



Centre de recherches routières
Votre partenaire pour des routes durables



Thickness estimation of road pavement layers using Ground Penetrating Radar

Dr. Ir. Audrey Van der Wielen

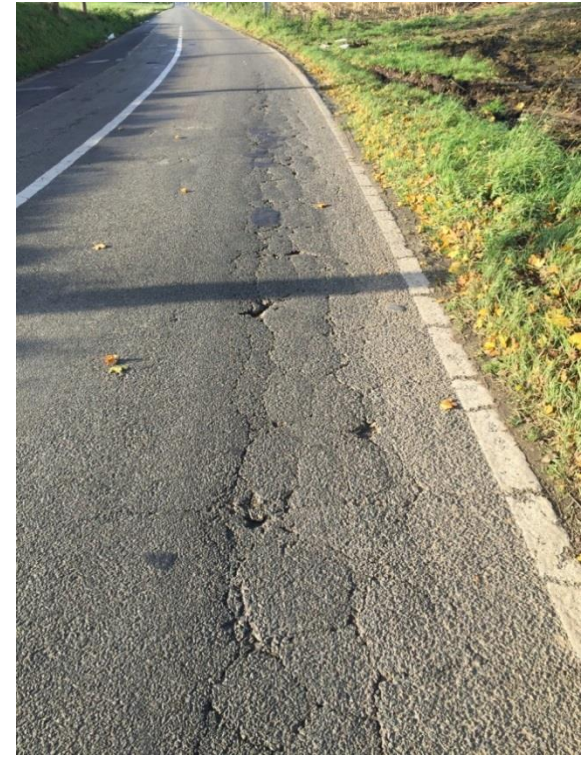
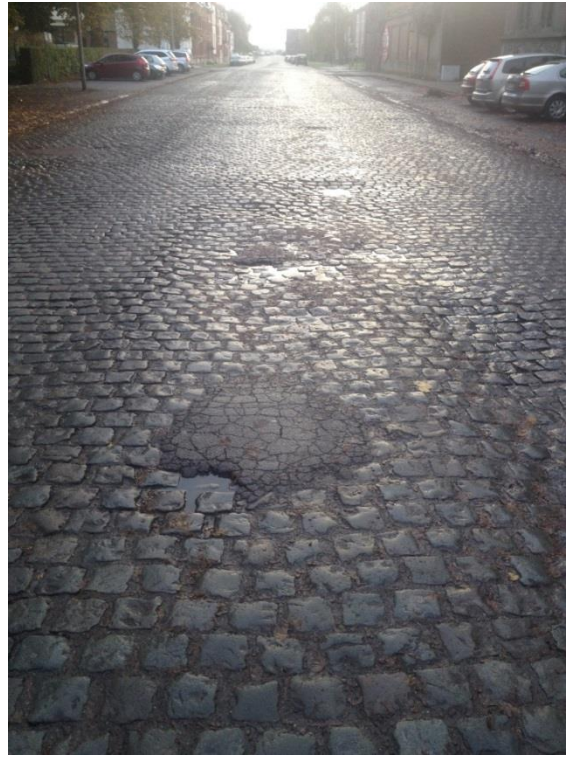
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Dr. Carl Van Geem



ECTRI – FEHRL – FERSI

Young Researchers Seminar 2015



www.sauvonsnosroutes.be



Prior to any road maintenance work, a structural evaluation is needed

- Selection of the type of rehabilitation
 - Structural rehabilitation
 - Overlay
- In Belgium, the road structure evaluation methodology includes deflection measurements

Application of a
controlled load



Measurement of
the local deflection



Deflection measurements can be performed by two methods

Falling Weight Deflectometer (FWD)



