LASER SCANNING FOR GEOTECHNICAL ENGINEERING

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Abstract: Laser scanning technology allows contact-free determination of space coordinates, 3D modelling and visualization of complex structures and buildings, underground openings with extraordinary speed, precision, comprehensiveness, and security. The aim of this contribution is to introduce the practical use of this technology.

1. Introduction

SG-Geotechnika is the leading company on Czech market engaged in geotechnical and environmental engineering and well-established partner of significant world companies.

Department of Geodesy Engineering specializes in measuring of underground structures, mainly of tunnels. Another part of our department specialises in laser scanning application.

Currently we use laser scanning system HDS 3000 (High Definition Surveying) of Leica Geosystems company (Fig.1).

The main body of our work with HDS system are the laser scanning applications used mainly for determination of exact shape of underground structures, inaccessible rock faces, bridges and engineering buildings.

The HDS 3000 system consists of two basic components: the scanner itself and its accessories and the Cyclone control and processing software. The scanner is a panorama-type device with capability of surveying objects up to distance of 100 m due to material reflection (recommended operating distance is 50 m). The measurement is based on the 3D polar method principle. The distance is determined via the transit time. The field of view of the scanner is full 360° horizontal x 270° vertical. The measurement speed is 1800 points per second and the maximum number of points is limited to the value of 20000 x 5000 points in one scan. Scanning is done with precision of 6 mm for a single point and 2 mm for a modelled surface. The scanner utilizes a green-colour laser conforming to the 2nd safety class according to the CFR 1040 standard. The system supports standard surveying procedures, such as instrument setup over a known or assumed survey point, height-of-instrument measurement, and instrument orientation.

The scanner is equipped with a digital camera used to capture previews and set the field of view for scanning and for automatic coverage of point clouds with real colours.

The Cyclone-Scan module is installed in a portable computer and its task is to control the scanner itself, to store data and to process them. The data acquired with the measurement are immediately saved into directories. The program further performs a basic data processing, such as connecting individual scans into one unit and basic modelling.

Fig. 1: HDS 3000 laser scanning system

2. Applications

2.1. Tunnels

Scanning of the tunnel lining is very important for comparison of real state to the designed cross-section (the nominal profile).

It is accurate and the fastest way, how can the client learn if he really gets the tunnel he paid for, without deviations from the project.

As the tunnel scanning has to be done during construction, it is important that it can be done fast, causing minimum delays for other contractors.

According to our experience scanning speed can be as fast as 100 meters of full tunnel profile per hour.

Using this technology we get 3D digital model of tunnel tube in shape of so called point clouds (Fig. 2).

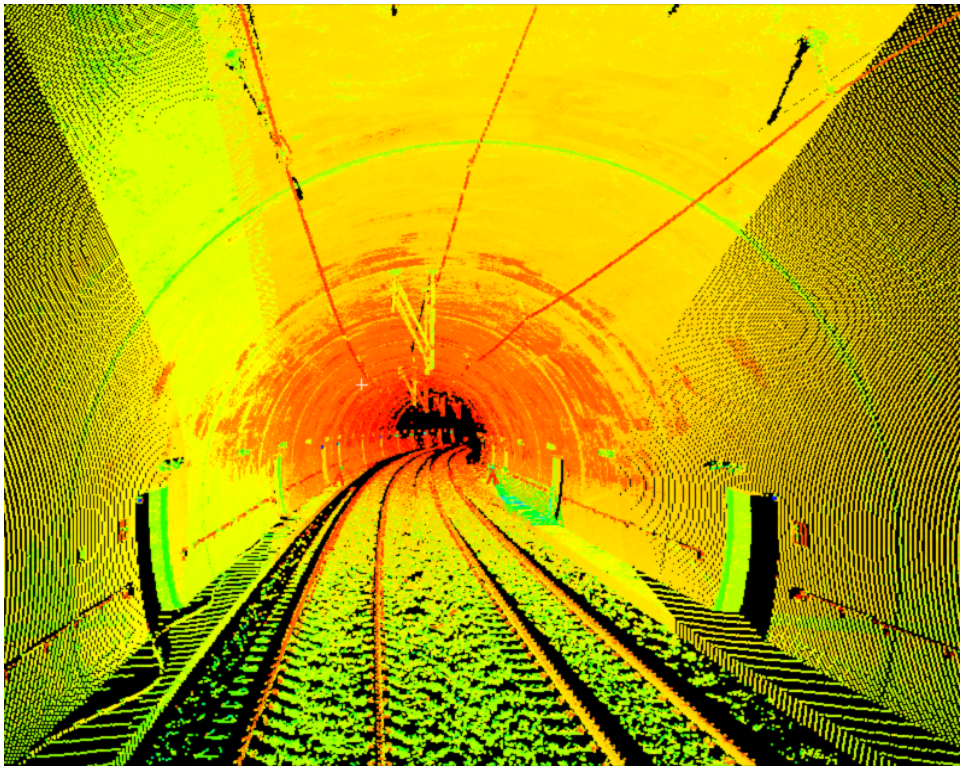

Fig. 2: Secondary lining of tunnel displayed in form of point clouds

The measured data processing proceeds after the terrain work is finished. We acquire about dozens of millions points at each stage. The Cyclone software then transfers (registers) all measured points into arbitrary 3D coordinate system required by client. Subsequently we remove all unwanted data (air pipes, construction mechanization, cables, etc.). Then the tunnel scan is divided into 100 meters sections, where the manufacturer of the scanner guarantees sufficient accuracy of 3D point position determination. These arranged point clouds work as a groundwork for 3D tunnel tube model creation in the shape of Triangulated Irregular Network (TIN).

