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COMPARATIVE MEASUREMENTS OF GROUND PENETRATING RADARS USED FOR ROAD AND BRIDGE DIAGNOSTICS IN THE CZECH REPUBLIC AND FRANCE

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Abstract

The paper describes the current situation regarding the comparative measurement and accuracy of ground penetrating radars (GPR). GPR measurements are used for non-destructive diagnostic of roads and bridges, specifically for measuring pavement layer thickness and determining the location and position of reinforcement in concrete. The information used in the paper is based on the performed in-situ measurements. The conclusion includes recommendations of how to perform and evaluate the in-situ GPR comparative measurements.

Key words

GPR (Ground Penetrating Radar), non-destructive diagnostics, pavement layer thickness, reinforcement, cement concrete pavement, comparative measurement.

1. INTRODUCTION

Ground Penetrating Radar (GPR) is traditionally used in diagnostics of transport infrastructure. It can either be used for one-off structure condition diagnostics or comparison of a development over a time period. At present, GPR is commonly used for diagnostics of roads at the project level (i.e. evaluation of shorter road sections) and rarely used at the network level.

One of the first applications of GPR in road engineering was to determine road layer thickness [1-4]. In this case, measurements are performed on both asphalt and cement concrete pavements, each with their own specific features. Given that, roads are line structures, accuracy of the localization measurement play an essential role. The measurements are usually performed on a longitudinal basis and under high speeds, so that road traffic is not restricted. In this case, the measurement is performed using a single or several horn antennas, or GPR device designed for 3D measurements [5-8].

An extended application of GPR is the localization of built-in reinforcement. For pavements, the elements in question include dowels and tie bars in jointed unreinforced concrete pavement (referred to as concrete pavement [9-10]). For bridges, the cover of reinforcement in bridge decks are evaluated more frequently [11-16]. For these applications, a cart with a single or more dipole antennas and measurements at walking speed are most commonly used.

The paper analyses a situation concerning in-situ comparative measurements of ground penetrating radars used for road and bridge diagnostics. Technical regulations and situations in individual countries are described in Chapter 1.1 and 1.2. Comparative measurements of GPR systems carried out in the Czech Republic and France with conclusions formulated on the basis of performed measurements are mentioned in Chapters 2 and 3. Recommendations for performance of GPR comparative measurements focused on two applications, pavement layer thickness and reinforcement position in concrete, are presented in Chapter 4.

1.1 TECHNICAL REGULATIONS

There is currently no European standard addressing the diagnostics of roads and bridges by GPR. No creation or adoption of any standards from ASTM D6432-11, ASTM D4748-10 (2015), ASTM D6087-08 (2015) is currently expected within CEN.

However, on the national level within Europe there are guidelines and regulations targeting the diagnostics of transport infrastructure conditions using GPR. The most detailed ones are English DMRB 7.3.2 (2008) and DMRB 3.1.7 (2006), German Merkblatt B 10 (2008) and recommendations produced within the European project MARA-NORD in 2011. More recently, European GPR Association has published guidelines for pavement structural surveys GS1601 (2016) and the Belgian Road Research Centre has produced a recommendation guide ME91/16 for pavement applications.

A European project COST TU1208: Civil Engineering Applications of Ground Penetrating Radar has been in progress since 2013 to 2017. The planned outcomes of the project include recommendations for the design of a new European standard. Among these, one recommendation guide is devoted to flexible pavements and another to concrete structures. The calibration procedures and verification for different types of GPR systems are always stated by manufacturers. Four basic procedures are specified in ASTM D6087-08 (2015).

THERE IS NO STANDARD OR OFFICIAL RECOMMENDATION OF HOW TO PERFORM COMPARATIVE MEASUREMENTS OF GPR, FOR DIAGNOSTICS OF TRANSPORT INFRASTRUCTURE CONDITIONS. 1.2 SITUATION IN INDIVIDUAL COUNTRIES

Representatives from 13 European countries were contacted as part of project COST TU1208. At least one comparative measurement of GPR on roads was confirmed in two cases, with one business partner reporting a comparative measurement on a railway. All partners reported having no technical specifications, methodology or operational manual available for comparative measurements of GPR.

None of the 13 countries require a certificate to be issued by a relevant state administration body or road administrator from companies carrying out GPR diagnostics.

Of the 13 countries, 4 use their own specific technical specification, methodology or operational manual for the measurements by GPR. Obtained accuracies for the applications determining pavement layer thicknesses and location (depth) of reinforcement in concrete pavements range from 3 to 15 %, depending on specific layer thickness and its location.

The determination of electromagnetic signal propagation speed is performed using different methods including usage of table values for corresponding pavement layers, method of reflective coefficient for horn antennas, CMP method (Common Mid Point)/WARR (Wide-Angle Reflection and Refraction) as well as measuring relative permittivity, e.g. with the use of Percometer. The most commonly used method is using drilled cores, measuring layer thickness in isolation joints, and measuring height before and after the laying of pavement layers. When determining the reinforcement depth location, software analysis of hyperbole shapes from measurement reports is used.

