INFLUENCES OF DIFFERENT MATERIALS ON THE MEASUREMENTS OF A FULL-WAVEFORM TERRESTRIAL LASER SCANNER

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ABSTRACT

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). Some authors focus on the data quality of a terrestrial laser scanner. Most of them are interested in the geometrical accuracy of the scanner (errors of instrumental axis, range accuracy using target, etc.). In this paper, the influence of different materials on the recorded measurements of a full-waveform terrestrial laser scanner (FW - TLS) VZ – 400 was studied. The measurements were focused on the materials used at buildings facades (wood, concrete and plaster), different coloured sheets and several minerals.

Key words: *Full-waveform terrestrial laser scanner, amplitude, wetness*

1 INTRODUCTION

During the last few years, terrestrial laser scanning has become a standard method of data acquisition in close range domain. Conventional terrestrial laser systems do not record the structure of the reflected waveform. Furthermore, 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. Laser scanning is mainly used in urban and vegetated areas.

Voegtle et al. discussed [3] the influence of the materials commonly used at building facades on measurements of a terrestrial laser scanner (TRIMBLE GX) and focused on the geometric accuracy of the range measurement and recorded intensity of the materials.

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 aim of this article is to find out the influences of different materials on the measurement of the FW – TLS. The realized experiments were focused on how the different realistic object materials (wood, concrete, plaster and mineral) and different coloured sheets influence the measurements of the full-waveform terrestrial laser scanner VZ – 400.

2 FULL–WAVEFORM TERRESTRIAL LASER SCANNER

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. Specifications for the scanner are given in Table 1.

Parameter	Long Range Mode	High Speed Mode
Effective pulse rate	42 000 Hz	122 000 Hz
Max. measurement range (reflectivity 90%)	600 m	350 m
Max. measurement range (reflectivity 20%)	280 m	160
Minimal range	1,5 m	
Range accuracy	5 mm	
Range precision	3 mm	
Beam divergence	0,35 mrad	
Angular resolution	0,0005°	
Horizontal scanning range	0° up to max. 360°	
Vertical scanning range	Up to 100° (+60/ -40°)	
Laser wavelength	1550 (near infrared)	

Tab. 1 Specifications of VZ – 400 [2]

The resulting data for a single measurement point are the coordinates X, Y, Z, the amplitude, the reflectance and the deviation. The parameters are described [2] as follows.

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.

The **reflectance** is the ratio of the (measured) calibrated amplitude value of the target echo to the calibrated amplitude value of a diffusely reflecting white target at the same distance, orientated orthonormal to the beam axis and with a size in excess of the laser footprint. The actual reflectance is given in decibels (dB). Negative values indicate diffusely reflecting targets, whereas positive values are usually retro – reflecting targets.

The **deviation** is a property describing the change of the received echo pulse shape compared to the emitted pulse shape. Deviation 0 is the ideal case and means no distortion and the received pulse fits 100% to the emitted pulse.

The values of the amplitude were used to describe the results of the experiments.

3 ANALYSIS OF MATERIALS

The different materials were placed on a table at a distance of 5 m (See Figure 1). The concrete samples tagged with numbers from 1 to 10 were put on the table at a distance of 6 m. The wooden samples were hung on the wall at the 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.). Figures 2, 4 and 6 show the sample arrangements. The mean amplitude and the standard deviation were computed for each sample and then compared to each other.

