The European GPR Association Guidelines for Pavement Structural Surveys

Document Reference: GS1601
V1.0
12/04/2016

EUROPEAN GPR ASSOCIATION

1 Scope

This document relates to Ground Penetrating Radar surveys carried out on highway or street pavements as well as private roads providing they are hard standing (not dirt or gravel roads). It does not consider surveys of airport pavements as these require special consideration. It considers only those surveys performed specifically to ascertain information directly relating to the pavement itself. It does not consider surveys performed over pavements to ascertain location of targets beneath the pavement such as buried utilities or archeologically remains as these require special consideration, although it is noted that occasionally such surveys are combined.

This document aims to provide guidance to EuroGPR association members to ensure they undertake GPR surveys on pavements in a safe and responsible manner. It is not meant to provide a specification of how every variation of pavement GPR survey should be performed. EuroGPR members are required to conform to any local or national specification for these surveys that may be already in place.

This document will also be useful to those who have the responsibility of commissioning GPR surveys for pavements and utilising and storing the data produced.

2 The nature of pavement structural surveys

Surveys generally fall into two categories of deliverable, surveys for pavement construction and surveys for pavement material condition. Often there is overlap between them and they are often not mutually exclusive. In many cases GPR surveys of this nature can be carried out at or close to traffic-speed whilst maintaining the desired data density. The surveys can also be performed at much slower speeds within traffic management either using a vehicle or using man-portable system configurations, for example if transverse profiles are required.

2.1 Pavement construction

Pavement construction surveys deal with identification of the nature of the pavement construction. They are occasionally performed to populate pavement management systems due to the lack of or unreliable 'as built' records on older and heavily maintained pavements and often to provide construction modelling for pavement residual structural life assessment. They can also be performed as a quality control measurement of construction to ensure the built pavement matches the design specification.

The vast majority of pavement construction surveys using GPR aim to deliver material layer thickness as by their nature, pavements are constructed in layers. However, it should be noted that GPR detects interfaces between two contrasting materials. This means that in order for GPR to deliver 'layer thicknesses' the data analyst must have confidence that the interface at the top *and* the bottom of the layer has been resolved in the GPR record. There are reasons why this might not be possible, for example the material layer may be very thin and the GPR of insufficient resolution to distinguish between the upper and lower surface of the layer. Or the contrast between the layer being measured and either the upper or lower material may be insufficient to cause a strong enough reflection at the interface to be visible in the GPR record.

Therefore GPR surveys of pavement construction should generally report identified interface depths. Layer thickness can be reported in the following notable exceptions:

- The number of material layers present can be verified by an independent source of construction information, such as a core or an as-built record which can be confirm the quantity of layers measured by the GPR is the correct number expected.
- If layer thickness of only major material types is required, for example asphalt thickness and concrete thickness.

Surveys can also deliver other information relating to specific types of pavements, for example it can deliver the arrangement of rebar in reinforced concrete pavements and bridge decks.

2.2 Pavement condition

GPR can provide information relating to the apparent condition of a pavement and due to its high productivity and low disruptive nature can provide a useful reconnasance survey to direct more resource intensive investigation. Typical deliverables include apparent material density variation and voiding, and apparent moisture variation.

3 Limitations of GPR use on Pavements

The following is a list of commonly held (but not exhaustive) limitations regarding the use of GPR on pavements:

- GPR cannot penetrate metal (e.g. closely spaced rebar) or other highly electrically conductive materials.
- GPR surveys should be avoided when it is raining and should not be carried out when standing water is present on the surface of the pavement.
- GPR surveys must not be carried out on roads treated with de-icing salts in case of significant penetration of salt water into the pavement materials.

4 Survey Assessment

Upon receiving the initial enquiry or request for survey services, the *survey contractor* should carry out an assessment to determine if GPR is a feasible approach to the *client's* investigation requirements. The assessment should primarily be based on the likely capability of GPR to meet the investigation objectives but should also be based on whether another technique will be more cost effective, accurate or practical.