There are only few documented results of GPR comparative measurements performed in-situ, e.g. project reports of MARA-NORD and American research programme SHRP: Strategic Highway Research Program.

Some papers point out the importance to develop a methodology for calibrating GPR devices and to verify their proper operation. Results of several tests carried out in order to evaluate the stability of a GPR system working with different antennas was described [17-18], a relationship between GPR frequencies, optimal thresholds, and signal accuracy was analysed [19]. Other papers focus directly to signal processing techniques in relation to the quality of the acquired data and the purposes of the surveys [20].

The results of comparative measurements of pavement layer thickness are also reported by sources outside Europe. An American paper [21] describes a comparison of four non-destructive methods: GPR, IE (impact echo), MIRA (ultrasonic pulse-echo) and MISW (multiple impact surface waves). Layer thickness was measured on concrete roads and asphalt pavements. The measurements of GPR using different producers were performed with the use of different central transmission frequencies and antenna types (dipole antennas, horn antennas, 3D device). Some of the stated GPR measurement accuracies are alarming. In comparison with core drilling, the relative error for the determination of concrete pavement thickness by GPR ranged from 6 % to 83 %.

The above emphasises that accuracies reached by GPR measurements need to be specified in greater details, ideally detailing comparative measurements with a larger number of GPR systems from different manufacturers and operators.

2. COMPARATIVE MEASUREMENTS OF GPRS

There are several ways to approach in-situ comparative measurements. We can find inspiration from other NDT methods that are used for pavement diagnostics, e.g. measurement of longitudinal unevenness of pavement surfaces (IRI parameter), skid resistance of pavement surfaces (friction coefficient), and bearing capacity of roads (deflections under loading). The replicability of measurements produced by different devices directly measuring the same road pavement parameter are determined. Comparative measurements of these parameters are performed at both national and international level, for example through the Dutch programme CROW (bearing capacity), European projects ROSANNE (skid resistance), and FILTER (unevenness).

In the case that it is possible to compare the measured results of the real condition, a comparison is done with the results of measurement performed by a reference device with higher accuracy (e.g. in case of unevenness).

In the case this cannot be performed, the golden centre (e.g. for measurement of friction coefficient and pavement deflections) is determined for results of individual devices involved in the comparison. However, this method is more complicated and may lead to a higher error.

After participating in the comparative measurement, the owners of devices that met the set requirements of repeatability and reproducibility receive a certificate for measuring the particular parameter from a relevant body of the state administrator/ administrator of transport infrastructure.

Regarding GPR, the comparative measurement should include at least 2 applications:

- Pavement layer thickness measurement (including bound and unbound layers from different materials).
- Localization of built-in reinforcement (e.g. in cement concrete).

Examples of comparative measurements performed in the Czech Republic and France are described in the following three chapters.

2.1 COMPARATIVE MEASUREMENT OF GPRS IN THE CZECH REPUBLIC – PAVEMENT LAYER THICKNESS DETERMINATION

Comparative measurements of devices used for measuring variable pavement characteristics are performed in the Czech Republic in accordance with technical specification of the Ministry of Transport TP 207: Accuracy trial. The specification deals with measuring surface characteristics and pavement deflections.

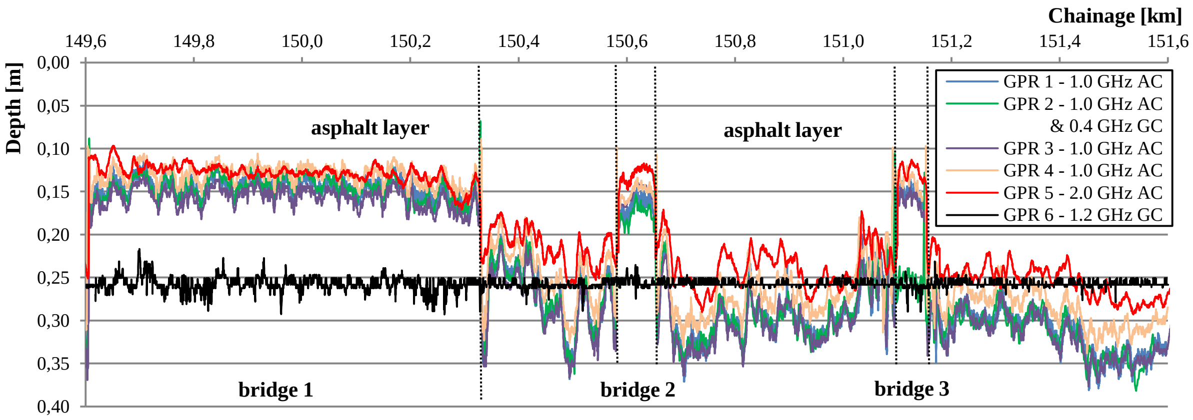
In 2015, the authors of this paper designed a method to extend accuracy experiment to continuous measurement of pavement layer thickness by GPR on reference road sections. The design is based on the results of the first performed comparative GPR measurement on a two-kilometre motorway section with three bridge structures (six organizations participated in the experiment).

