SPECTRAL CHARACTERISTICS OF DIFFERENT BUILDING MATERIALS BY THE EYES OF LASER SCANNING

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ABSTRACT

During the last few years, terrestrial laser scanning has become a standard method of data acquisition in close range domain. Full-waveform terrestrial laser scanning is a recent technology which is able to digitize and record the complete waveform of the backscattered echo. It gives additional information about the structure and physical backscattering properties of the illuminated surface (reflectance and geometry). In this paper, the influence of different materials on the reflectivity was studied. The factors influencing material reflectivity were: laser wavelength, surface material type, surface colour and wetness. The measurements were focused on the materials used at buildings facades (wood, concrete and plaster). The measurements were performed by full-waveform terrestrial laser scanner (FW - TLS) VZ-400 and spectrometer ASD FieldSpec 4. The aim of this work was to find out what the differences in reflectance spectrum of used material were and whether the materials could be distinguished by their reflectance at 1550 nm (the laser wavelength of VZ-400).

Key words: *Material reflectivity, spectrometer, full-waveform terrestrial laser scanner, amplitude, wetness*

1 INTRODUCTION

Full-waveform terrestrial laser systems (FW - TLS) capture and digitize the full structure of the waveform of the reflected laser pulse providing more measures of change than only range. The measurements are influenced by many factors, p. e. distance, incidence angles or material reflectivity.

Carrea et al. described [1] that the material reflectivity might be defined as the ratio between the power of the reflected and incident signals. The material reflectivity varied from zero for a completely absorbing surface to one for a completely reflecting surface. The factors influencing material reflectivity were as follows: laser wavelength, surface material type, surface colour, surface temperature and moisture.

The influence of the materials commonly used at building facades and the influence of range and incidence angle on measurements of a full-waveform terrestrial laser scanner VZ-400 was described in [2].

The aim of this article is to verify whether the full-waveform terrestrial laser scanner VZ-400 could be used for the classification of the different realistic object materials (wood, concrete and plaster). The determination of reflectance spectrum differences of the materials including the wetness influence was proved by spectrometer. The attention was focused on the reflectance of the wavelength 1550 nm (the VZ-400 laser wavelength). The reflectance results of the spectrometer were compared to the amplitude results of the full-waveform terrestrial laser scanner VZ-400.

2 FULL–WAVEFORM TERRESTRIAL LASER SCANNER AND SPECTROMETER

The **full-waveform terrestrial laser scanner VZ-400** manufactured by Riegl was used for the experiments. The VZ-400 relies on the principle of pulsed time of flight measurement and applies echo digitization and online waveform processing. The VZ-400 works in laser wavelength 1550 nm (near-infrared) [3].

The resulting data for a single measurement point are the coordinates X, Y, Z, the amplitude, the reflectance and the deviation [3]. The values of the amplitude were used to describe the results of the experiments. The VZ-400 provides a calibrated **amplitude** value scaled in decibels (dB). The calibrated amplitude is a signal strength property of the received optical target echo signal. It is defined as the ratio of the actual detected optical amplitude versus the detection threshold.

Spectrometer FieldSpec 4 Hi-Res manufactured by ASD Inc. provides uniform data collection across the entire solar irradiance spectrum, in visible (VIS), near-infrared (NIR) and short-wavelength infrared (SWIR) region (350 – 2500 nm) [4]. The reflectance varies from zero for a completely absorbing surface to one for a completely reflecting surface.

3 ANALYSIS OF MATERIALS

The measurements were performed in two phases. In the first phase, all samples were measured by laser scanner VZ-400 and in the second phase by spectrometer FieldSpec 4 Hi-Res.

The full-waveform terrestrial laser scanner VZ-400 was mounted on a tripod at a distance of 5 m from the realistic object materials (concrete and plasters) placed on a table (See Figure 1). The wooden samples were hung on the wall at a distance from 1,5 m up to 2 m with an inclination angle from 30° to 38° (This configuration was due to the cramped conditions of the hall where the wooden samples were hung.). The mean amplitude and the standard deviation were computed for each sample and then compared to each other.

Spectrometer FieldSpec 4 Hi-Res equipped with a Contact Probe [5] was used for a contact measurement of a spectral response of the samples (See Figure 2). A calibrated white reference panel was used [6]. A surface reflectance curve was obtained in 1 nm resolution.

The average of five spectral bands from 1548 nm to 1552 nm was used for a comparison with the amplitude value from the full-waveform terrestrial laser scanner VZ-400.