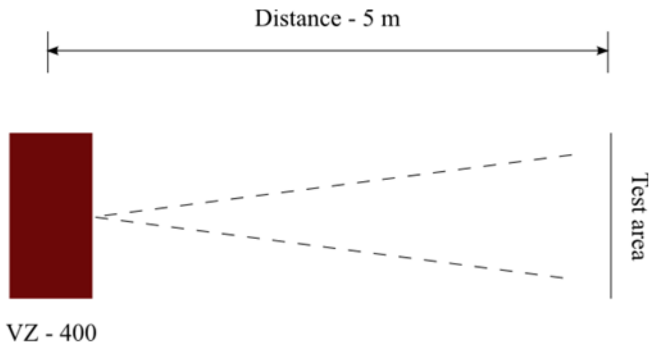

Fig. 1 Principle of the test configuration

3.1 Analysis of plaster materials, gauze and polystyrene

Four samples were measured: Sisi Comfort (white plaster, manufactured by Cemix), M – Cemix (dark plaster, manufactured by Cemix), gauze and polystyrene. The value of the mean amplitude of M – Cemix was the lowest: 29,5 dB (See Fig. 3). It could be caused by its dark colour. No significant effect could be verified for the other samples. The standard deviation of amplitude for these samples varied from 0,25 dB for polystyrene to 1,04 dB for M – Cemix.

Fig. 2 Plasters, minerals and woods sitting on the table

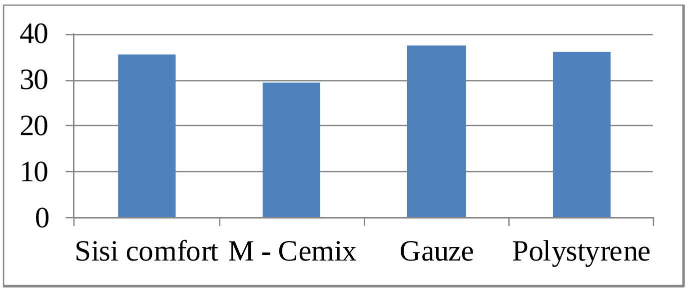

Fig. 3 Mean amplitude values for plasters, gauze and polystyrene (dB)

3.2 Analysis of different species of wood

At the test board different species of wood were hung on the wall: 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 Fig. 4).

Fig. 4 Different species of wood

Comparing the differences of the mean amplitudes, the species could not be distinguished by analysing the amplitude values. Only dark plywood was left out because of its different colour which could cause the low amplitude value (24,3 dB). The mean amplitude values lied in the same domain and varied from 33,9 dB for steamed beech to 35,9 dB for pine. The standard deviation of amplitude varied from 0,37 dB for block board to 0,82 dB for spruce.

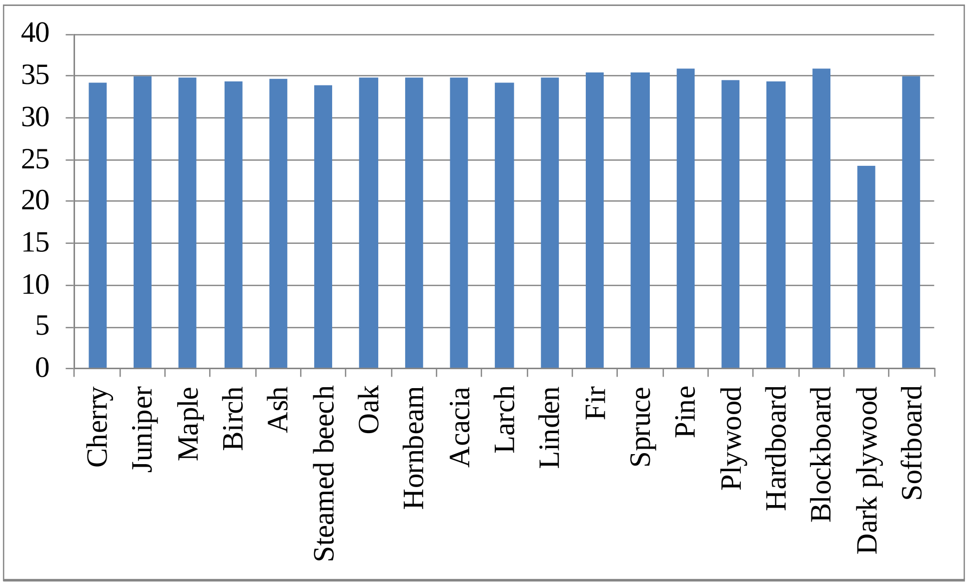

Fig. 5 Mean amplitude values for different species of wood (dB)

3.3 Analysis of different types of concretes

Ten different types of concretes were positioned on the table at a 6 metre distance from the scanner. The concretes differed by the used mixture and were marked from 1 to 10 (See Fig. 6).The mean amplitude values varied from 33,2 dB for the first concrete to 36,9 dB for the second one. The standard deviation of amplitude for these samples varied from 0,47 dB for the 4th concrete to 1,52 dB for the 7th one.