The specific measurement of total thickness of asphalt layers was performed in the middle of the right (slow) traffic lane. Individual measurements were performed without traffic restrictions, under traffic flow speed, and were performed on different days. The decision concerning used signal processing methodology was left to each participant according to its common practice. The real thickness was verified by several core drills and the evaluation was made in two levels.

In the first level the participants had no available information from drills and each comparative measurement participant needed to determine electromagnetic signal propagation velocity using their own methods. In this case, the signal propagation velocity used by individual participants ranged between 0.116 and 0.150 m/ns.

In the second level, the experiment participants were given information from one drill. Based on known asphalt layer thickness in a specific place, it was possible to determine the electromagnetic signal propagation velocity more accurately and reached an average value of around 0.130 m/ns. The difference between individual evaluation levels along the whole monitored road section is presented in Fig. 1.

When evaluating comparative measurement results, the measurements of two organizations were disqualified. One organization failed to maintain the recommended steps of measuring and the layer courses provided insufficient detail. The other stated a constant thickness of asphalt layers of approx. 260 mm for the whole monitored section.



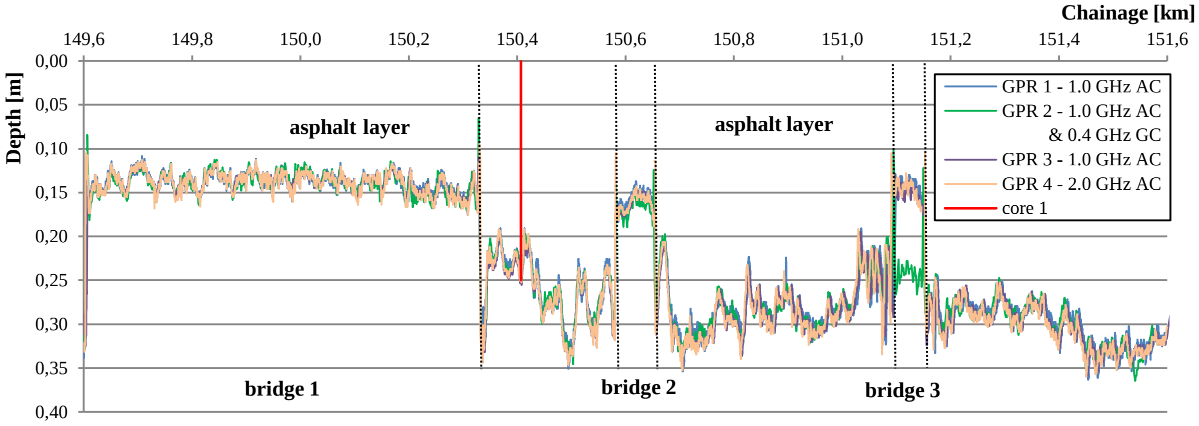


Fig. 1 *Comparative measurement of road layer thickness on reference motorway section – results of first evaluation level (top), results of second evaluation level after calibration with the use of core drill (bottom), AC – means air-coupled antenna, GC – means ground-coupled antenna*

The asphalt layer thicknesses on bridges determined by the organizations and marked GPR 1 to GPR 4 are very similar; they only differ in one case, on bridge No. 3 (see Fig. 1). The error was made on identifying the edge between the asphalt layer and concrete bridge deck.

When comparing the results of 4 organizations, individual 5-metre segments were taken into account. The difference in determined asphalt layer thickness from the average value on bridges ranged from 3 to 15 mm, i.e. 1 - 9 % of layer thickness. The difference in determined asphalt layer thickness from the average value outside bridges ranged from 10 to 18 mm, i.e. 3 - 5 % of layer thickness.

Along with the evaluation of measured layer thickness, driven distance on the monitored section was also compared. The maximum error was within 4 metres, i.e. less than 0.2 %.

2.2 COMPARATIVE MEASUREMENT OF GPRS IN FRANCE – PAVEMENT LAYER THICKNESS DETERMINATION

In the 2000, the Technical and Scientific Network (TSN) of the French Ministry of Environment, Energy and Sea organized a comparative experiment for their different GPR systems for road layer thicknesses measurement.

Three GPR systems were tested with several central frequency antennas: 400 and 900 MHz ground-coupled antennas and 1000, 1500 and 2000 MHz air-coupled antennas.

The final objective was to estimate the global uncertainty on layer thickness measurements, including the influence of time window effect, reference (coring location), scan picking, ambient temperature, height of antenna, speed of acquisition, repeatability and reproducibility.

Three types of course were tested; asphalt, concrete and unbound layers, implying several types of interfaces with specific electromagnetic contrasts and depths to detect. Interfaces between two successive courses are generally easy to detect, due to their high electromagnetic contrast, and correspond to a first family tests (Fam. 1). A second family of tests gathered all the other interfaces, which is more difficult to detect either due to low electromagnetic contrast between two similar layers or to important and variable depths (Fam. 2).

This notion of family of interface was designed by the TSN and validated by the Ministry, which also set some specific class of accuracy, limiting the uncertainty of road thickness estimation, in relation to road managers requirements.

