

Sources of kinematic excitation of vehicle

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Abstract. The road unevenness represents the main source of kinematic excitation of vehicle. During the process of solving the problem of vehicle road interaction the road unevenness represents the input value. The unevenness must be mapped, mathematically described and then used as an input value for numerical simulation of moving load effect on pavements. The submitted paper is dedicated to the description of such procedures.

1 Introduction

Describing the unevenness of pavement is an important part of the investigation of vehicle road interaction. There are many options for analysis of measured data and the paper deals with the analysis of statistical properties where numerical computing environment MATLAB was used to simplify the process of computing and for graphical expression of values. In the first step, the unevenness of runway in Žilina Airport was measured by spatial scanning and levelling, in the second step, reached data were studied.

2 Measurements

The measured part of the runway was 464.0 m long and 4.0 m wide in increments of 0.25 m. First, 17 longitudinal road profiles were mapped using the spatial scanning method. Subsequently, 2 longitudinal road profiles were measured using levelling, so the comparison of those 2 sets of data obtained by two distinct methods was possible to provide. The part of the runway in a range from 280.0 to 420.0 m was selected to examine since was almost linear. This means that it is possible to separate dynamical part of the record and remove longitudinal slope. The three-dimensional model of data reached from the scanning of all 17 profiles is presented in Fig.1. The data were adjusted when necessary, regarding the problems during measuring and the resulting inefficiency. The selected part of the runway is shown in Fig.2.

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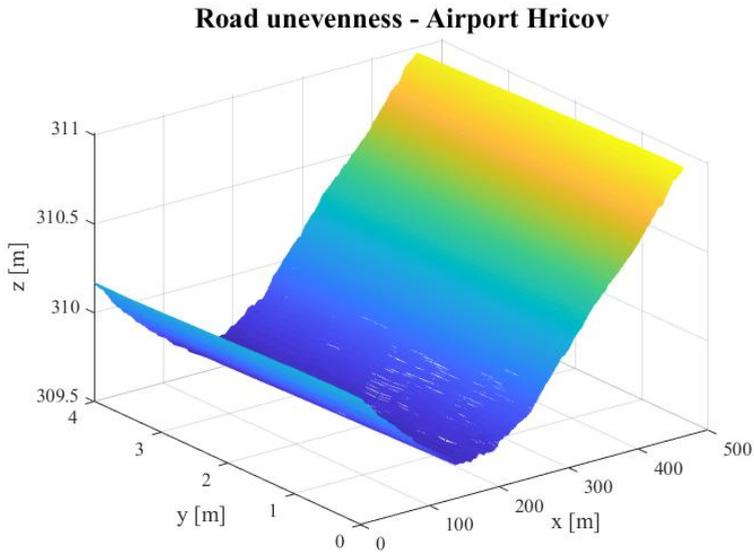


Fig. 1. Three - dimensional model of scanned runway.

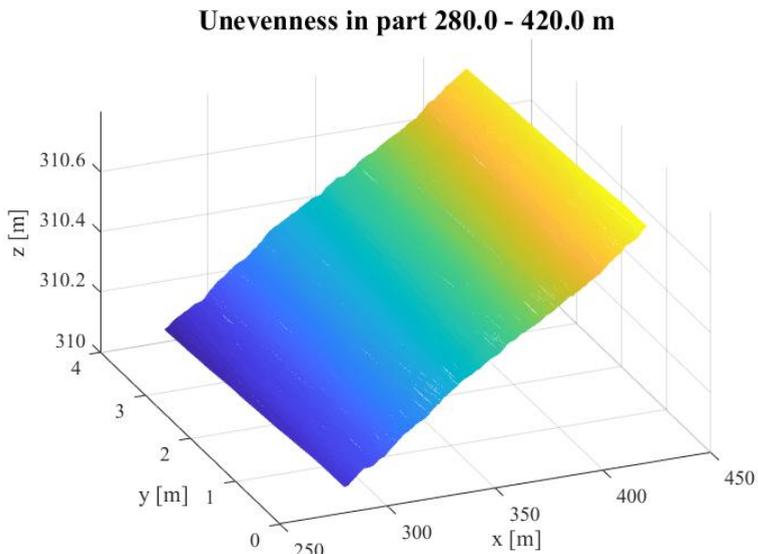


Fig. 2. Selected part of the measured runway.

