Using of Laser Scanners in Pavement Management

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Abstract. The presented article introduces the utilization of laser scanning technology in the field of pavement management (PM) systems. Thanks to many advantages that allow objectification of road surface characteristics in a more holistic and sophisticated way, right decision-making within the PM, both at the network and project level. Specifically, outputs from the installed road scanners, such as SRS, Trimble CX and Lynx SG1 Mobile Mapper, have been combined to improve the accuracy. There has been found data correlation dependence of the development of rut depth for non-rigid pavements by evaluation of data from measurements at the public transport stop Hurbanova in Žilina during the years 1994 to 2018.

1. Introduction

The article presents the results of research activities of authors in the field of objectification of road surface morphology thanks to laser scanner technology with the priority to an orientation on the flatness of their surface [1, 2]. Nowadays remote control and measurements of various parameters of engineering structures become more and more useful due to relatively low cost, short acquisition time and sufficient accuracy for engineering purposes. The newest development of geodetic techniques is widely applied to check dimensions, deformations and movements. Recently, some new ideas of checking temperature distribution and its influence on engineering structures were studied [3, 4]. The importance of acquiring information from current on-site observations were emphasized by Sobala and Rybak [5]. Demonstration of importance of geotechnical monitoring of structures and deviations between measured and calculated results, which are necessary for structural health monitoring and calibration of numerical models were studied by Drusa and Vlcek [6].

Road surface morphology is the instantaneous arrangement of all road surface elements. It is the sum of all height deviations of surface points from an ideally flat (projected) surface, which is vertical sections of the observed planes form profiles as a random combination of waves with different wavelengths and amplitudes. These deviations determine the instantaneous values of road parameter variables [7, 8].

Regular measurement of road unevenness is important information in the field of Pavement management (PM). Based on the correct evaluation of the progress of deformations and their condition, optimal use of taxes in maintenance and rehabilitation (M&R) can be achieved through a cost-effective strategy of design, construction and rehabilitation strategy of pavements. PM system is a set of tools (one of which may be BIM - Building Information Modelling) and methods for managerial planning of...
construction and maintenance of road and airport pavements to ensure their operational condition for a given period of time [9]. PM is often seen as part of a broader governance scheme, such as asset management (U.S. Federal Highway Administration System), and requires consideration of a more holistic approach to assessment, analysis, and implementation.

Information on traffic, existing conditions, environmental data and the history of road network construction provide the basis for all subsequent activities in the PM. Special attention must be paid to the accurate but practical testing of existing roads - the use of automated and non-destructive testing without disrupting of traffic (Figure 1).

**Figure 1.** Representation of unevenness of the road surface of the public transport stop Mostná in Žilina acquired by the Lynx SG1 Mobile Mapper UNIZA device

### 2. Basic methods of laser 3D scanning

Laser scanning (also known as lidar) combines controlled steering of laser beams with a laser rangefinder. By taking a distance measurement in every direction the scanner rapidly captures the surface shape of objects, buildings and landscapes in selected resolution. Construction of a full 3D model involves combining multiple surface models obtained from different viewing angles, or the admixing of other known constraints. Laser scanners vary in type of use and can be stationary, or mobile.

Stationary scanners are usually installed on a tripod or on a special pad for scanning objects. Mobile scanners can be installed on aircrafts, helicopters or drone vehicles. Currently, there are many types of scanners that differ in their resolution. Scanners actually used by the Research centre of UNIZA are used for mobile mapping of objects (Figure 2), for objectification of road evenness and for measurement of microtexture of road surface (Figure 3).