Fig. 6 Different types of concretes

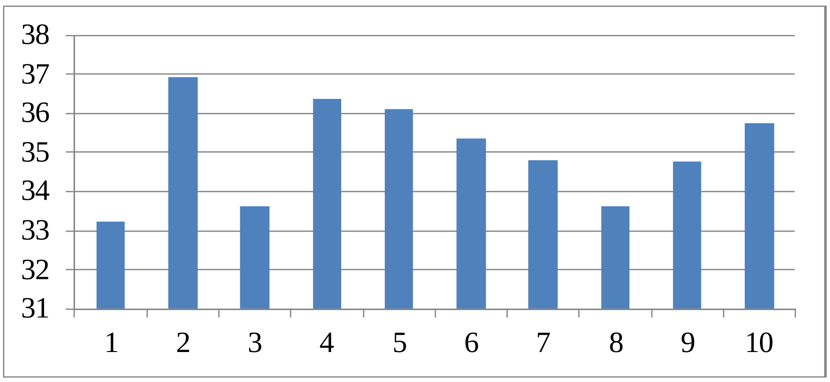

Fig. 7 Mean amplitude values for different types of concretes (dB)

3.4 Analysis of different types of minerals

At the test area, five different types of minerals were positioned: limestone, diorite, sandstone, rhyolite, gneiss. The highest mean amplitude (35,0 dB) was estimated for limestone and the lowest one (27,0 dB) for sandstone. Therefore, the type of mineral can be distinguished by analysing the amplitude values. The standard deviation of amplitude varied from 0,48 dB for limestone to 1,18 dB for gneiss.

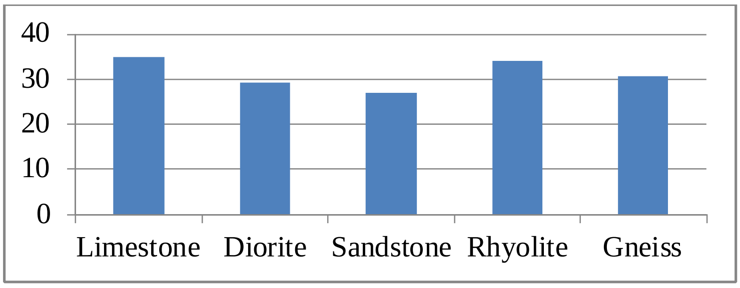

Fig. 8 Mean amplitude values for different species of minerals (dB)

3.5 Analysis of different coloured sheets

Different coloured sheets (white, yellow, pink, red, blue, green and black) were placed on the table at a 5 m distance from the scanner (See Fig. 9). It could be shown that the mean amplitude value was related to the colour. The highest mean amplitude (36,9 dB) was obtained for the white and yellow sheets. The lowest value (27,2 dB) was obtained for the black sheet. The other coloured sheets could not be distinguished by analysing the amplitude values. The standard deviation of amplitude varied from 0,29 dB for the white and yellow sheets to 0,55 dB for the black one.

