. 5. Fragments: report of route geometry and its horizontal view with stationing

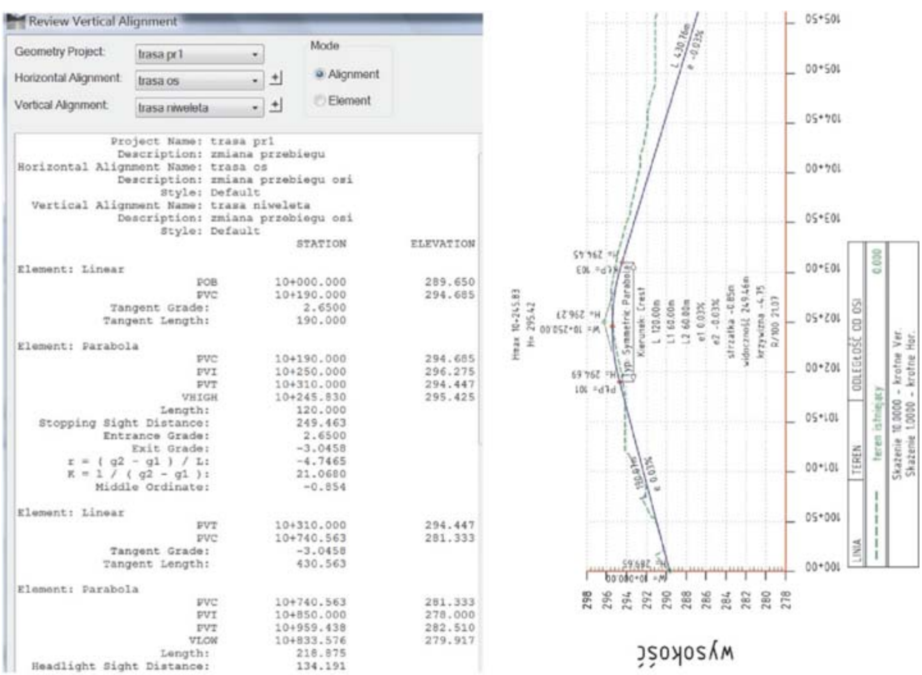

Fig. 6. Fragments: report of route geometry and route and terrain profile view

The following activity of designer's work is a calculation of ground works and reports generation. The application offers a few calculation methods. The volume is computed with the use of a triangle mesh method, grid mesh method and an end--area method. The last element of this phase is a mass-haul diagram generation.

Preparing reports of particular calculation phases, printings of design figures and a visualization of designed object as an image batch or animated movie showing the drive through a designed road are terminal activities of the project.

The accepted project is realized in the terrain conditions. Since then, a surveyor begins executing his responsibilities. The scope of his responsibilities includes geodesic elaboration of the project and its terrain realization supervising. *InRoads* applications series enables to prepare data in an interactive way to set out the objects in four groups (Fig. 7). The first group applies to elements connected with the ground surface such as geodetic position of set location and designed objects, eg. slopes or breaklines.

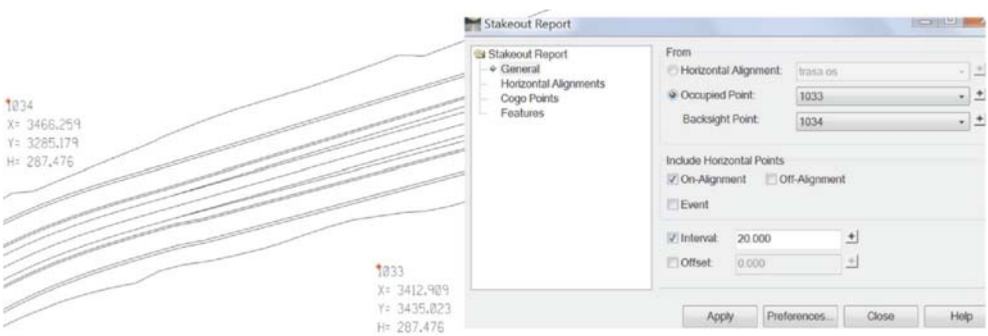

Fig. 7. Interactive report generating for route and terrain elements' ranging

The next group applies to geometric elements, which are control points, route characteristic points and linear elements, such as axes and road margins. The next group contains elements of technical infrastructure, eg. pipes, culverts, manholes or waterways. The last group applies to graphic elements which can be indicated in CAD application. The whole documentation which contains data necessary to set out the objects is prepared in as XML files. The software includes a large number of templates, with the use of which a XML report is prepared. The designer and surveyors are able to prepare reports which contain geometric parameters of the route elements and the rout's coordinates of characteristic points. The above file format is useful when coordinate points are set out (GPS, tachometer). It is also possible to generate reports which contain poles coordinates and angular and linear sizes to be placed in the terrain (tachometer) (Fig. 8). The application is also equipped in quick setting of control points tools, which are useful in a set out object correctness verification.

Centerline Stakeout Report

Centerline Alignment: trasa os

Offset From Centerline	BS	OC	FS Station	Angle Right	Distance
0.000	1034	1033	10+280.000	387.2765	103.960
0.000	1034	1033	10+300.000	392.6460	85.610
0.000	1034	1033	10+320.000	0.7898	68.156
0.000	1034	1033	10+340.000	14.1183	52.549
0.000	1034	1033	10+360.000	36.6003	40.958
0.000	1034	1033	10+380.000	68.9695	37.332
...	...	...	...	...	...

Centerline Alignment: Breakline1

Offset From Centerline	BS	OC	FS Station	Angle Right	Distance
0.000	1034	1033	0+004.113	140.7815	143.734
0.000	1034	1033	0+013.335	141.8048	140.724
0.000	1034	1033	0+015.874	142.0889	139.927
0.000	1034	1033	0+018.874	142.4251	138.986
...	...	...	...	...	...

Cogo Points:

Offset From Centerline	BS	OC	FS Station	Angle Right	Distance
	1034	1033		376.7280	33.446
	1034	1033		365.2194	56.779

Fig. 8. Fragment of the report on quantities for elements' ranging with use of a pole method

4. Summary

Poland's plans connected with making up the delays in communication routes' development put a construction industry on a huge challenge. Also the surveyors dealing with water and land engineering has to be prepared for work with the use of modern technology. They should gain topical knowledge in the scope of software and maintenance of modern geodesic devices and to utilise automatic systems of construction machinery work operation.

Currently communication routes' designs are prepared with the use of computer applications. They enable acceleration of some design works as well as increase of design accuracy with the use of a digital map version. The use of versatile and developed program suites makes designing of the complex technology sequence possible, which enables efficient project realisation. *Bentley InRoads Suite* series enables preparing design with automatic transition from geodesic data to a design and successive its realisation in terrain.

References

[1] *Bentley InRoads XM Edition. Roadway Designer Tutorial*. Bentley 2007 (digital version of the manual is available in folder c:\Program Files\Bentley\InRoads Group V8.9\Sample Data).

[2] *Bentley InRoads XM Edition. Working with InRoads*. Bentley 2007 (digital version of the manual and files to individual exercising are available in folder c:\Program Files\Bentley\InRoads Group V8.9\Sample Data).

[3] Strach M.: *Wykorzystanie aplikacji firmy Bentley do projektowania transportu kolejowego* [Application of Bentley software to design rail infrastructure]. Geodezja (semiannual of AGH), t. 12, z. 2, pp. 181–189.

[4] Zieliński T.: *InRoads 2004 Edition, version 8.7. Application for computer aided road designing*. ELPIL, Warszawa 2007.