The relation between values of one profile can be approximated by the linear function as shown in Fig.3. This means that the curve of unevenness has the linear part and the dynamical part. The linear part is caused by longitudinal slope and is not important for further analysis. The important compound is the dynamical part, which can be separated.

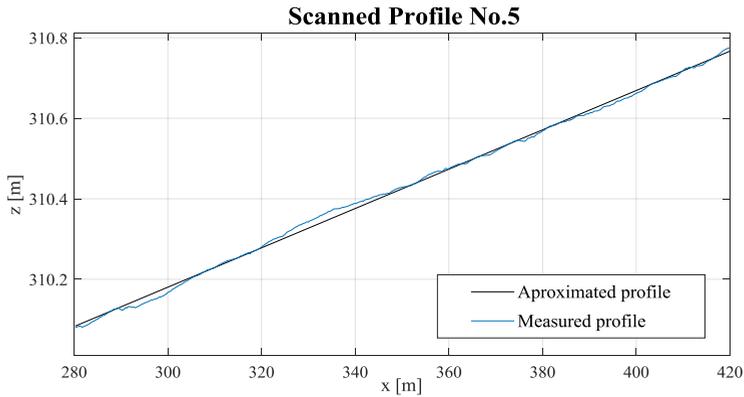


Fig. 3. Aproximation by the linear function of scanned profile No. 5.

After separating the dynamical component as displayed on Fig.4, the height above sea level was also cancelled, only unevenness was left in.

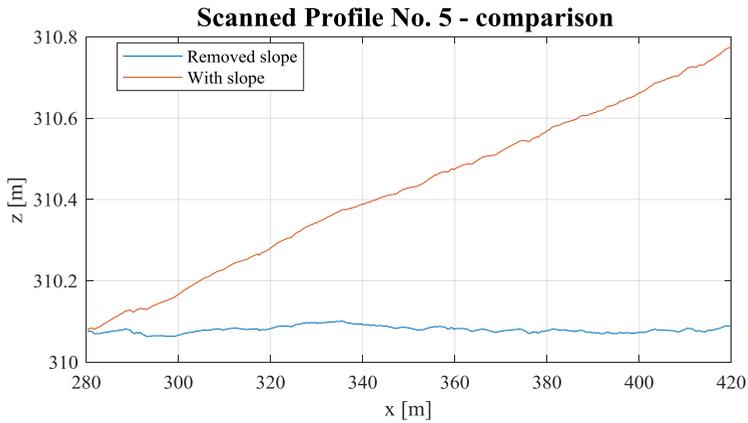


Fig. 4. Longitudinal profile- original profile with slope and with removed slope.

The Fig.5 shows a sequential graph of the unevenness of scanned profile with removed longitudinal slope and with zero average height above sea level.

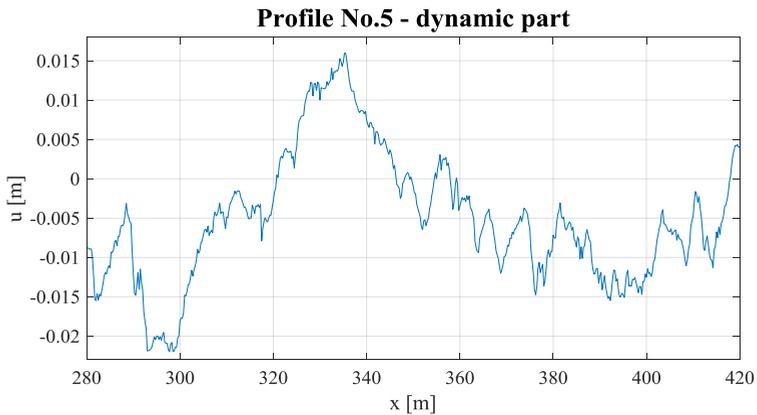


Fig. 5. Dynamic part of unevennes of scanned Profile No. 5.

3 Statistical characteristics

Data obtained from deleting the longitudinal slope were analyzed. Some of the equations of characteristics performed in the analysis are the following:

Root mean square average deviation

$$R_q = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - m_x)^2} \tag{1}$$

Variance

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N (x_i - m_x)^2 \tag{2}$$

Skewness- asymmetry coefficient

$$R_{sk} = \frac{\sum_{i=1}^N (x_i - m_x)^3}{N \cdot \sigma^3} \tag{3}$$

Kurtosis- kurtosis coefficient

$$R_{ku} = \frac{\sum_{i=1}^N (x_i - m_x)^4}{N \cdot \sigma^4} \tag{4}$$

Those descriptive characteristics are shown in Table 1. The values were calculated in centimetres. Two sets of data of two longitudinal profiles have been compared to discover if there is a considerable difference between reached values from measurement and whether the statistical properties of two profiles are discrepant.