If the outcome of the assessment is that the likelihood of a GPR survey being successful is low, the *client* should be informed. The way forward from this point may be via one of the following approaches:

- The *survey contractor* can recommend an alternative technique or perhaps a suite of techniques that may have a better chance of meeting the survey objectives.
- The *survey contractor* can recommend a pilot scale trial to reduce risk, if the scale of the whole survey warrants this approach

5 Survey Specification

Assuming the decision to go ahead with a GPR survey is reached, in advance of undertaking a pavement structural survey, the *survey contractor* and the *client* should agree a suitable survey

specification or strategy which should include written evidence of agreement of the following minimum information:

- Key survey aims or deliverables
- Traffic management requirements
- Site specific health and safety requirements, as a minimum a risk assessment should be performed and a method statement provided.
- Agreed working hours (if under traffic management) or working time restrictions, e.g. not during peak traffic.
- Survey data outputs formats
- Definition of the survey extent(s) and coverage including:
    - Start and end positions and how they should be identified, typically by section/chainage, marker-post, spatial (GPS) coordinates or other physical feature.
    - For vehicle based surveys, the number and position of measurement offsets required, e.g. wheelpath positions or measured offset positions relative to lane dividers, as well as the number of lanes to be covered, should be agreed.
    - For 'on foot' surveys, the number and position of all individual profiles or grid density if a full orthogonal grid is to be used.
    - The in-line GPR measurement interval; for traffic-speed vehicle based surveys this will most often be the minimum spacing achieved by the GPR system in order to conform to the site definition of traffic-speed. This may also determine whether or not the survey can be performed at traffic speed if the spacing required is less than that achievable by the system when operated at local site traffic-speed.
- The type of antenna or range of antennas to be used must be agreed in advance following expert guidance from the *survey contractor* and will depend on the following:
    - The maximum penetration required from the GPR data, the survey contractor should provide realistic estimates of signal penetration to the client.
    - The minimum desired target size or layer thickness, again the survey contractor should provide a realistic indication of this and guidance to the client.
    - The type of targets and materials under investigation.
    - The local environmental conditions.
- How the velocity calibration will be performed; if cores are to be used the following should be agreed:
    - Who will be taking them (in some cases the *survey contractor* or *client* may be also the coring contractor or it might be a 3rd party contractor appointed by the *client* or *survey contractor*)
    - The number of cores available/to be taken.
    - How they are located (section/chainage or GPS) and to what accuracy.

- When the core data will be available and what format it will take.

- The *survey contractor* should state what risks there are to the project. Risks will include conditions that may prevent the survey from being effective, may prevent the survey from being delivered on time or may prevent the survey from being delivered within budget. Such risks may include but are not limited to:
  - Weather conditions, either during the survey or for a period before the survey that may render the survey or certain deliverables unreliable.
  - Surface contamination, for example winter maintenance de-icing salts or gritting.
  - Staffing and equipment resource conflicts.
  - Delays in obtaining calibration data, particularly core data from a third party contractor.
- Deliverable timescales should be agreed. Results of GPR pavement surveys often feed into other pavement evaluation techniques. Delays in delivering GPR data may have a domino effect down the chain and lead to significant delays on a the client's own project delivery.
- The overall cost of the survey, breakdown of charges and conditions under which additional charges may be occurred. The latter may be included in the *survey contractor's* standard terms and conditions for undertaking surveys.
- The format and presentation of the deliverables.

6 Location Referencing

Incorrect or inadequate location referencing is one of the primary causes of error in GPR surveys on pavements. This error can be triggered by errors in matching GPR location to core locations when performing calibrations and generally in the reporting of GPR data. The former error is not always the result of errors in the GPR but can also come from errors in the core location measurement, especially if a third party contractor is involved. The *survey contractor* should ensure that every effort is made to minimise the risk of location referencing errors.

6.1 Vehicle based location referencing

The minimum requirement for location referencing of traffic-speed data is by elapsed chainage from reference points. In order to achieve this, the survey must utilise at least one odometer wheel connected to the GPR to control scan rate and provide chainage measurement. These odometers are often built into the wheels of dedicated survey vehicles but can also be additional wheels that are towed behind the vehicle along with the GPR system, mounted on the wheel nuts of a none driven wheel or more recently can be laser distance measurement instruments.

So called 'time based' or 'continuous' GPR collection modes should not be used for traffic speed GPR surveys.

It is important to ensure that the distance measurement system is correctly calibrated. The *survey contractor* should select a suitable site to perform a calibration check. The check should be performed weekly or whenever the equipment is used if less frequent than weekly. For devices attached to wheels with pneumatic tyres, the tyre pressures should be checked regularly and before the calibration check.

The most common method for delineating chainage measurement is by manually entered event markers in the GPR data, often known as push-button events. This introduces inherent error into the GPR data due to normal reaction times for an operator pressing a button over the required reference point in a vehicle travelling at traffic-speed. This error should be taken into account when reporting GPR with this method and when performing odometer calibration checks with this method.