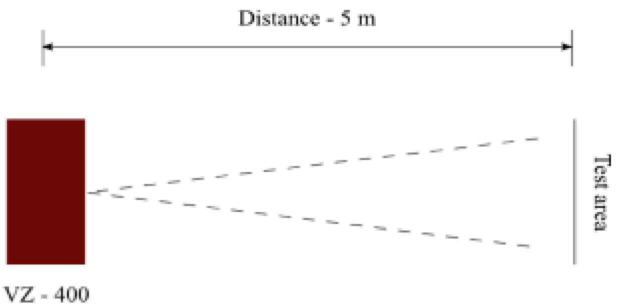

Fig. 1 Principle of the test configuration

Fig. 2 Measuring by spectrometer

3.1 Analysis of plaster materials, gauze and concrete cube

Four samples were measured: Sisi Comfort (white plaster, manufactured by Cemix), M – Cemix (dark plaster, manufactured by Cemix), gauze and concrete cube (See Figure 3).

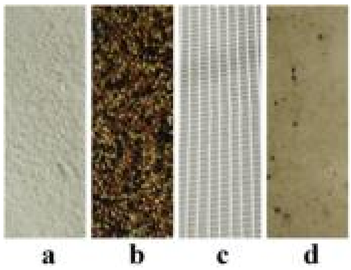

Fig. 3 Measured samples: a) Sisi Comfort, b) M – Cemix, c) gauze and d) concrete cube

The spectral responses of these materials are shown in Figure 4. The highest reflectance in the wavelength 1550 nm was recorded for gauze (68%) and plaster SISI Comfort (57%) and the lowest reflectance was detected for concrete cube (38%) and plaster M – Cemix (24%). The standard deviation of the reflectance was calculated less than 0,3%.

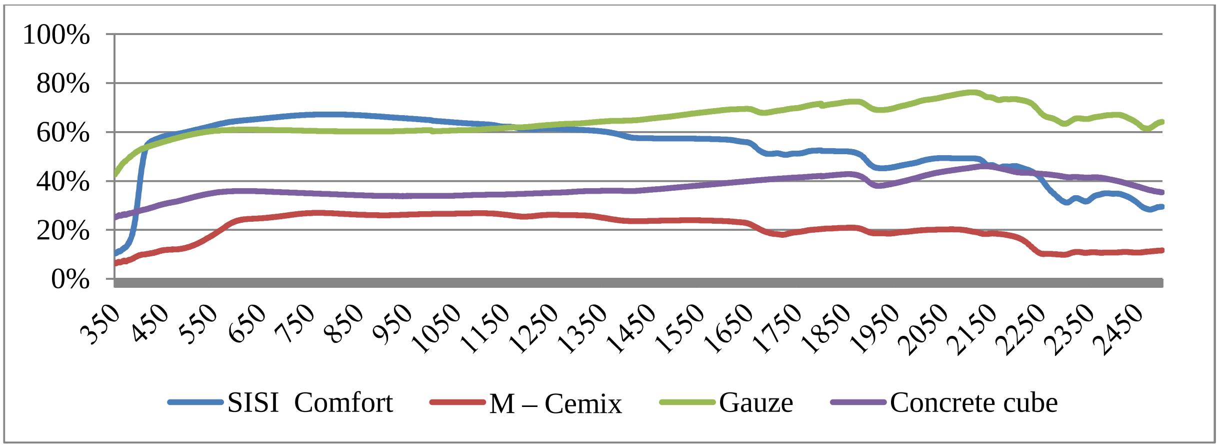

Fig. 4 Spectral responses of plaster materials, gauze and concrete cube

The value of the mean amplitude of M – Cemix was the lowest – 29,5 dB (See Figure 5). It was caused by its dark colour which absorbed more radiation. The standard deviation of amplitude for these samples varied from 0,40 dB for plaster SISI Comfort to 1,04 dB for M – Cemix.