Table 1. Descriptive statistics for values in centimetres.

	Profile No. 5		Profile No. 13	
	Scanning	Levelling	Scanning	Levelling
Range	3.7992	3.9746	3.9966	3.9340
Variance	0.6861	0.6982	0.8833	0.8530
Kurtosis	2.9446	3.0066	2.6521	2.7337
Skewness	0.4156	0.2387	0.3829	0.3942
Standard deviation	0.8283	0.8356	0.9399	0.9236

4 Comparison of values and verification of their likeness

Due to this table, it is possible to compare the accuracy of methods used for measurements. Also, it is relevant to argue that in the case of descriptive statistics it is not very important which longitudinal profile is measured. In both cases, scanning and levelling, in both profiles, those statistics did not differ significantly. The evidence of affinity is shown in the following figures (Fig 6, Fig. 7, Fig. 8, Fig 9). When comparing the unevenness of both

profiles using one method, the major difference can be observed. This can be documented in Fig. 6 and Fig. 7. Comparison of two methods does not reveal considerable variance, which is affirmed by Fig. 8 and Fig. 9 and by values in Table 1.

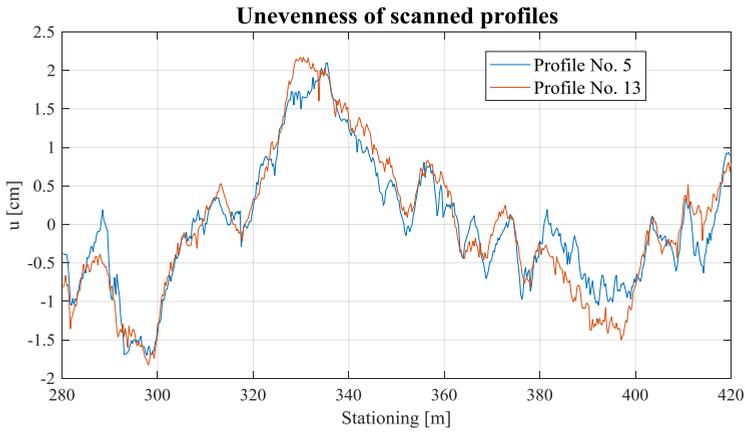


Fig. 6. Scanned profile No. 5 and No. 13.

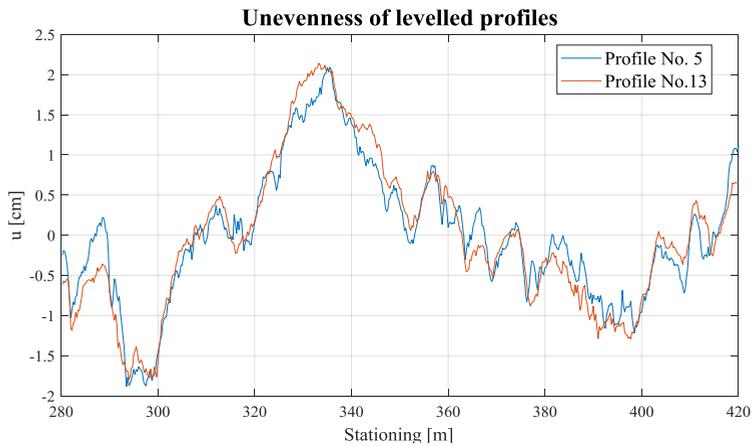


Fig. 7. Levelled profile No. 5 and No. 13.

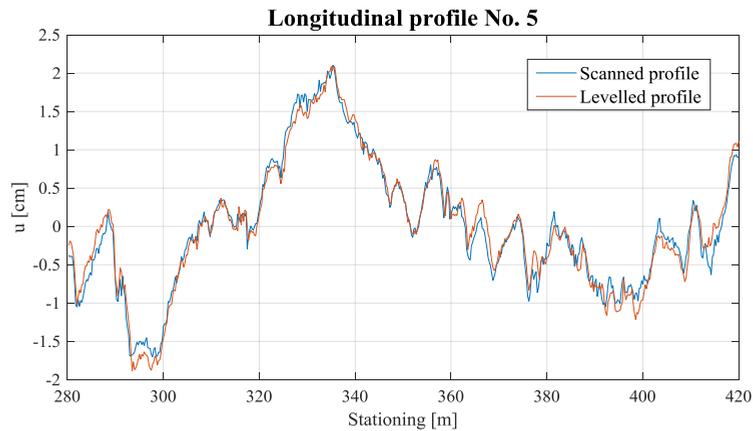


Fig. 8. Scanned and levelled longitudinal profile No. 5.