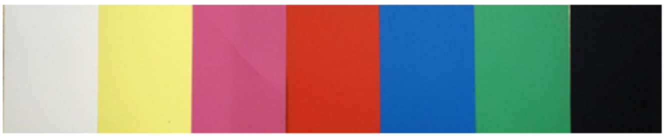

Fig. 9 Used coloured sheets

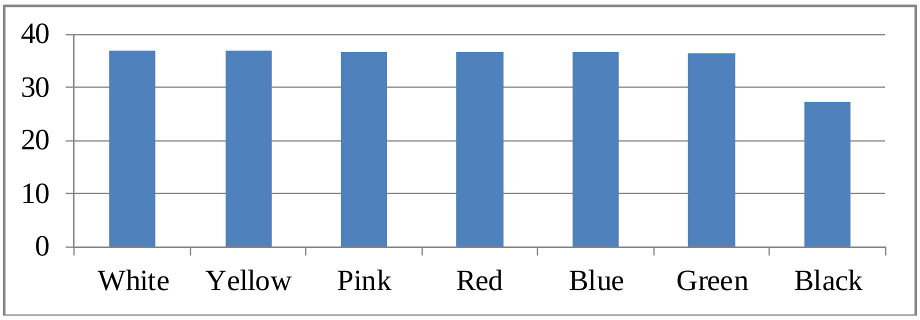

Fig. 10 Mean amplitude values for different coloured papers (dB)

3.6 Analysis of the influence of wetness

The influence of the wetness was analysed in two phases. Plasters and minerals were measured in the first phase and different types of concretes in the second one.

Two types of plasters (Sisi comfort and M – Cemix), polystyrene and minerals were wetted. The measurements were carried out in the original state (t_0), state immediately after wetting (t_1) and state of drying out – 15 minutes after wetting (t_2). The Table 3 shows the differences between particular states. It could be seen that the mean amplitude value had decreased after wetting samples (See the third column Δt_{10}) and increased during drying after 15 minutes (See the 4th column Δt_{21}). The 5th column compares the original state and the state after 15 minutes drying out (Δt_{20}). The values of amplitude differences between particular states under 0,5 dB are at the level of the mean standard deviation.

Materiel	t_0	Δt_{10}	Δt_{21}	Δt_{20}
Sisi comfort	35,5	-1,2	0,8	-0,4
M – Cemix	29,5	-2,4	1,0	-1,4
Polystyrene	36,2	0,0	0,2	0,2
Limestone	35,0	-1,8	1,1	-0,7
Diorite	29,2	-1,9	1,6	-0,4
Sandstone	27,0	-0,7	0,6	-0,2
Rhyolite	34,0	-0,7	0,5	-0,2
Gneiss	30,6	-0,6	0,1	-0,5

Tab. 2 Differences of mean amplitude values (dB) for plasters and minerals at time intervals

Each sample of concrete was wetted. The measurements were carried out in the original state (t_0), state immediately after wetting (t_1) and state of drying out – an hour after wetting (t_2). The Table 2 shows the differences between particular states. It could be seen the mean amplitude value had decreased after wetting samples (See the third column Δt_{10}) and increased during drying after one hour (See the 4^{th} column Δt_{21}). The 5^{th} column compares the original state and the state after one hour drying out.

Concrete	t_0	Δt_{10}	Δt_{21}	Δt_{20}
1	33,2	-3,5	2,7	0,9
2	36,9	-0,1	0,2	0,0
3	33,6	-3,3	1,1	2,2
4	36,4	-1,3	0,9	0,4
5	36,1	-1,5	1,3	0,2
6	35,4	-1,1	0,7	0,4
7	34,8	-0,8	0,7	0,1
8	33,6	-1,7	1,6	0,1
9	34,8	-1,1	0,9	0,2
10	35,8	-2,4	1,9	0,5

Tab. 3 Differences of mean amplitude values (dB) for different types of concretes at time intervals

Wetness for different types of concretes, minerals and plasters influence the value of amplitude.

4 CONCLUSION

The influences of different materials on the measurement of the full–waveform terrestrial laser scanner VZ – 400 were presented in this paper. The results show 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 amplitude.

In the future these tests should be repeated with other types of terrestrial laser scanners. Furthermore, testing should be done on the influence of different incidence angles or different distances between the scanner and the object with the full–waveform terrestrial laser scanner VZ – 400.

Acknowledgment

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Literature

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