Consequences of a complex using of 3D approach in the implementation of the road reconstruction - usage of TLS stop&go and usage of paving control system for milling machines

Přikryl, M. and Kutil, L.

Control System International a.s., Papírenská 114/5, 160 00 Praha 6, Czech Republic
Web site: www. controlsystem.cz, E-mail: office@controlsystem.cz

Abstract

The main subject of this paper is the implications of the use of 3D approach during the various stages of reconstruction of the road surface. It focuses primarily on the geometric quality of the work, on which among others depends the lifetime. Its practical application of using 3D approach, which has been implemented on the reconstruction project of the road surface on the 5th May street in Prague in July-August 2012. Activities using 3D approach, which has been implemented on the project:

1. 3D data collection by terrestrial laser scanning before reconstruction and digital terrain model creation
2. Creation of 3D design
3. Construction Automation by remote control of the road surface milling machine
4. 3D Quality Checking

Key words: terrestrial laser scanning (TLS), digital terrain model (DTM), 3D design, construction automation, quality checking

1 3D DATA COLLECTION

1.1 INTRODUCTION

TLS technology can be effectively used for measuring road surface before the actual reconstruction, both to document the current status and for identifying sites beyond specified damage tolerance (e.g. ruts, etc.). Furthermore, it can be used for the generating of the base model for the project, for quality control of milling and placing of new layers. After completion of the reconstruction it can be used for the status checking of the road surface during the usage (change monitoring) and for the control of selected sub-elements of infrastructure, such as bridge expansion joints/locks, etc.

1.2 ACTIVITY

Data collection was executed in order to create a base model for the project of the flat road on 2.61 km long lap. Specified requirements: Detailed points measured on the cover layer of the road in 0.2 m raster, in a density of 25 points per m^2. Planimetric/site line elements, namely the borders of the asphalt cover layer of a roads, traffic lanes and location ofcrash barriers. The points on the line in 0.3 m interval by reason of the triangulation quality for the digital terrain model.

Figure 1 3D TLS – technology of the precise measurement of the road surface

The processing of point clouds scanned during the measurements were executed in several successive steps (Fig 2). The individual points were transformed into the coordinate system of the construction stake-out network, subsequently it was performed by using the correlation of point clouds the adjustment of the individual scanner position measurements (positions of measurement).

Figure 2 Basic output: 3D point clouds with details of road and surroundings

1.3 OUTPUTS

After the noise abatement from the measurement and removal of unwanted scanned objects (cars, vegetation, ...), filtering of point clouds in the required density followed, and the classification of points into layers - asphalt roadway, the surroundings , the center lanes. The main output is the classified highly accurate (0.003 m) DMT (Fig. 3).

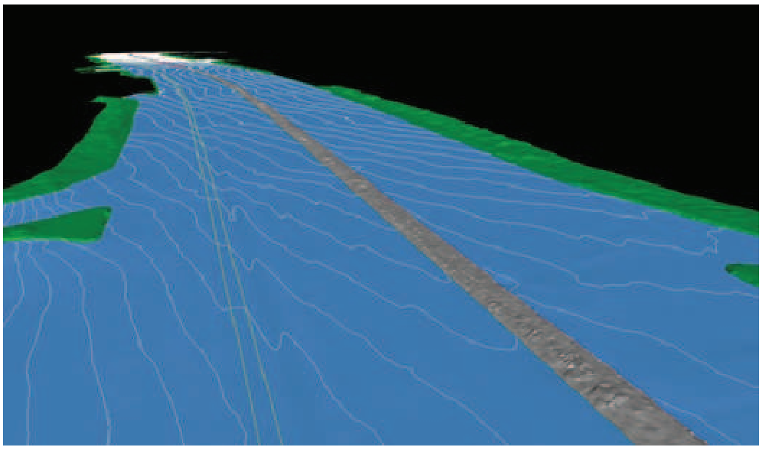

Figure 3 High-precision DMT (height standard deviation 0.003 m)

Height standard deviation determining height is given by:

$$\sigma z = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(z_i - z_i^K)^2} \qquad (1)$$

where z_i is the measured value of the 3D TLS, z^K_i is the measured value by method of measuring with higher accuracy (verification of measurement) in the 357 control points and N is the number of differences.

