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Non-invasive and Effective Method of the Pavement Investigation: Ground Penetrating Radar

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Abstract

Recently, a considerable large emphasis is put on diagnostic methods, which are non-invasive, simple, safe, time efficient and non-intrusive from the viewpoint of interference with traffic flow of particular road. From this point of view, very convenient is use of the GPR method in terms of the pavement and road investigation. We used two Horn antennas (1 GHz and 2 GHz) on the test field to verify its construction.

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Keywords: GPR; test field; 1GHz antenna; 2GHz antenna

1. Introduction

Road users require safe, economical and comfortable driving. At present, the lack of financial resources for road infrastructure therefore saves on repair of roads and it has the consequence that in the repair of damages of roads are not followed by technological procedures and the duration of repaired damages very short. In order to avoid wastage of material and time of workers, started in the world to use non-destructive method of testing road surface based on the transmitting of short pulses of high-frequency electromagnetic energy into the material. By analyse the received radar reflections from the boundaries of layers, we can conclude information about the investigated materials, [1]. From the measurements, it is possible to determine the layer thickness but also the cause of various damages. Based on this analysed road structure, we can determine the optimal repair or reconstruction of the deformed road. This article is focused on the collection of data regarding pavement structure using the interpretation of the radargrams.

The method of GPR has been implemented on an experimental field of the University of Žilina in Žilina, where we monitored the progress and deformation of individual construction layers of asphalt pavement described in following Sec. 2.

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2. Practical application of advanced data collection methods on the pavement test field

For evaluation of a measurement method, measured subject has to be thoroughly known and measured data has to be collated with known reality. In the context of PMS research, an experimental pavement test field in scale of 1:1 was constructed. This test field is part of the pavement accelerated testing facility. The research links up with pavement research performed by company VUIS-roads in the 90's. The general principle of APT testing is to apply artificially inducted load similar to real life traffic load in a compressed time period, thus providing an expedited means of evaluating factors associated with traffic-pavement interaction [2], [3].

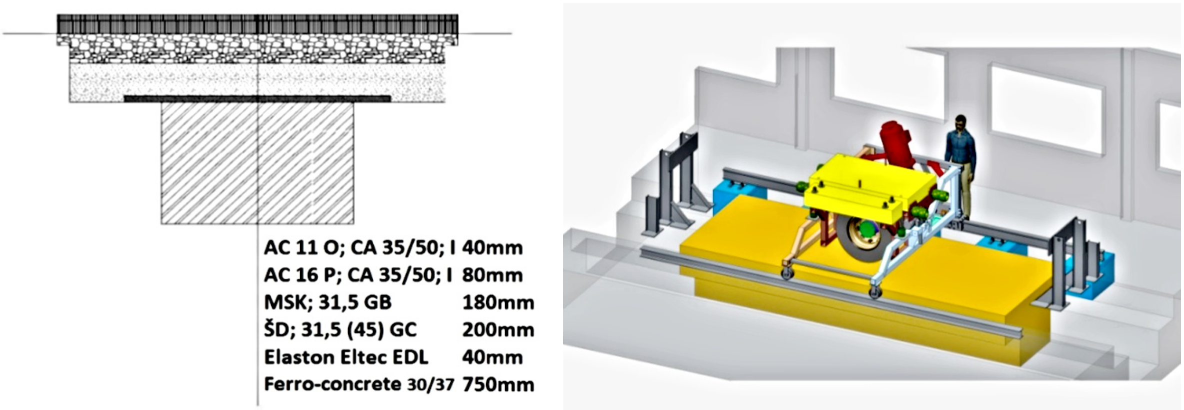

Fig. 1. (a) Accelerated Pavement Testing Facility of the University of Žilina - cross section of pavement test field, (b) design of the facility.

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. These layers are connected by penetrating coating PS; 0.5 kg/m^2. The road base is a mechanically bound aggregate MSK 31.5 GB; 180 mm thick. Sub-base is gravel (crushed stone); 31.5 (45) GC; 200 mm thick. Conformity of all supplied materials has been confirmed by tests affirming the quality elaborate supplied by the constructor; quality of particular layers was confirmed through quality tests performed during the construction as prescribed in the test plan.