Static or nearly static measurements were done on homogeneous granite slabs (thicknesses: 48, 50 and 52 mm) and on an indoor 5-m long road test-site (presenting 4 types of structures). Similarly, dynamic measurements were done on the same days (same time of day), on 9 road sections of 100m long, at 40 km/h for air-coupled antennas and 30 km/h for towed system supporting ground-coupled antennas. For the dynamic test focused on the speed acquisition, vehicles rolled from 20 to 60 km/h.

GPR data processing steps were following:

- on the granite slabs and the 5m road test site, the stability of the amplitude pickings was studied using their averages and standard-deviations,
- on the 100m road sections, after an adjustment of the longitudinal location, the calculation of the average and standard-deviation of GPR scans for every measurement were performed.

The decision concerning used signal processing methodology was left to each participant according to its common practice. While analyzing the results, the experimental campaign showed the negligible effect of the height of the antennas, the ambient temperature, the time window and vehicle velocity on measurements. The uncertainty of reference (choice and measurement of cores) on the estimation of the layers along the sections was evaluated to 0.8 mm.

The global uncertainties of the GPR systems remains are depicted in Fig. 2 for the two families of layer interfaces. All systems remain under the requested class of accuracy. Moreover, it is interesting to state, ground and air-coupled present similar uncertainties, and that these ones do not increase as the central frequency of antennas decreases.

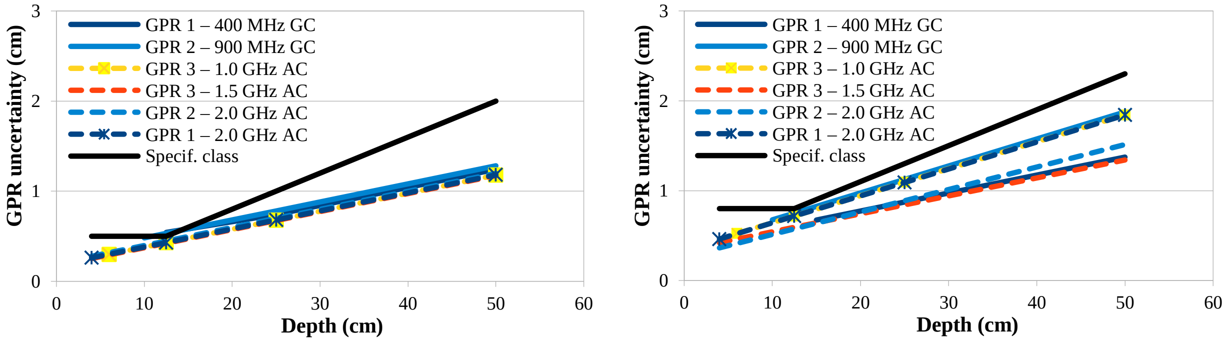


Fig. 2 *Uncertainties of GPR measurements for several systems for different kind of interfaces: Fam. 1 (left) and Fam. 2 (right), AC – means air-coupled antenna, GC – means ground-coupled antenna*

2.3 COMPARATIVE MEASUREMENT OF GPRs IN THE CZECH REPUBLIC – LOCALIZATION OF DOWELS IN CONCRETE PAVEMENTS

The authors of the paper have focused on the diagnostics of localization of dowels in concrete pavements since 2009, which is when they started using a two-channel GPR, doing experiments on laboratory samples, and subsequently performing measurements on roads in-situ [9].

The first comparative measurement of dowel localizations in concrete pavement was performed by the Czech Road and Motorway Directorate in 2010. Based on comparison of determined and real position of three dowels, found by core drilling, the GPR method accuracy was found insufficient. A subsequent analysis discovered that inaccuracies were caused by the incorrect determination of electromagnetic signal propagation velocity by individual measurement participants.

Following this, several comparative measurements were performed testing road sections built by companies specialized in laying concrete pavements, when more attention was paid to the correct determination of electromagnetic signal propagation velocity. The result was higher accuracy in localization of dowels and their tilt.

An example of a comparative measurement result in 2012 is shown in Fig. 3. The measurement concerned a concrete pavement joint with 30 dowels in different positions. The measurements were performed in two lines, 200 mm left and right of the joint. EM signal propagation speed was determined by the CMP method (v=0.101 m/ns).

Subsequently, the pavement was cut in these lines along the entire height and the positions of individual dowels were measured in horizontal and vertical direction. The data helped to determine the real depth of dowel position and calculate their tilt. Based on the real depth of a single dowel, the electromagnetic signal propagation velocity through concrete was adjusted (v=0.094m/ns). Fig. 3 presents inaccuracy of the localization of dowels and their vertical tilt, and the cause of the inaccuracy due to the electromagnetic signal propagation velocity used. While the electromagnetic signal propagation speed plays a crucial role in the depth determination, it does not play a major role for the vertical tilt calculation.