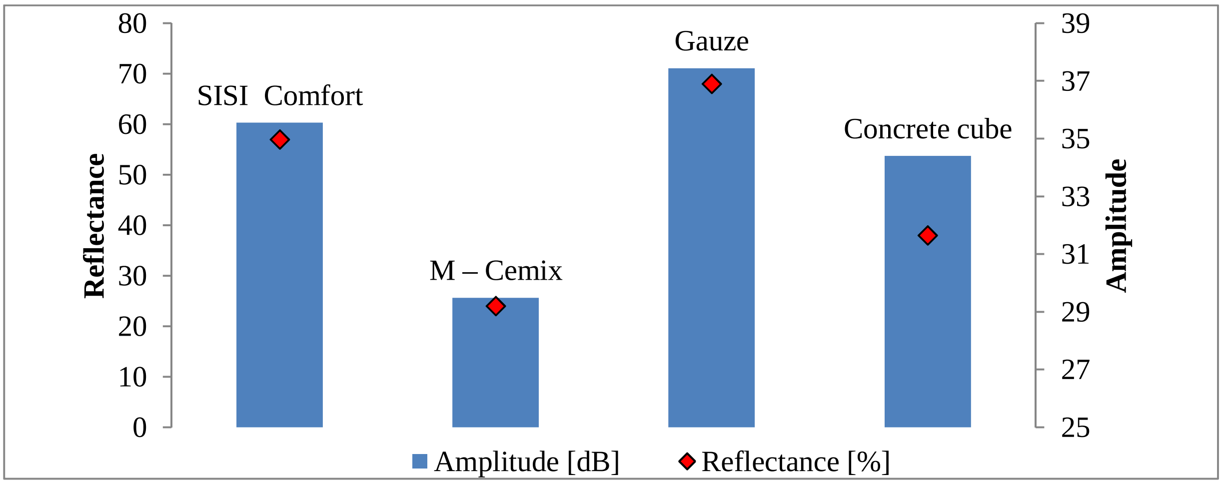

Fig. 5 Reflectance and mean amplitude values for plasters, gauze and concrete cube

The spectrometer FieldSpec 4 Hi-Res results corresponded with the full-waveform terrestrial laser scanner VZ-400 results (See Figure 5). These materials could be distinguished by their reflectivity and amplitude at 1550 nm.

3.2 Analysis of different species of wood

At the test board different species of wood were studied: cherry, juniper, maple, birch, ash, steamed beech, oak, hornbeam, acacia, larch, linden, fir, spruce, pine, plywood, hardboard, block board, dark plywood and soft board (See Figure 6). All the wood surfaces were unfinished except the dark plywood that was painted.

Fig. 6 Different species of wood

All kinds of the woods except the dark plywood were characterised by the similar form of spectral response (See Figure 7). Several samples were omitted from the visualisation for a better arrangement as their curve goes along with the other ones. The dark plywood reflectance variance was lower than the reflectance variance of the other wood samples. The dark plywood differed from the others because its surface was covered by black paint.

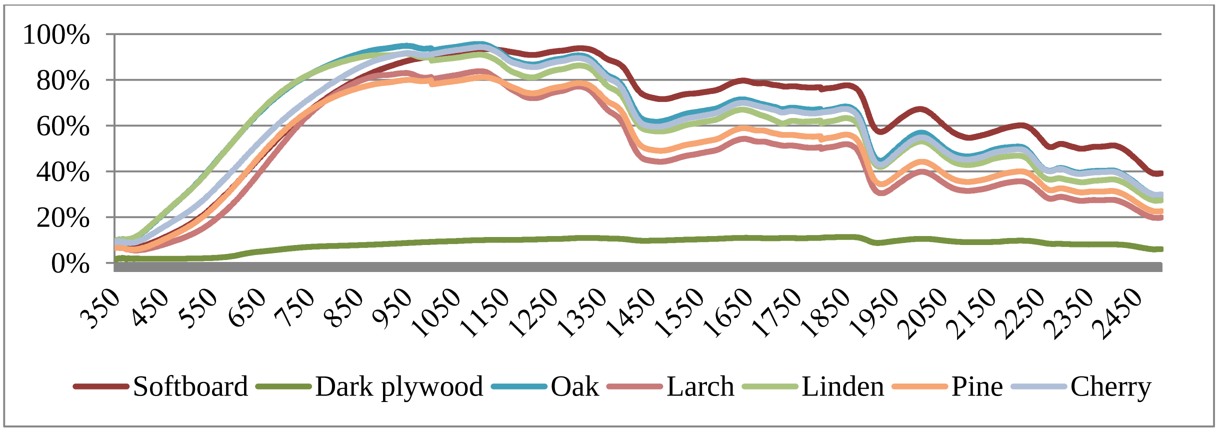

Fig. 7 Spectral responses of several samples of woods

In Figure 8, the reflectance is presented for all kinds of wood for the wavelength 1550 nm. The mean reflectance varied from 10% for dark plywood to 74% for soft board. The median reflectance was 59% for maple. The wooden samples could be distinguished by reflectance. The standard deviation of reflectance was insignificant.