Use of a GPS receiver is recommended as an additional method of relocation. The traffic-speed capable systems produced by all EuroGPR manufacturers have the capability to use a GPS receiver. Even a low-cost consumer grade GPS unit is useful as an independent check of the wheel odometer for highlighting obvious errors in chainage measurement or marker event placement.

If GPS derived spatial coordinates are to be included with the deliverables of the survey, the GPS system used should be considered 'survey grade' and be calibrated according the manufacturers recommendations.

6.2 On foot survey location referencing

There are numerous methods of providing location referencing for on foot GPR surveys, the *survey contractor* should ensure that the appropriate methodology is utilised for the survey application and the *client's* desired accuracy requirements.

7 Data Quality and Backup

The *survey contractor* should ensure that all collected data is checked for appropriate content ideally before leaving the survey site. This is often possible in real-time via the data collection system software streaming data to the screen in real-time. A simple check of data file sizes can also be an early clue to a malfunctioning system. One or more random data files from the data set should be opened to check data quality and file corruption before leaving site.

The collected data should be duplicated to a separate storage media from the data collection system at the end of a data collection shift.

8 Data Reporting

The results from a pavement GPR survey should be presented in the format agreed in the survey specification, ultimately it should be in a format that can be easily understood by the *client*.

The *survey contractor* should make available the raw and processed GPR data for the *client* to view if requested. The *client* is unlikely to have GPR analysis software and should be advised on a suitable viewing software package, which are generally provided free of charge via GPR manufacturers and third party GPR software providers.

Numerical data should be provided in a standard format such as Microsoft Excel or ASCII text file. Graphical interpretation data should also be provided in a standard and pre-agreed format, if this is not possible or practical, the *survey contractor* must provide suitable viewing software as part of their deliverables.

A written report is not generally required for routine pavement construction surveys but may be required for pavement condition surveys and for pavement construction surveys if the following circumstances are met:

- Conditions arose (either anticipated or otherwise) that significantly affected the outcome of the survey. In which case the report should clearly reassess the effectiveness of the survey.
- The outcome of the survey required a great deal of subjective interpretation; for example, the number of cores was not sufficient for the construction variability or the GPR did not seem to agree with a significant proportion of the calibration data provided.
- The *client* is relatively unfamiliar with GPR.

9 The Survey Contractor's Obligations

The *survey contractor* is generally obliged to conduct their business in an ethical manner and respect the reputation of the GPR industry as well as their own.

9.1 Local GPR regulations

The survey contractor must be aware of any local or national regulatory control over GPR where they will be operating. They must comply with any regulations at all times when operating. The contractor may consult the EuroGPR website or contact the EuroGPR committee directly for the latest information relating to local or national regulations.

9.2 Project Management

The contractor should have effective project management policies in place. Throughout the contractor, the contractor should inform the client of the progress of the survey and any changes to the risks agreed in the specification stage.

9.3 Mis-selling

The contractor must be realistic in its sales and marketing activities and specifically not over promise on GPR capabilities. If the client has requested a solution that has not been proven by the contractor, the contractor should seek input from the industry in the form of reviewing previous work. Alternatively the contractor should offer a survey trial where key objectives can be reviewed before commitment is made to a larger survey or a breakout clause included in the larger survey if it becomes apparent the survey is less effective than originally anticipated.

10 Definitions

Deliverable: The interpretation of a data set delivered to the survey client.

As Built Records, pavement construction records that detail the original pavement construction and any changes made to the construction thereafter.

Chainage, a distance measured along an imaginary line corresponding to the centre of the road.

Event Markers are digital marks placed in the data to record the position of key survey points on the site relative to the data.

Location Referencing, a system of determining the position of a GPR measurement relative to other measurements or to an external frame of reference such as spatial coordinates.

Man-Portable System, GPR system pulled or pushed by hand using a suitable trolley or skid plate and handle arrangement.

Odometer Wheel, an instrument that measures/records distance travelled by a vehicle

Pavemen,: bound surfaced road or highway

Rebar, a steel bar or mesh of steel wires used as a tension device in reinforced concrete to strengthen the concrete.

Residual structural life, The calculated remaining structural life of a pavement

Scheme, A defined project to investigate the construction and/or condition of a section of sections of road pavement and define maintenance needs.

Section, Delineated section of highway (ranging in length) allowing reference in a pavement management system.

Traffic-speed, the minimum speed required on a given highway to negate the local requirements for traffic management.

Wheelpath, a longitudinal measurement offset defined relative to the lane centreline. Local definitions vary.

Version History

Ver. No.	Description	Drafted By	Approved By	Publication Date
V1.0	Committee reviewed draft for publication	Adam Cook	Committee	12/04/2016