3. Diagnosis road construction layers using GPR (Ground Penetrating Radar)

Among current methods of geophysical survey, the most effective, in terms of diagnostics road construction (except of FWD), is GPR method. The reasons for growing popularity of the GPR method are its non-destructive nature, high resolution, ideal depth range (depending on the transmitting antenna), low cost and high speed of a survey. Moreover, it can be carried out in full traffic. Data acquisition is performed in situ by GPR device, consisting of transmitter and receiver antenna, control unit and a computer [4]. The measurement is carried out directly on the surface of a studied structure. In our case, it was used the device from GSSI - SIR 20 with Horn - type antenna (center frequency of 1 and 2 GHz). Transmitter and receiver antenna is hanged above surface at a distance of about 0.45 m (Fig. 2).

GPR is a relatively fast method of geophysical survey. It is based on emitting of a high-frequency electromagnetic signal in regular time impulses into the rock, soil or anthropogenic environment and its subsequent registration of passing and reflected waves from bodies and interfaces. The position system (e.g., GPS, odometer) is an important part of the measurement system that identifies the position of each measurement within the measured distance. Several GPR time records (A - scan) at regular intervals along specified profile form B - scan or a radargram. A radargram shows continuous record of measurements along a profile. Data processing is carried out in a specialized software system. Modified data is then interpreted and graphically processed in the end. Thicknesses of layers, possible delamination, also built objects, inhomogeneity and other hidden faults can be calculated from the resulting travel times.

Fig. 2. Measurement with GPR on the testing field.

4. Results of the GPR survey

In this paper we compare results obtained by measurements on the mentioned test field by two Horn-type antennas (1GHz and 2GHz). We set a profile that was measured with both antennas (1.4 m) This profile was perpendicular to the running wheel. The resulting radargrams differ a bit qualitatively.

Profile measured with the 1GHz Horn – type antenna (Fig. 3) shows only 3 layers instead of 4. The uppermost layer stays unrevealed. This antenna has bigger depth range to compare with 2GHz antenna however we did not need to take an advantage of this fact. The layer depths for this measurement are shown in the tab 1.

Tab. 1 Depths of the test field layers with trigger interval of 0.1 m, their average value and dielectric constant

Profile	**layer 1**	**layer 2**	**layer 3**	**layer 4**
distance [m]	**depth [cm]**	**depth [cm]**	**depth [cm]**	**depth [cm]**
0.0	-	12	30	50
0.1	-	12	30	50
0.2	-	12	30	50
0.3	-	12	30	50
0.4	-	12	29	50
0.5	-	12	29	50
0.6	-	12	29	50
0.7	-	11	29	50
0.8	-	11	30	50
0.9	-	11	30	50
1.0	-	11	30	50
1.1	-	11	30	50
1.2	-	11	29	51
1.3	-	12	29	51
1.4	-	12	30	50
average	**-**	**12**	**30**	**50**
Diel.const.	**-**	**8,1**	**8,6**	**10,3**