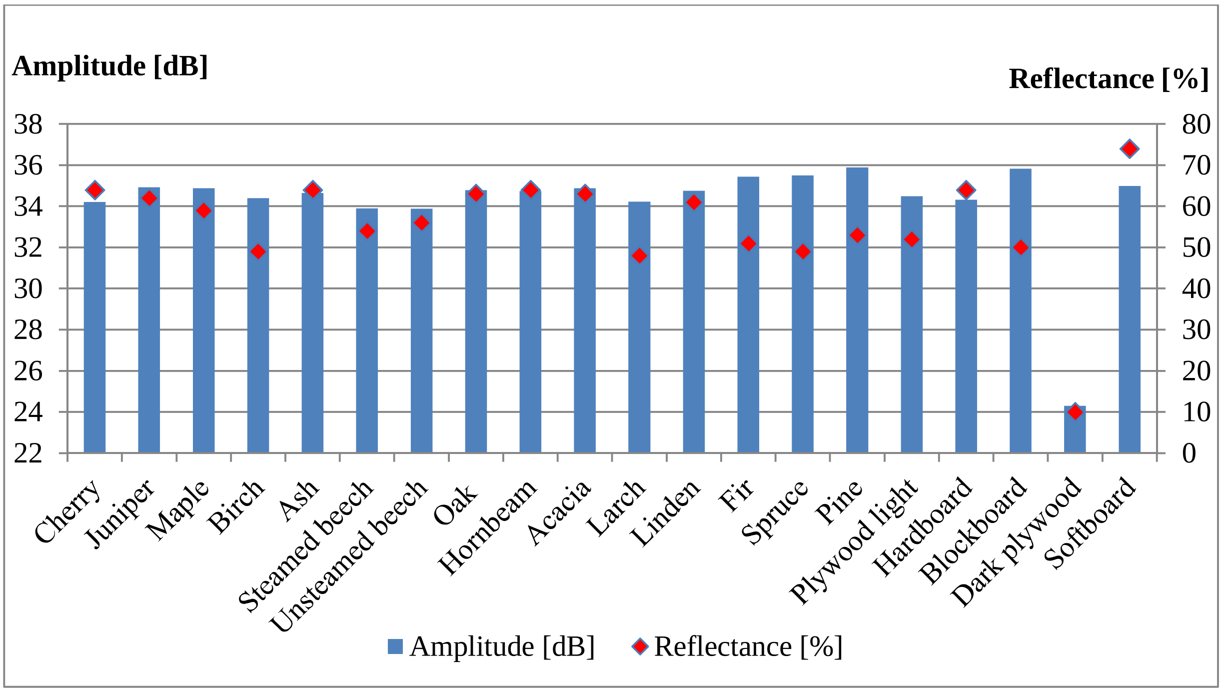

Fig. 8 Reflectance and amplitude values for different species of wood in the wavelength 1550 nm

Comparing the differences of the mean amplitudes, the species could not be distinguished by analysing the amplitude values (See Figure 8). The mean amplitude values lied in the same domain and varied from 33,9 dB for steamed beech to 35,9 dB for pine. Only dark plywood was left out (Its low amplitude value was set as 24,3 dB.). The standard deviation of amplitude varied from 0,37 dB for block board to 0,82 dB for spruce and achieved the differences amplitude values between particular wooden samples.

3.3 Analysis of the influence of wetness

A concrete cube was used to demonstrate and prove the influence of wetness on reflectance and amplitude. The measurements were carried out in the original state (t_0), state immediately after wetting (t_1) and states of drying out – 10 minutes after wetting (t_2), 20 minutes after wetting (t_3) and 30 minutes after wetting (t_4). The wetness for the concrete cube influenced the reflectance in the whole spectrum. In Figure 10, the spectral curves show particular states. In the wet state the spectral curve decreased to the lower reflectance level and the depression in SWIR got bigger. During drying out the spectral curve increased to higher reflectance level and the depression in SWIR was reduced. It demonstrated the fact that the water behaved like nearly an absolutely black body in SWIR.