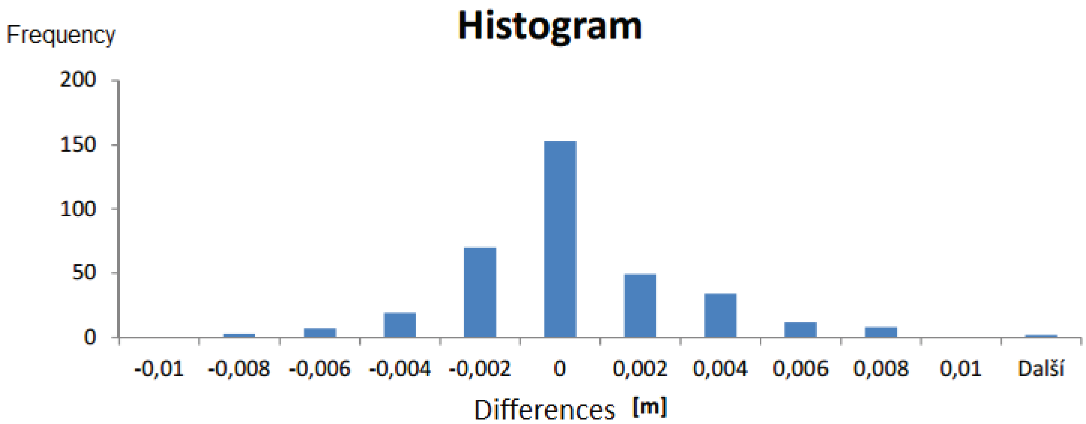

Figure 4 Height standard deviation histogram

2 3D DESIGN

2.1 INTRODUCTION

3D design is an important stage of 3D automated construction, the depth milling and new road surface follows from the model design of the flat pavement. It is necessary it to be created a very accurate DTM, it to correspond with reality on the site. 3D project must be designed properly so that it complied with slopes, flow conditions and the continuity of existing surfaces.

2.2 ACTIVITY

Flat road project (Fig. 5) was based on data from TLS. It has been designed with maximal flatness and fulfilment of the vertical alignment radius with the points density of 2 m in the longitudinal direction and of 1 m in the cross direction.

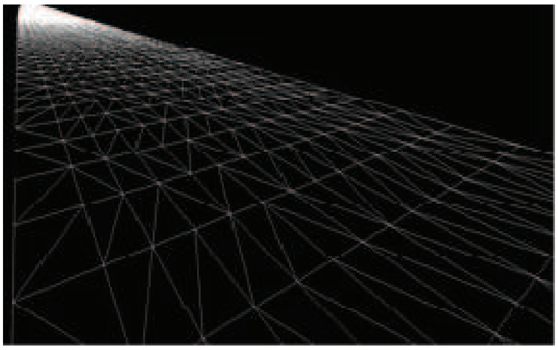

Figure 5 Example of the flat road design

2.3 OUTPUTS

3D flat road project was created in AutoCAD dxf format and Trimble terrain model (ttm).

3 CONSTRUCTION AUTOMATION

3.1 INTRODUCTION

It was used the automatic height control and cross slope system of Trimble milling drum. Trimble company cooperates in the development of levelling systems also with suppliers of construction machines (e.g. Caterpillar, Liebherr, Volvo, John Deer), who directly fit the machines in production with "TRIMBLE READY" installation kit, which allows quick installation and transfer of individual components between machines of various types and brands.

The milling machines performing the milling of the road surfaces were equipped with installation kit that allows flexibly to connect the levelling system and perform the milling works directly according to 3D design.

3.2 ACTIVITY

At using automated 3D control of milling works it is necessary to properly prepare 3D design and then it is subsequently inserted into 3D control unit. It controls the entire levelling system and operator of milling machine enters all the requirements for automatic height and cross slope control of milling drum.

On the side of milling machine, directly above the milling drum is placed electronic telescopic mast with the special 360 ° communication reflecting prism that is continuously tracked and simultaneously measured by the robotic total station. Before starting of the measurement it is necessary to orient the total station to two known points, in order it can determine the exact location and orientation of the milling drum in the space.

As mentioned above, 3D design data are stored on a memory card in 3D control unit. It processes the measured data from the total station and compares them with the stored design values. It subsequently automatically guides and maintains through the machine hydraulics the milling drum in the requested height and in cross slope, which requires projected DTM.

It is required the high accuracy of performed works at milling. For guidance of milling machine the Universal robotic total station equipped by fastest servomotors was used, which allows the high-speed tracking and by this way equipped machine can perform the construction works with millimetres accuracy and simultaneously it eliminates a rather complicated and time-consuming preparation of a levelling string, which copies the designed future terrain and by which the milling machine is guided.

4 CHECK OF 3D QUALITY

4.1 COMPARISON OF DTM BEFORE RECONSTRUCTION AND 3D DESIGN

From the differential DTM (Fig. 6) it´s seen the corrugated surface of the road in the longitudinal and cross directions with significantly beaten tracks.