Today's scanners have built-in sensitive mirror cameras that scan the surface of the scanned object and ensure the fidelity of its textures. At the output of such a system is a very accurate spatial copy of the scanned object on a reduced scale. The device SRS (Static Road Scanner) of the Department of Road Construction FCEI UNIZA is designed for measuring the morphology of road surfaces with a resolution of up to 15 μm (Figure 3).
3. Validation of road irregularities by a terrestrial laser scanner

Current scanner systems are able to scan a desired object with a 3D scanner and use a program to create a point cloud corresponding to the object being scanned. When applying laser scanning to the issue of road unevenness, the terrestrial laser scanner Trimble CX using a combined method of measurement, pulse (time-of-flight) and phase (phase shift), is used at Faculty of Civil Engineering of UNIZA. The range of the device is 1.2 to 80 m at 90% reflectance, and up to 50 m at 18% reflectance. Scan speed is 54,000 dots/s. Standard deviation is 1 mm per length of 30 m; 1.8 mm per 80 m, for a horizontal angle is 15" and for a vertical angle is 25". Modelled surface accuracy is ± 3 mm, laser beam trace size is 8 mm per 25 m; 13 mm at 50 m, with min. angular step of 0.002°. The first measurement of the flatness
of the road surface of a public transport stop with the Trimble CX device was performed and evaluated in 2013 in the Trimble Realworks 6.0 and the outputs of which can be imported into the AutoCAD program in the .dwg format or .ptc format.

The second measurement of the flatness of the road surface in question was carried out on 22.10.2015 from two measuring stations (MS) in full traffic without direct contact with the road surface (the time required to perform a detailed scan from one station was three minutes). On the map (Figure 4, right), which is the basis for a more detailed quantification of road surface irregularities, surface deformations in the form of rutted tracks are visible. The generated profiles show the shape of the road surface in the form of sections, enabling the evaluation of the overall state of road flatness together with the determination of the limit values of deformations.

From the profiles thus obtained, it was possible to compare with traditional methods of measuring inequalities. For the purposes of comparison with the standard procedure for measuring road irregularities with a 3 m levelling bar, maximal value of the depth of the right track \( R_{\text{max Trimble}} = 76 \text{ mm} \), which represents a relatively exact match with the data obtained by the levelling bar from 2015 \( R_{\text{max bar 3m}} = 73 \text{ mm} \). The third measurement was performed with a mobile 3D scanner Optech Lynx SG 1 owned by the UNIZA Research Centre.

![Perspective view from MS2 together with background images and surface map obtained from a point cloud](image)

**Figure 4.** Perspective view from MS2 together with background images and surface map obtained from a point cloud

The device uses 2 LIDAR sensors, each with a power of 600 kHz and a range of 360 °. LIDAR (Light Detection and Ranging) is an abbreviation for optical remote sensing technology using pulsed radar beams to measure the distance between an object and a LIDAR located on board an aircraft. The range of the device is up to 250 m, at 10% reflectivity. Scan speed can be set up to 1.2 million dots per second. The vehicle speed during the measurement can be up to 100 km / h. Accuracy of the modelled area ± 5 mm, georefined position accuracy ± 5 cm depends on the quality of GPS signal reception. The device is equipped with a 360° panoramic 5 MPx camera and the measurement of the flatness of the surface of the Hurbanova public transport stop was carried out in 2018 (Figure 5).
Figure 5. Generated profiles and visible irregularities on the road surface of the Hurbanova public transport stop in Žilina, October 2015

Output shown in figure 6 was obtained in Optech LMS 6.1 software and outputs can be imported into programs supporting point clouds in .las format, e.g. Microstation, and others.

Figure 6. Evaluations of the flatness of the 10 m section of the road of the Hurbanova public transport stop from January 2018. Legend: yellow - levelling plane 0 mm, green -5 mm, blue -15 mm, purple more than -25 mm.

4. Conclusions
The paper presents examples of outputs realized by a team of employees of the Faculty of Civil Engineering and the UNIZA Research Centre in the field of laser scanning of road surfaces enabling a more holistic, sophisticated way of decision-making within PM at the network and project level. Specifically, the outputs of laser scanning devices SRS, Trimle CX and Lynx SG1 Mobile Mapper UNIZA are presented, the main advantage of which is their non-contact way of obtaining the necessary data on the transverse flatness of the road surface. The main attention is paid to the measurement of the transverse unevenness of the road surface of the public transport stop on Hurbanova Street, where measurements of this parameter (Figure 3, 5, 6) were performed from 1994 to 2018. Based on these measurements, the necessary correlation dependence of the transverse unevenness of non-rigid pavement of public transport stops was estimated based on the number of design axle crossings.

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