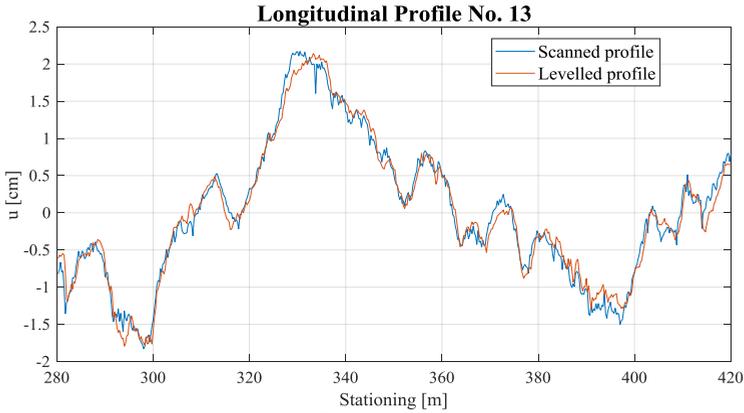


Fig. 9. Scanned and levelled longitudinal profile No. 13.

The most varying values were the asymmetry coefficients. The most symmetrical probability distribution density was evaluated in case of levelling of profile 5 and the least in case of scanning of profile 5. The graphical expression of this property is displayed on Fig.12 and Fig.10. The kurtosis coefficient did not differ much, but we can also observe minor differences mainly in the way how the curve of Gaussian normal distribution reaches the value 0.5.

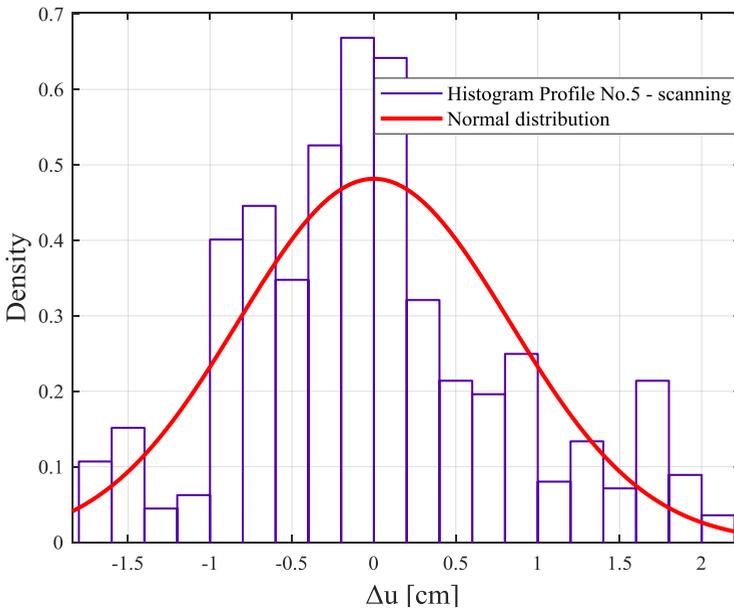


Fig. 10. Histogram and probability distribution density – scanned Profile No. 5.

