XXIII R-S-P seminar, Theoretical Foundation of Civil Engineering (23RSP) (TFoCE 2014)

Using of 3D Road Surface Model for Monitoring of Transverse Unevenness and Skid Resistance

Martin Slabej*<sup>a</sup>, Peter Kotek<sup>b</sup>

<sup>a</sup>Research centre University of Žilina, Univerzitná 8215/1, 010 26 Žilina Slovakia
<sup>b</sup>Department of Highway Engineering, Faculty of Civil Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovakia

Abstract

Qualitative characteristics of pavement in wide range reflects the pavement serviceability, which is a summary of the characteristics of the pavement, providing a fast, smooth, economical and especially safe driving of motor-vehicles. The target factor of pavement serviceability and safety of roads represents the quality of their surface properties. Within the Research Center of the University of Žilina are dealing among others with scanning the pavement surface in order to monitor the individual parameters of pavement serviceability. This paper deals with the creation, analysis and evaluation of 3D-road surface model in terms of two properties pavement serviceability – the rut depth and its texture.

Keywords: pavement serviceability, 3D scanner, profile, rut depth, texture

1. Introduction

Pavement diagnostics is together with the collection of traffic data and updating process of current database of the road network, the main input of pavement management processes. It is the most challenging process of the entire PMS in terms of financial, time, technological and personnel resources. This article is focused on the collection of data regarding pavement structure using the interpretation and collection of data regarding the quality of road surface by scanning its surface with a laser beam.

2. Testing field and measurement equipment

The test field has a length of 6 meters and a width of 2.2 meters. The pavement structure was designed as a pavement for a road with traffic load class TLC III. It is a flexible pavement with bitumen concrete surfacing. The wearing base layer is made of asphalt concrete (AC) 11; CA 35/50; 40 mm thick. The base course layer is made of asphalt concrete (AC) 16 P, CA 35/50; 80 mm thick.

* Corresponding author. Tel.: + 421 41/ 513 5930; fax: + 421 41/ 513 5510.
E-mail address: matrin.slabej@rc.uniza.sk.
The road base is a mechanically bound aggregate MSK 31.5 GB; 180 mm thick. Sub-base is gravel ŠD; 31.5 (45) GC; 200 mm thick.

The laser scanning technology allows focusing in detail on the pavement surface and it’s near surroundings in a coordinate system. In many cases, it is a more detailed measurement than it is provided by other technologies. Among other advantages of this method a self-moving machine can be included, which does not need any other external mechanisms, that can make difficult to scan remote surfaces and thereby negatively affect the measurement itself [1]. The system allows free movement of the object during scanning. It is also possible to see an image of the scanned surface in real time. On the test field (Fig. 1) were realized the measurements using a smaller type of handheld 3D scanner - ZScanner 800 (Fig. 2) with a maximum resolution of 0.1 mm. The disadvantage of handheld equipment is time consuming measurement and the evaluation.

3. Transverse evenness

The evaluation of evenness road in transversal direction consists in measurement of transverse evenness as aberrance from theoretical condition. From this reason is in terminology important to differentiate these two basic terms. Transverse road evenness is unevenness of road surface in vertical direction on the traffic direction. It expresses as the difference between existing and theoretical transversal profile of road. The measurement and evaluation of transverse evenness is realised because of determination quality of road pavement from the aspect of permanent deformations, which are well-known as road rut.

By measurement of transverse evenness are valuating these parameters:
rut depth /RD/ – vertical distance between connection of apex wave and the lowest point of wave,
permanent deformations /PD/ – vertical distance between first and last point of measured profile and the lowest point of wave (fig. 3),
water depth /WD/ – vertical distance between horizontal flat ground in the position the lowest point of wave and the lowest point of wave (fig. 3).

The creation of road ruts (Fig. 3) is as a result of mostly two dominant aspects; in first case over limited traffic load and excessive traffic density and in second case parking and staying heavy trucks on unassimilated surface of pavement – especially inappropriately elected surface. From this reason is very helpful to use the testing field (Fig. 1), [2].

4. Texture

Texture of pavement surface has great impact on anti-skid features of the pavement, maybe the greatest. It is the morphological layout of material of the pavement surface. It is usually described by surface profile which is defined by two coordinates. They are a combination of bumps described by wavelength (horizontal projection of bumps) and amplitude showing vertical projection of bumps in terms of given range. The surface texture influences plenty characteristics of car-pavement collaboration including friction by wet weather, noise, water spraying, rolling resistance, tyre wear and damage of the car. In the point of view of skid resistance microtexture and macrotexture have their special meaning [3], [4].

Microtexture reflects tiny prominences on aggregate grains and describes how the grains are smooth or rough and therefore the friction between tyre and pavement surface rises. It is characterised by wavelength range from 0.001 to 0.2 mm and amplitude range from 0.0 to 0.2 mm [5]. Due to the range there is created impression of rough surface but microtexture is usually too soft to recognize it visually. Microtexture of aggregate surface issues elementary friction level and is important on dry surface by low speed up to 40 km/h. Another important meaning lies in an interruption of continual water film and creation direct contact of tyre with pavement surface [5]. Values of microtexture are partially influenced by the ability of aggregates to keep sharp edges and so maintain rough surface which should resist to smoothing caused by truck traffic at longest. Microtexture is partly depended on composition of an asphalt mixture as mineralogical structure of aggregates, max grain size, percentage of small aggregates, and content and type of asphalt binding.