It is also possible to get volume of difference between as-built condition and project. In the special DMT Atlas software modules that have been created with the cooperation with our experts, we create as-built tunnel lining map of deviations from the project. The deviations are drawn in colour scale (Fig.3). The problematic places, where for example, the lining surface interferes with the nominal profile, can be exactly determined. The construction contractor can thus easily mark the problematic places and make the corrections according to the project.

The other possible outputs are drawn cross sections of the tunnel, again with the colour deviations map (Fig.4). The chainage of cross sections, the deviation intervals and the colour map could be chosen according to the need of the client. The results can be exported to dxf, bmp or wmf format. We have long time experience in giving results in digital shape in pdf format. The volumes can be also evaluated from the measured values.

The data are saved in digital form in our company and it is possible to go back to individual projects at any time and to solve actual demands of the client.

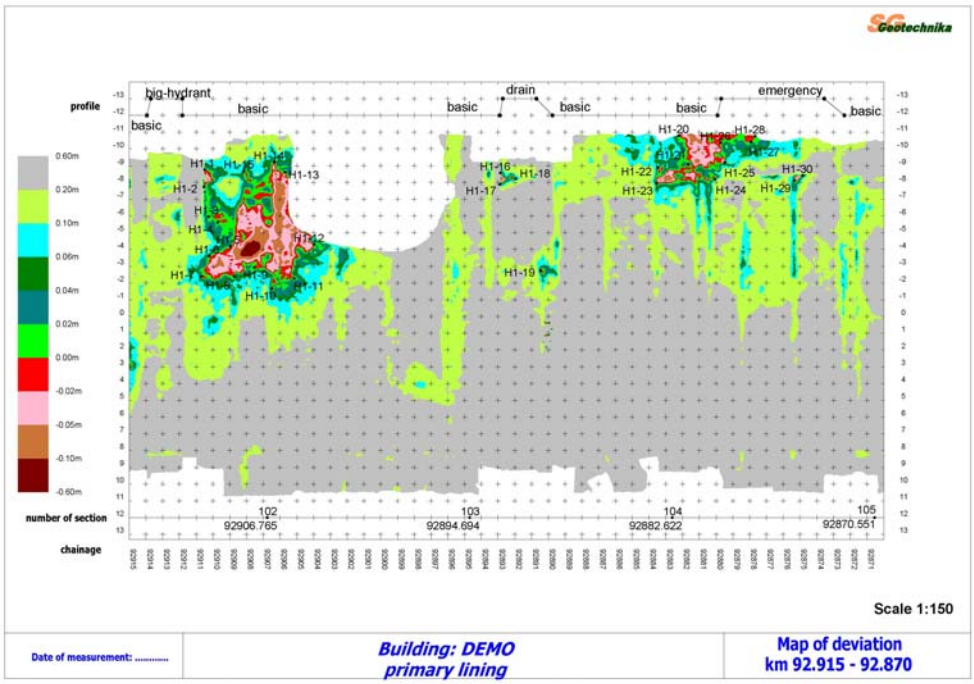

Fig. 3: Expanded part of the surveyed tunnel lining – map of deviations from the project