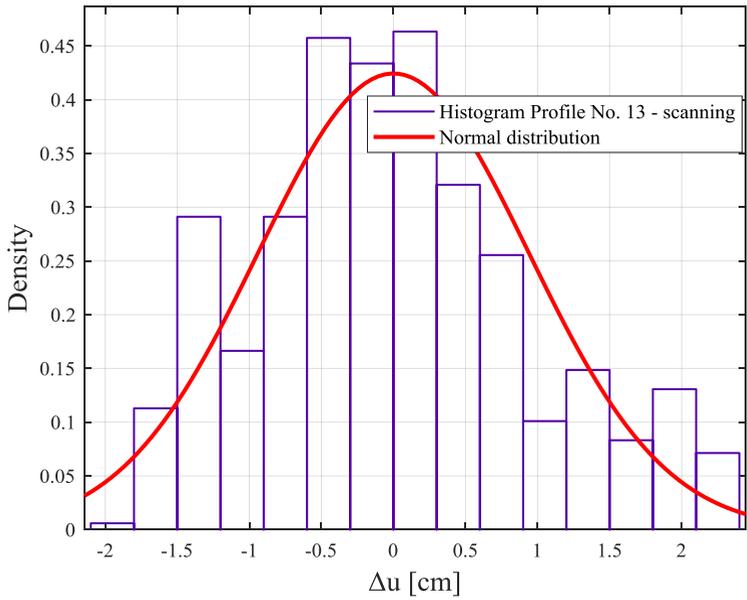


Fig. 11. Histogram and probability distribution density - scanned Profile No. 13.

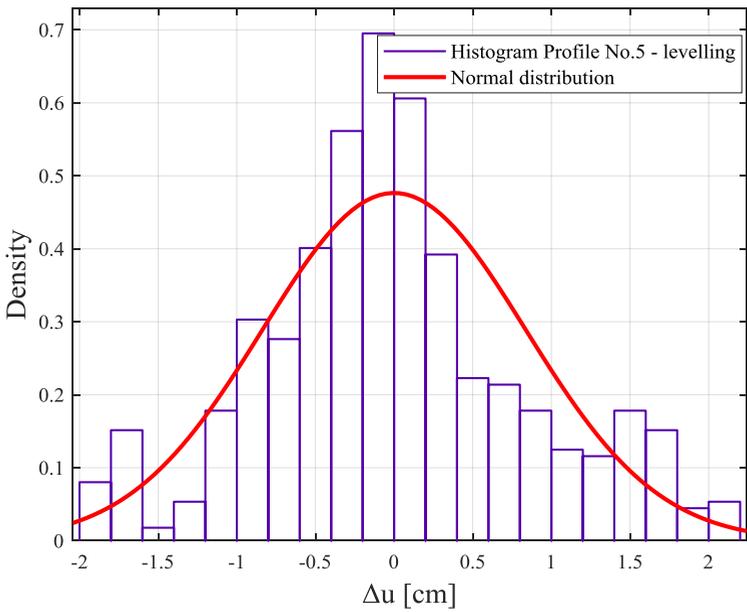


Fig. 12. Histogram and probability distribution density - levelled Profile No. 5.

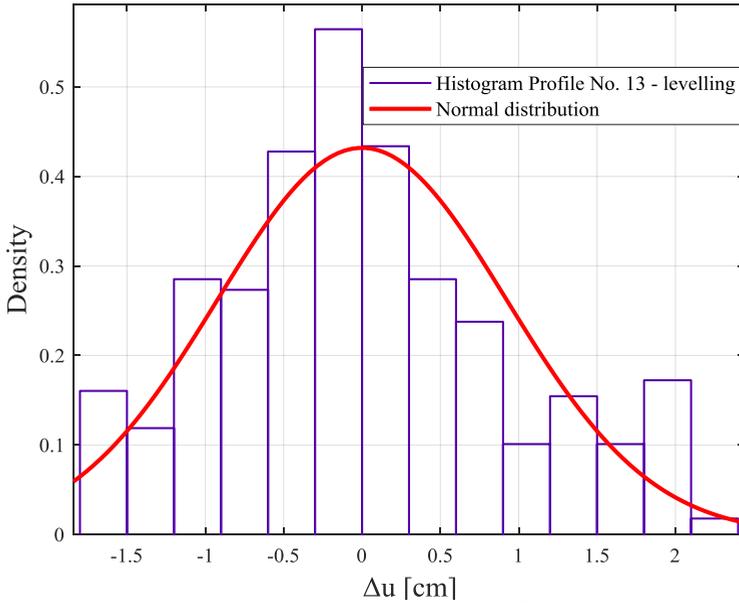


Fig. 13. Histogram and probability distribution density - levelled Profile No. 13.

5 Conclusion

Runway unevenness as an important input for solving the interaction road – vehicle demands attention. In this paper, two sets of data obtained by two ways of measuring and some of their statistics were presented. Based on the analysis, we assume that it is possible to reach applicable values from both used methods. The values of two longitudinal profiles varied but their statistics were comparable. The next step would be to estimate the power spectral density of this road profile and classify the category of pavement according to the standard ISO 8608.

This work was supported by Grant system of the University of Zilina.

References

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