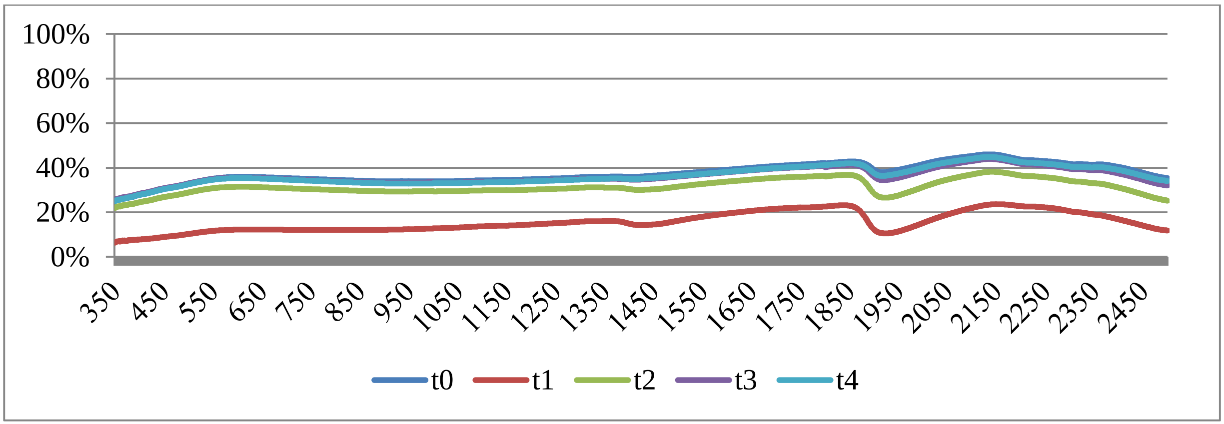

Fig. 9 Spectral responses of concrete

Table 1 shows the influences of wetness for the concrete cube in the 1550 nm wavelength. The reflectance and amplitude both decreased with the wetness and contrarily increased while drying. After 20 minutes of drying, the concrete cube was almost at the same state as before the wetness.

Concrete	t_0	t_1	t_2	t_3
Reflectance	38%	18%	33%	37%
Amplitude	35,8 dB	33,4 dB	33,8 dB	34,1 dB
MSE of amplitude	0,68 dB	1,02 dB	0,70 dB	0,79 dB

Tab. 1 The amplitude and reflectance of concrete cube in the wavelength 1550 nm

4 CONCLUSION

In this paper two types of data were presented, the reflectance measured by spectrometer FieldSpec 4 Hi-Res and the amplitude measured by the full–waveform terrestrial laser scanner VZ – 400. The attention was focused on the reflectance of the wavelength 1550 nm.

The spectral responses and amplitudes were measured for the different realistic object materials (wood, concrete and plaster). The plasters and concrete cube could be well differentiated by the reflectance and amplitude in the wavelength 1550 nm. All kinds of woods had almost the same form of reflectance spectrum except the dark plywood whose surface was covered with black paint. The wooden samples could be distinguished by reflectance in the wavelength 1550 nm. On the contrary these samples would be hard to classify using the measured amplitude.

The results of the influence of wetness showed that the spectral responses differed in the course of getting wet and getting dry. The reflectance confirmed that the water behaved as nearly an absolute black body in SWIR.

The spectrometer FieldSpec 4 Hi-Res results confirmed that the samples could be distinguished in the wavelength 1550 nm. The full-waveform terrestrial laser scanner VZ-400 results showed how complicated it is to describe the changes of amplitude value for the used materials and finding out the special features of materials only by the assessment of this quantity in the wavelength 1550 nm without any additional information.

Acknowledgment

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Literature

1 Carrea, D., Abellan, A., Humair, F., Matasci, B., Derron, M.-H., Jaboyedoff, M., 2016. Correction of terrestrial LiDAR intensity channel using Oren–Nayar reflectance model: An application to lithological differentiation. ISPRS Journal of Photogrammetry and Remote Sensing, 113, pp. 17-29.

2 KUČEROVÁ, Eva. Influences of range and incidence angle on measurements of a full - waveform terrestrial laser scanner VZ - 400. *Czech Journal of Civil Engineering VĚDECKÝ ČASOPIS OBORU STAVEBNICTVÍ* [online]. 2017, **2017**(1), 78-83 [cit. 2017-11-10]. ISSN 2336 - 7148. Dostupné z: http://www.scientificjournals.eu/magazine/2017/CJCE_2017_01.pdf

3 Instruction manual of VZ – 400.

4 *ASD Inc., a PANalytical Company: FieldSpec 4 Hi-Res: High Resolution Spectroradiometer* [online]. [cit. 2017-11-10]. Accessible from: https://www.asdi.com/products-and-services/fieldspec-spectroradiometers/fieldspec-4-hi-res

5 *ASD Inc., a PANalytical Company: Contact Probe* [online]. [cit. 2017-11-10]. Accessible from: https://www.asdi.com/products-and-services/accessories/contact-probe

6 *ASD Inc., a PANalytical Company: Reference Panels* [online]. [cit. 2017-11-10]. Accessible from: https://www.asdi.com/products-and-services/accessories/reference-panels