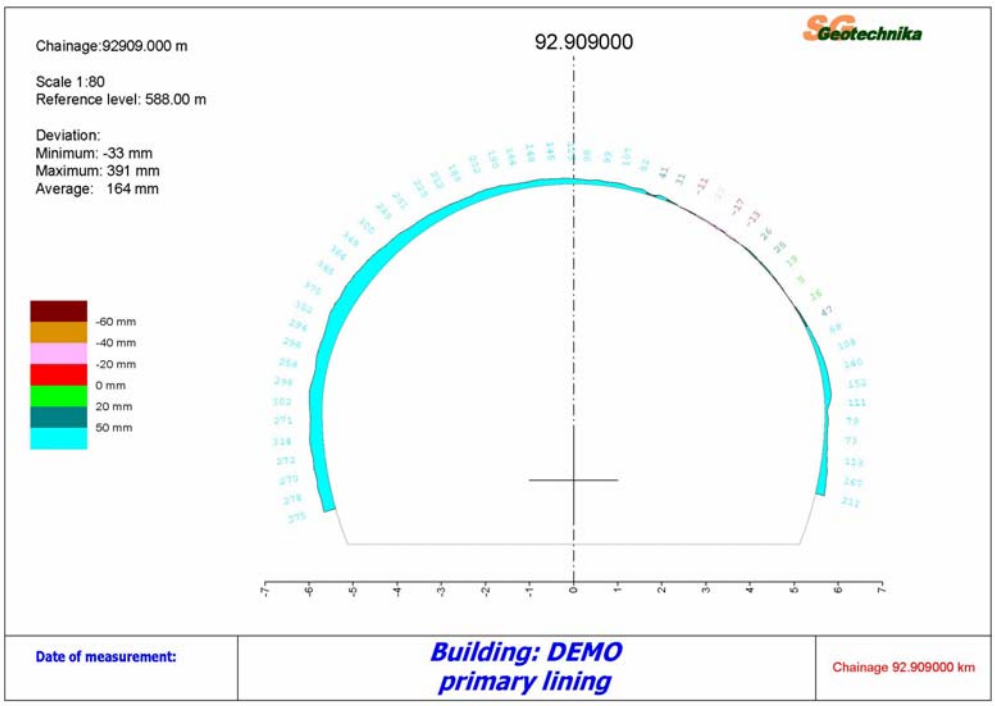

Fig. 4: Cross section of the tunnel – deviations of the finished tunnel from the project

2.2. Rock faces

Surveying of inaccessible rock face made by HDS system has become almost classical task. The advantage of laser scanning technology compared to classical methods is the accurate and fast contact free measurement from safe distance. Scanning of rock face works as groundwork for design of the rock remediation and for preparation of accurate as-is documentation after the remediation.

The preliminary works (removal of bushes in scanning area, foundation of point field by GPS station, etc.) are made before scanning itself. The rock faces are in most cases largely rangy, and consequently we scan from many positions to cover all the geometry.

The first processing in Cyclone software is in all tasks similar. Point clouds are registered to a common coordinate system and cleaned from noise. In next step the cleaned point clouds are merged in one group that serves as groundwork for creating rock face 3D model in the shape of TIN (Fig. 5). It is possible to generate from this model individual cross sections and elevations (Fig. 6), which we export for example to graphical environment of AutoCAD or Microstation software. Design works follow after the export (Fig. 7).

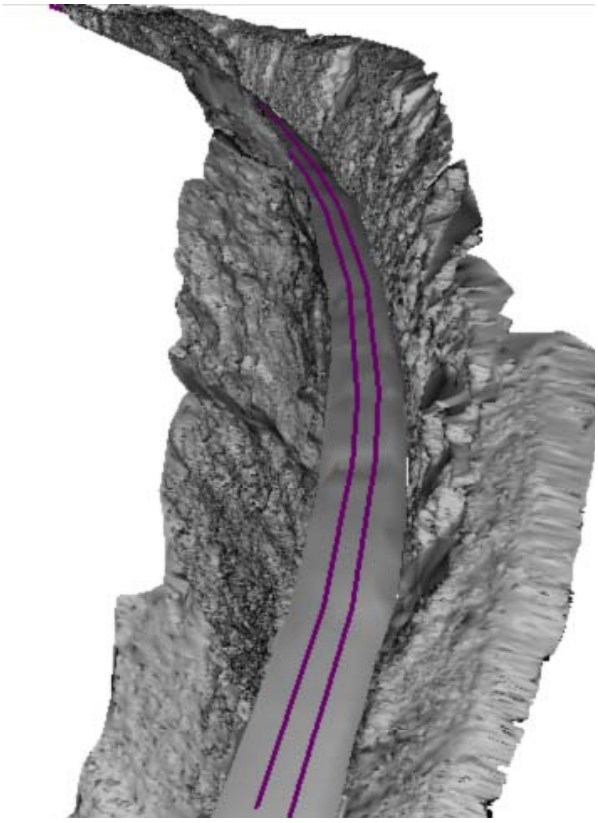

Fig.5: Digital terrain model in the shape of TIN

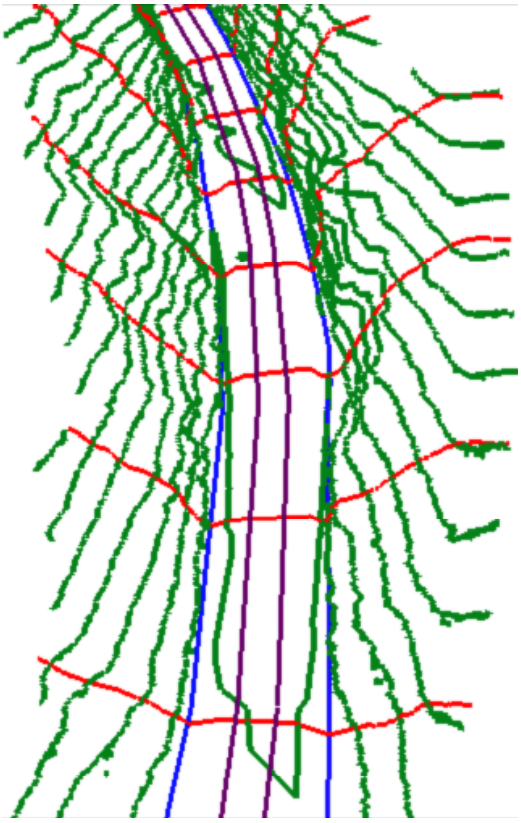

Fig.6: Digital terrain model in the shape of cross sections and elevations