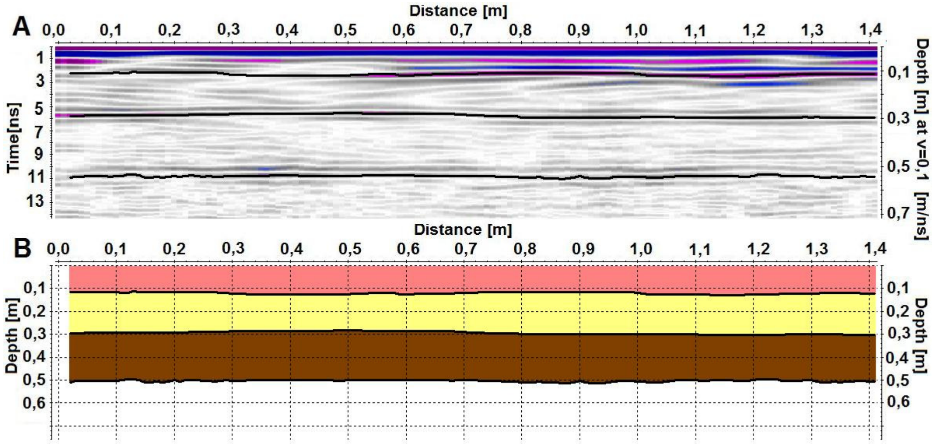

Fig 3 (A). The resulting radargram obtained by 1GHz antenna, black line indicates boundaries between the layers of the test field. (B) The resulting depth section of the test field.

Profile measured with the 2GHz Horn – type antenna (Fig. 4) shows all constructing layers as it is in the project documentation. The layer depths for this measurement are shown in the tab 2. It can be observed that the values of dielectric constant differ significantly comparing both cases. This can be explained by the different physical response of the surveyed materials on different high-frequency electromagnetic signal [5]. The interpreted depths of the constructing layers are not in a severe inconsistency.

Tab. 2 Depths of the test field layers with trigger interval of 0.1 m, their average value and dielectric constant.

Profile	**layer 1**	**layer 2**	**layer 3**	**layer 4**
distance [m]	**depth [cm]**	**depth [cm]**	**depth [cm]**	**depth [cm]**
0,0	4	13	31	51
0,1	4	13	31	51
0,2	4	13	31	50
0,3	4	13	30	50
0,4	4	12	29	50
0,5	4	12	30	50
0,6	4	12	30	50
0,7	4	12	30	50
0,8	4	13	30	51
0,9	4	12	30	50
1,0	4	12	30	51
1,1	4	12	30	51
1,2	4	12	30	50
1,3	3	12	30	51
1,4	4	13	31	51
average	**4**	**12**	**30**	**50**
Diel.const.	**4,6**	**4,9**	**13,3**	**13,6**

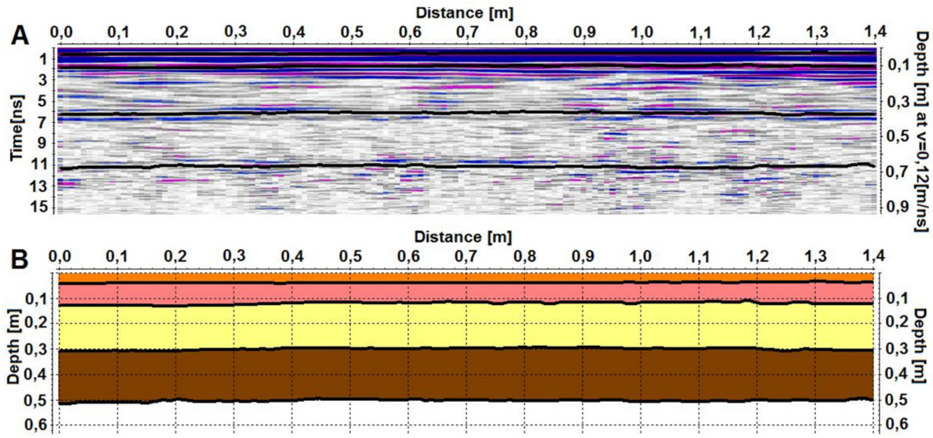

Fig 4 (A). The resulting radargram obtained by 2 GHz antenna, black line indicates boundaries between the layers of the test field. (B). The resulting depth section of the test field.

3. Conclusion

We compare two radargrams measured with two antennas. However the result obtained with the 2GHz Horn type antenna may seem better, the 1GHz antenna can bring deeper information. In specific practical situations, when the constructing layers are deeper, 1GHz antenna fits better. On the other hand, 2 GHz antenna works from the very top and therefore it can bring data about very shallow lying objects or layers.

Progressive methods for the assessment of road surface quality described in the article, are meant to facilitate the fulfilment of one of the central objectives of the research activity 3.1 – "research and development in the field of monitoring and assessment of transport infrastructure" in the framework of the Research centre founded under the auspices of the University of Žilina.

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