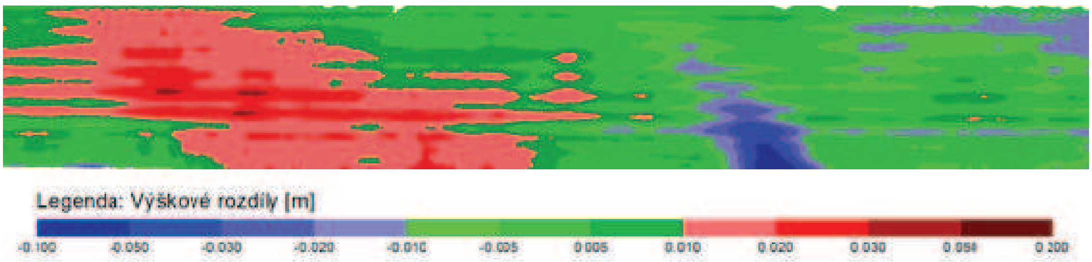

Figura 6 From the sample of differential DTM BEFORE RECONSTRUCTION it´s seen the road irregularity with significantly beaten tracks

The pie chart reflects the percentage of the tolerance compliance - comparison of the reality and the design (Fig. 7).

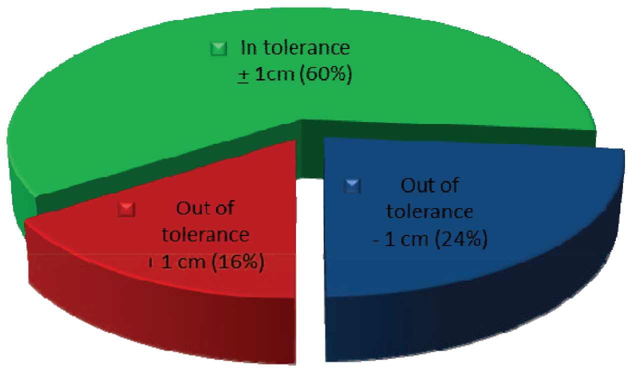

Figure 7 State before reconstruction

4.2 COMPARISON OF DTM AFTER MILLING AND 3D DESIGN

From differential DTM it´s seen that it managed to perform the road milling in toleration with flatness design.

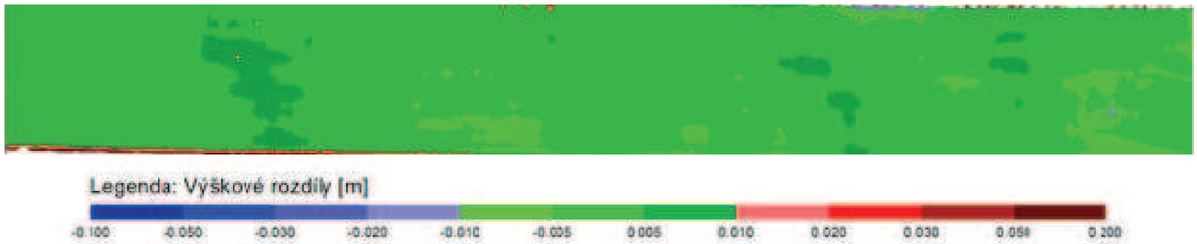

Figure 8 From the sample of the differential DTM it´s seen that it managed the roadmilling in tolerance with 3D design from 98.4%

The pie chart shows the percentage compliance of tolerance + 1 cm after milling (Fig. 9).

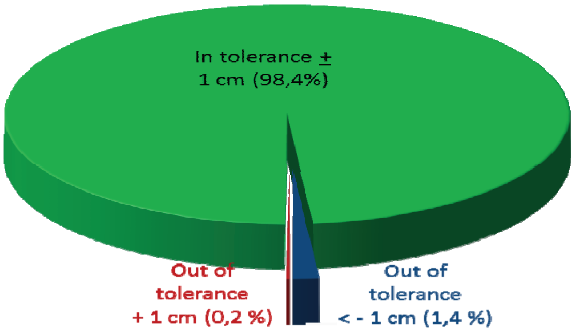

Figure 9 State after milling

4.3 COMPARISON OF DTM AFTER LAYING OF THE ASPHALT LAYER AND 3D DESIGN

From the differential DTM it´s seen that it managed to perform the laying of the road asphalt layer in tolerance with 3D design.