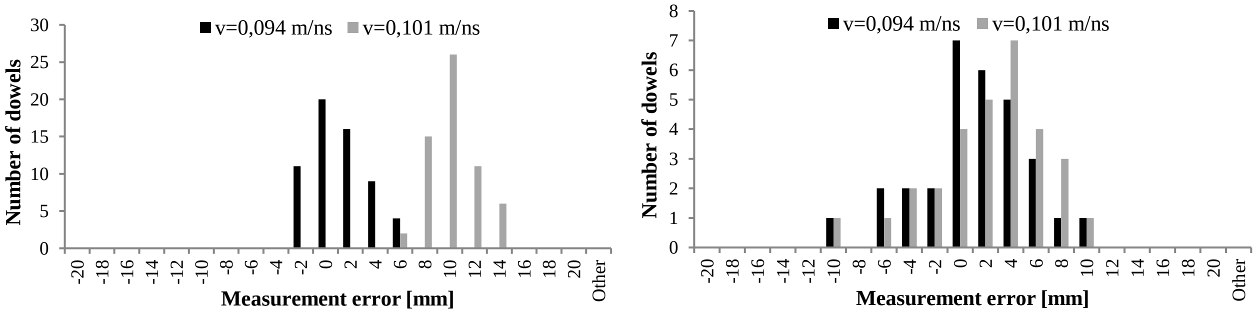


Fig. 3 *GPR measurement errors when using different electromagnetic signal propagation velocity – determination of depth of dowels in the joint (left), vertical tilt of dowels (right)*

The distrust of contractors as well as road administrators of this testing method initiated the need to minimize inaccuracies of GPR measurements and to perform comparative measurements like with other NDT methods which are used for road diagnostics.

In 2015 another comparative measurement of GPRs adjusted for localization of dowels and tie bars in concrete pavements was performed with two-channel GPR systems, see Fig. 4, left.

Several isolation joints between two pavement sections were selected where the locations of dowels and tie bars were measured directly in the joint (Fig. 4, right) with use of a calibrated steel rule measure and a tape measure. The thickness of concrete above the reinforcement was recorded vertically and distances of reinforcement centres were recorded horizontally. The following day a new section the concrete pavement was laid and it was measured by GPR devices after it hardened.

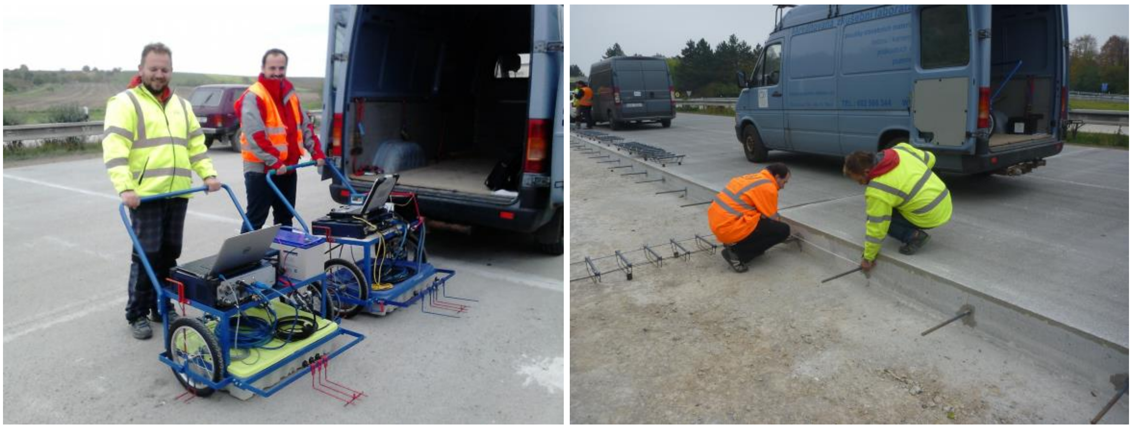


Fig. 4 *Two-channel GPR device for localization of dowels and tie bars in concrete pavement (left), method of direct localization of reinforcement in isolation joints (right)*

The signal processing included the following steps: time-zero correction, signal amplification, signal filtering (vertical IIR filters, background removal), migration velocity analysis and interactive interpretation.

Monitored parameters for the evaluation of measured position of dowels and tie bars were as follows:

- Stationing in a joint (horizontal distances of dowel and tie bar centres).
- Depth of placement in a joint (related to the centre of dowel and tie bar).
- Tilt in horizontal and vertical direction (measured by 2 antennas overrunning in three different positions; up to 6 positions of dowel/tie bar recorded).

Repeatability was analysed through three identical overruns made with each cart during the localization of dowels (Fig. 5) and tie bars. When localizing tie bar positions, the results were compared with the real positions in the isolation joints (Fig. 6).