Macrotexture of pavement surface is responsible for basic drain ability of pavement. It represents irregularities on pavement surface and describes a way in which single aggregate grains are ordered. It is characterised by wavelength range from 0.25 to 10 mm and amplitude range from 0.2 to 10 mm [5]. It is important for fast water diversion from surface of wet pavement because the water acts as lubricant and it shows in the friction between tyre and pavement. Macrotexture plays serious role by middle and higher speeds of vehicle (over 40 km/h). A good macrotexture can be get by suitable proposal of aggregates-mortar rate. It can be also achieved with proper combination of methods of final surface modification.

5. Analysis of measuring data

The scale and accuracy of scanning are important for correct formulation of the requested level of texture and for implementation of scanned data. Scanning with the help of 3D scanner enables formulation of surface in three proportions and therefore complex information about the pavement surface is available. To compare accuracy of the process, the scanning was done in four resolutions: 2, 1, 0.5, and 0.2 mm, examples are in Fig. 4. The values were selected with a view to potentialities of the device and also to the macrotexture defined above.
From the scanned surface can be displayed profile by an elected resolution, Fig. 5. It is clear that increasing accuracy of resolution scanning the profiles show tinier projections. Appropriately chosen scan accuracy is important for further processing of the measured data.
Based on profiles from measured surface the mean profile depth (MPD) was calculated and it is used to represent state of surface macrotexture. The values of the mean profile depth. The values of average depth profile are changing gradually with precision scanning. As the accuracy of scanning was rising the MPD value also raised. When the accuracy was incremented 0.1 mm the MPD value incremented 0.01 unit and dark columns are the scanned values.

<table>
<thead>
<tr>
<th>Accuracy (mm)</th>
<th>2</th>
<th>1.9</th>
<th>1.8</th>
<th>1.7</th>
<th>1.6</th>
<th>1.5</th>
<th>1.4</th>
<th>1.3</th>
<th>1.2</th>
<th>1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPD (mm)</td>
<td>0.604</td>
<td>0.612</td>
<td>0.619</td>
<td>0.627</td>
<td>0.634</td>
<td>0.642</td>
<td>0.649</td>
<td>0.657</td>
<td>0.664</td>
<td>0.672</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accuracy (mm)</th>
<th>1</th>
<th>0.9</th>
<th>0.8</th>
<th>0.7</th>
<th>0.6</th>
<th>0.5</th>
<th>0.4</th>
<th>0.3</th>
<th>0.2</th>
<th>0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPD (mm)</td>
<td>0.679</td>
<td>0.686</td>
<td>0.694</td>
<td>0.701</td>
<td>0.708</td>
<td>0.716</td>
<td>0.732</td>
<td>0.748</td>
<td>0.764</td>
<td>0.780</td>
</tr>
</tbody>
</table>

Scan unevenness is sufficient to scan at a lower resolution, seeing that the transverse unevenness is in the order of millimeter values. Scanning of cross section with a length of 1.6 meters and a width of 8 cm was realized with the scanning resolution accuracy of 1 mm. For better determination of analyzed profile and mainly due to the relatively difficult lighting conditions are used in the measurement template bounding observed cross section (Fig. 6).

Fig. 6 Template bordering the observed cross section.

Fig. 7 shows one of the evaluation of the cross section on the test field. As is immediately obvious, the transverse unevenness is not present, respectively intercepted unevenness is inappreciable value.
During the detailed and enlarged view of the edge of the profile are evident nails, which have their legitimate role in repeated measurements and will serve as a permanent points through which it will be possible to measure an identical profile in any timeframe. In the middle of profile is shown double axle, which simulates the real effects of crossover of the truck on the experimental field. Our priority effort will monitor changes in the surface properties of the pavement after a defined amount of axle loads. On the ground of this data will then be possible to determine the functions, which will predict the development of analysed serviceability parameters of pavement’s surface, depending primarily on the traffic load.

Conclusion

One of the most important and the most significant factors which directly influences economic factors as well as safety traffic on the roads is a parameter of serviceability. It is important not only from the perspective of properly elected maintenance, reconstruction, or planned road restoration. Constant road´s monitoring and analysing helps overall diagnostics of the road network.

This article introduces basic characteristics and two important parameters of serviceability skid resistance and transverse unevenness. It also points out on the necessity of the further monitoring and analysing the above mentioned parameters. They will create features and models that will later play an important role in the future predictions and thereby directly help to develop and attempt to improve our road network.

Acknowledgement

The research is supported by the European Regional Development Fund and the Slovak state budget for the project “Research Centre of University of Žilina”, ITMS 26220220183.

References