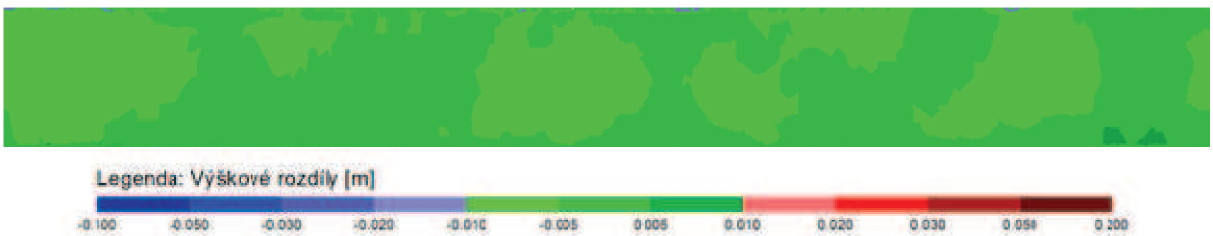

Figure 10 From the sample of differential DTM AFTER LAYING OF ASPHALT LAYER, it is obvious that it managed to perform the laying of the asphalt layer in tolerance with 3D projectfrom 99.6%

The pie chart shows the percentage compliance of tolerance + 1 cm after laying of asphalt layer (Fig. 11).

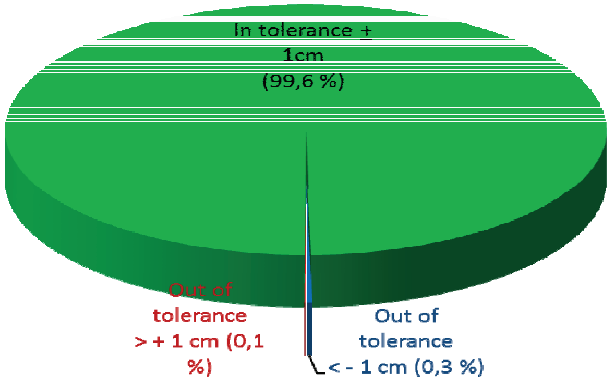

Figure 11 State after laying of the asphalt layer

5 CONCLUSION

The cost savings

By using accurate, relevant and high-quality 3D information during individual phases of the project it is possible during the road reconstruction realization to reach the similar results which this case study shows. Usage of 3D approach, besides already announced overall increase of the work quality, increase the driving comfort and safety of operation, also brings:

- Extending the lifetime of the road by more than 10%. (which in the European scale represents an annual reduction in the total number of kilometers of reconstructed roads by more than
- 45 000 km, when the average price of 1 km reconstructed road moves between 100 000-200 000 EUR [GIM INTERNATIONAL]
- Absolute control of the built-in material (eliminating the risks for unauthorized rework for non-performance of tolerance ±1 cm, which can represent up to 20% from the cost for the delivery and installation of material)

Standpoint of the contractor

It can be state that it has been achieved a significant priority in terms of improving noise ratios. As the main causes of successful compliance of this assignment can be indicate the using a thin surfacing with low noise Viaphone ® and achievement of a good-quality flatness of performed surface.

The usage of 3D approach inreconstruction realization from the perspective of the contractor affords the following benefits:

- Implementation of works with millimeter precision and minimization of the costs for surveying works (stake out, leveling string).
- Elimination of errors caused by manual operation of milled pavement thicknesses and so it does not come to the reduction of repairs lifetime because of infringement of the projected thickness of structural layers.
- Cost savings on the underlays of roadways substrates.

To achieve the ideal results it is necessary:

- to be pretentious on the development of 3D terrain model (slopes, drainage conditions, the sequence of existing surfaces and other engineering structures),
- to constantly check the observance of DMT by responsible surveyor.

Stand point of the main implementer of the usage of 3D approach during the implementation

Based on the study can be stated that using 3D approach during the implementation of the road reconstruction can be achieved, among other things:

- Minimization of errors, elimination of poor quality production, a significant increase in accuracy.
- A higher degree of transparency in the whole process.
- Time reduction needed for reconstruction, shortening of traffic closures, reduced impact on the environment (dust, noise, consumption of fossil fuels, CO_2 emissions).
- Savings in expected amount up to 10% from the total expended financial means

REFERENCES

PŘIKRYL, M.: Optimizing the Construction of Roads and Motorways, Stavební a investorské noviny. Year XVII, no.4, p.68-69, ISSN 1804-2864, 2010a.

PŘIKRYL, M.: The Most Accurate Measurement of Earthworks, Stavební a investorské noviny. Year XVII, no.10, p.6-7, ISSN 1804-2864, 2010b.

PŘIKRYL, M.: 3D Data For Efficiency And Savings. Road Conference 2011 Proceedings, section 2, p. 86, 2011.

PŘIKRYL, M., VOJTÍŠEK, M.: Case Study - The Contribution Of Comprehensive Utilization 3D Approach To The Implementation Road Reconstruction. Road Conference 2012 Proceedings, 2012.

PŘIKRYL, M., DOUŠA, P. KUTIL, L.: Benefits of using 3D Reconstruction Approach in Road Repair I / 2 Ricany near Prague. Conference Asphalt Pavements 2013 Proceedings