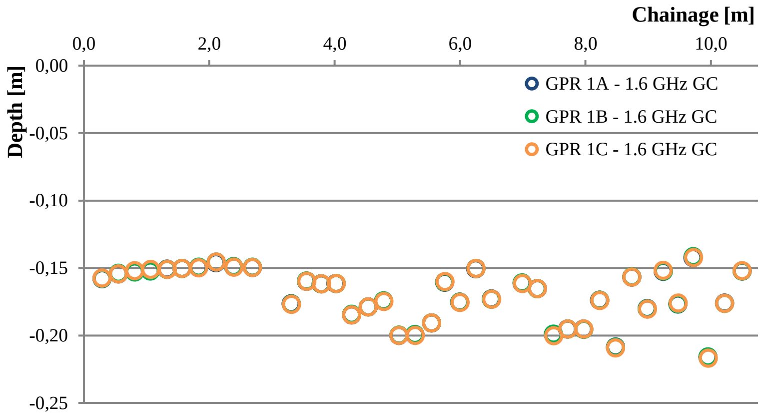


Fig. 5 *Repeatability of measurements – dowel positions in a construction joint – GPR device 1, three overruns, GC – means ground-coupled antenna*

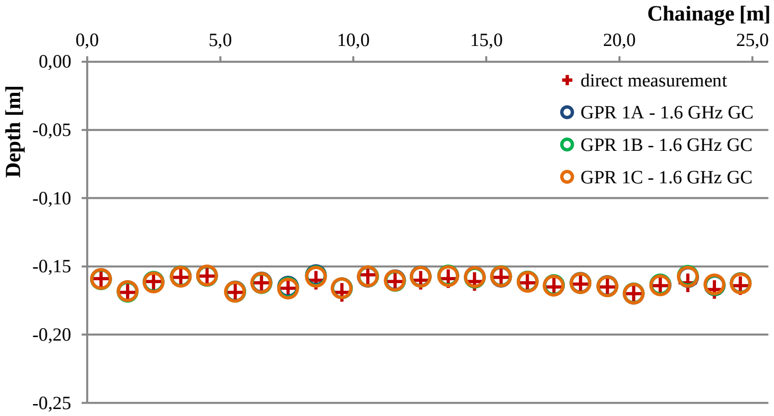


Fig. 6 *Localization of tie bars in an isolation joint in comparison with real position – GPR device 1, three overruns, GC – means ground-coupled antenna*

In order to determine built-in reinforcement location more accurately three overruns by a two-channel GPR device in three different lines were performed, i.e. up to six positions of a dowel or tie bar were recorded. Subsequently, the linearization of these points was performed.

The differences in location of monitored 220 dowels and tie bars in isolation joints measured in 2015, are shown in Fig. 7 concerning repeatability and Fig. 8 concerning comparison with true position.

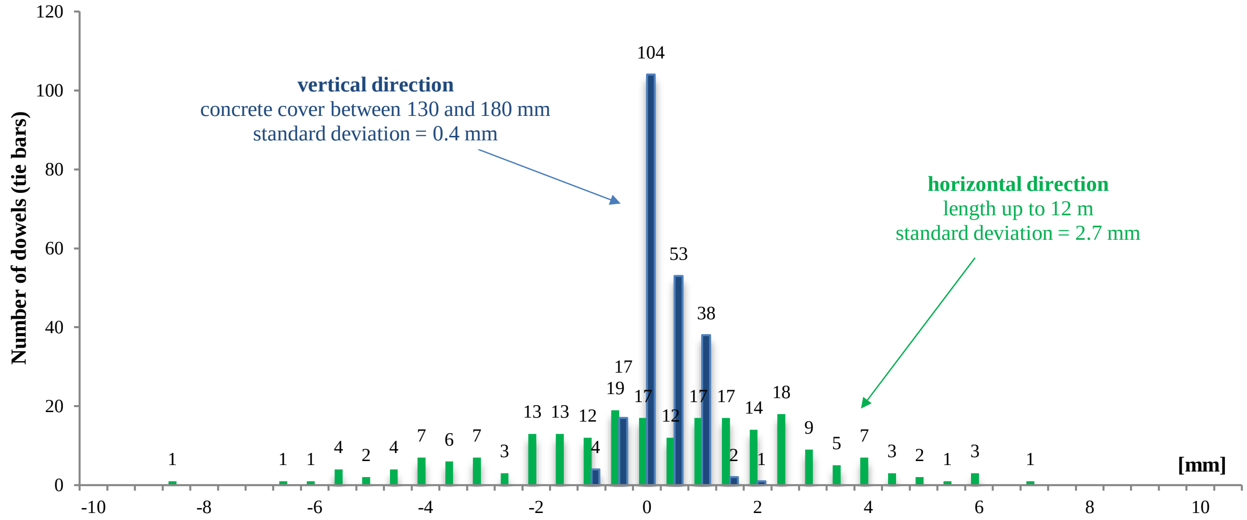


Fig 7 Repeatability of GPR measurements in horizontal and vertical direction for three overruns – results from 220 dowels and tie bars in isolation joints

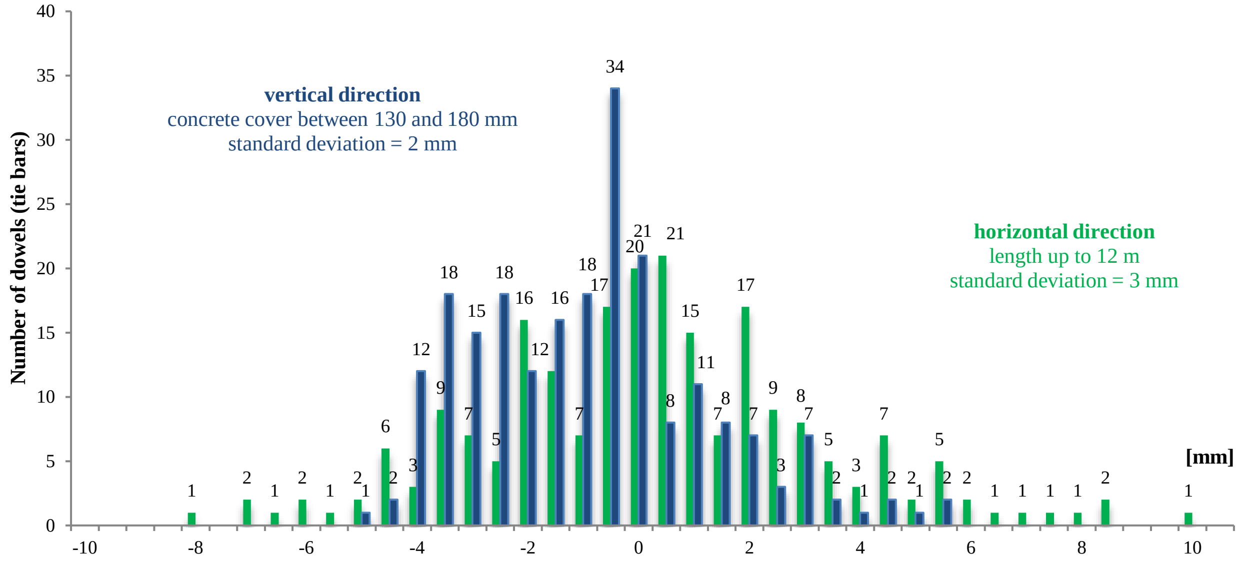


Fig 8 Accuracy of GPR measurements in horizontal and vertical direction – results from 220 dowels and tie bars in isolation joints

Based on all results of GPR measurements, the following conclusions were made:

- repeatability for 3 overruns:
  - in horizontal direction up to 7 mm,
  - in vertical direction up to 2 mm.
- accuracy for locating dowels (tie bars):
  - in horizontal direction up to 10 mm,
  - in vertical direction up to 5 mm.

Electromagnetic signal propagation velocity was determined on concrete pavement isolation joint. The accuracy in vertical direction is particularly influenced by the non-homogeneous nature of material (cement concrete) above the dowels (tie bars) in question. The accuracy in horizontal direction is particularly influenced by inaccuracy of the localization device, which is mounted on a wheel of the mobile device, correct setting of the beginning of measurement, and total driven distance, which was up to 12 m in this case.

3. CONCLUSIONS FROM PERFORMED MEASUREMENTS

In order to reach required accuracy, it is necessary to maintain certain rules for measuring and for evaluating the data measured by GPR.

The optimum setting of the equipment for a specific application includes an option to select the number of channels, frequency of antennas, speed of measurement, measured data localization method, etc. The option is often left for the device operators, since it is closely related to available devices.

The effect of correct determination of electromagnetic signal propagation velocity through a tested environment was found to be the most decisive factor for accurate determination of layer thickness or reinforcement depth. Standards and technical specifications show table values of electromagnetic signal propagation velocity and relative permittivity for different materials. Their ranges are considerably high for road materials, such as cement concrete and asphalt concrete, particularly due to the age and condition of the layer, non-homogeneousness, different moisture of materials, etc. Relative permittivity of cement concrete in tables ranges from 4 to 20 and the corresponding electromagnetic signal propagation velocity from 67 to 150 mm/ns. Using the table values for the data evaluation may lead to a considerable error. Based on Czech experience, the electromagnetic signal propagation velocity through concrete pavement ranges between 85 and 115 mm/ns.

Ideally, the specific electromagnetic signal propagation velocity should be determined with the use of core drills or by directly measuring of thickness or depth. If they cannot be used, CMP, WARR and other methods are employed to reach the maximum accuracy of this value.

Prerequisite for correct determination of horizontal position is sufficient accuracy of the device used for measuring of driven distance and the evenness of the measured surface. When measuring pavement layer thickness, the monitored road section is divided into smaller units to prevent serious errors. In some cases it was obvious that the depths are determined correctly but the driven distance was incorrect, which is particularly hazardous for the determination of electromagnetic signal propagation speed with the use of core drills performed in a specific position.

Regarding laboratory measurements, high accuracy is often reached particularly when determining the position of built-in reinforcement in horizontal and vertical directions. Repeatability of GPR measurements is usually not a problem.

The measurement data is processed with the use of different software with the aim of emphasizing the required areas and supress undesirable effects, such as passing vehicles, electric power network, etc. The data from measurements performed at new structures, rather than at older ones, are much clearer, which is particularly obvious at layers from asphalt concrete.

The interpretation of pavement layer thickness measurement data is performed in graphic form where all measured values along the whole monitored road section are shown. The evaluation uses the table form, where it is necessary to select an interval for the calculation of averages of measured thickness. This may be a source of inaccuracies at a sudden change in thickness, particularly in combination with inaccurate driven distance measurement.

The interpretation of built-in reinforcement position from measurement data, e.g. dowels in concrete pavement, is easier, since every reinforcement element is evaluated separately. The table marks the dowels which fail to meet the requirements for tilt and the accuracy of placement depth.

4. RECOMMENDATIONS FOR PERFORMANCE OF GPR COMPARATIVE MEASUREMENTS

Based on the existing experience, comparisons of different GPR devices, and performance of comparative measurements of GPRs and other NDT devices, the below mentioned general recommendations were formulated which are specifically related to two GPR applications, i.e. measuring of pavement layer thickness and localization of built-in reinforcement.

During the first phase, it is necessary to check the functionality of the GPR system, ideally on a reference sample from homogeneous material verifying the signal shape (time course, amplitude, signal-bias ratio) and its stability. This check should be made in regular intervals even outside comparative measurements. Related recommendations are shown in e.g. ASTM D6087-08 (2015), [19].

Thereafter, the process should be verified on a real structure or a large-scale testing sample. However, in case of testing sample there is a disadvantage that the results will become known over time and it is necessary to produce a new sample.

Apart from checking the correct determination of layer thickness/reinforcement depth, it is also necessary to verify devices used for measuring of a driven distance/measurement localization (DMI - Distance Measuring Instrument, GNSS - Global Navigation Satellite System).

Comparative measurements must generally be performed on the same day and under same conditions for all measurement participants.

Regarding the GPR, repeatability and reproducibility of individual devices should be performed. Setting specific requirements will be crucial, since they must reflect the purpose and required measurement accuracy.

4.1 Pavement layer thickness

The requirement for measurement accuracy needs to be based on the measurement purpose which the devices are to serve. European project ROSANNE deals with three different precision classes:

- Level 1 – measurements in construction contracts.
- Level 2 – measurements for the network monitoring and research.
- Level 3 – measurements for other purposes.

The specific requirement should be defined by a relevant state administration body, road administrator or other end users of measurement results.

The equipment used and signal processing methodology could be unspecified, however, it is necessary to state whether the measurement is performed along a single longitudinal line or it is a 3D measurement, to state required depth range, and minimum measurement speed.

Testing road sections should include traditional structures with asphalt concrete layers, or with concrete pavement respectively (in case they are applied on the road network). Thickness of new pavement layers can be measured by a laser scanner before and after their laying, which makes information on the real condition more accurate. Regarding older pavements, core drilling is made for carefully pre-selected positions. It is recommended to have at least 100 m long sections with changing layer thicknesses at their length.

The measurement should be performed by at least 3 repeated, consecutive, overruns of GPR devices. The evaluation of the measured data should ideally be performed at two levels, at first without calibration, while every participant determines the electromagnetic signal propagation velocity with their own method, and then with information from core drilling (location of drilling, individual layer thickness). Evaluation should be applied on both the repeatability of measurements by individual devices, and the difference between determined and real layer thickness. It is recommended to make averages every 1 metre for the measured thickness, which may be adjusted based on the frequency and extent of layer thickness changes.

4.2 Reinforcement position – with focus on dowels in concrete pavement

Although this is a different GPR application, a number of recommendations are similar to pavement layer thickness measurement.

It is diagnostics of small depths, therefore, vertical accuracy is usually required up to 1 cm (Czech technical specification of Ministry of Transport TP 233, [9]).

It is recommended during the measurement to use at least a two-channel device, which measures the dowel location in two points within a single overrun. Therefore, besides the location, it is possible to determine the tilt of dowels, which is evaluated.

The measurement should be performed on several joints of concrete pavement, where sufficient variability of dowel position (depth, spatial position) was determined in advance. The test sections should be produced with the use of at least two different concrete mixtures. The measurements should be performed at least three times, due to the evaluation of repeatability. The evaluation of the measured data should ideally be made at two levels, at first without calibration, while every participant determines the electromagnetic signal propagation velocity with their own method, and then with information on a position of one dowel for each concrete mixture (depth in the joint). The accuracy of localization of dowel in horizontal and vertical direction in a selected place, usually in a joint, and its tilt (horizontal and vertical displacement) is evaluated.

5. CONCLUSION

The performance of in-situ comparative measurements of GPR systems used for diagnostics of road infrastructure is currently not required and organised at national and international levels.

The paper presents the results of the measurements performed in the Czech Republic and France with achieved accuracies. Based on the existing experience and results of comparative measurements the general recommendations were formulated, which are specifically related to two GPR applications, i.e. measuring of pavement layer thickness and localization of built-in reinforcement. This methodology was integrated in technical specification of the Czech Ministry of Transport TP 207: Accuracy trial, where a new chapter focused on GPR comparative measurement was added in 2017.

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