Falling weight impacting the road

Cuviameter

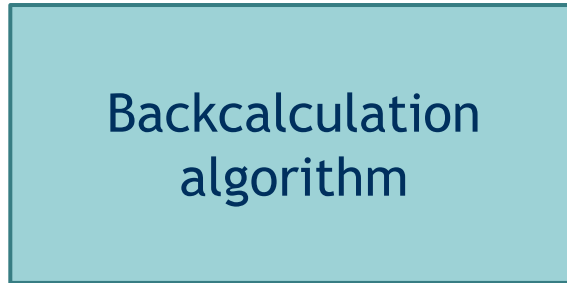


The truck itself is the load

➔ Local deflection measurements

To analyse the deflection measurements, the layer thickness has to be known

Deflection measurement



Mechanical properties of the different layers



Layers thicknesses



Coring

- Local damages
- Traffic interruption
- Local information



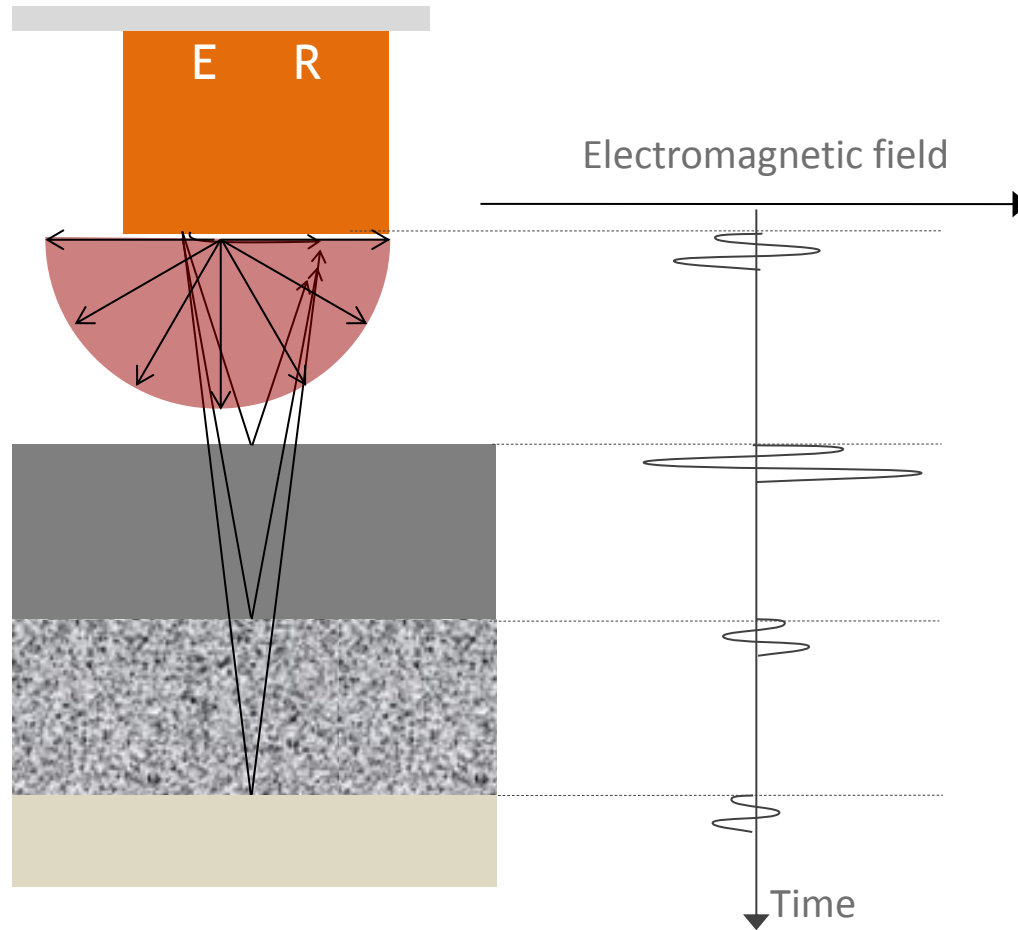
Ground Penetrating Radar

Thickness estimation of road pavement layers using Ground Penetrating Radar

- Ground Penetrating Radar principle
- Development of a thickness evaluation methodology
- Method validation and assessment



The GPR sends electromagnetic pulses that are reflected by the interfaces

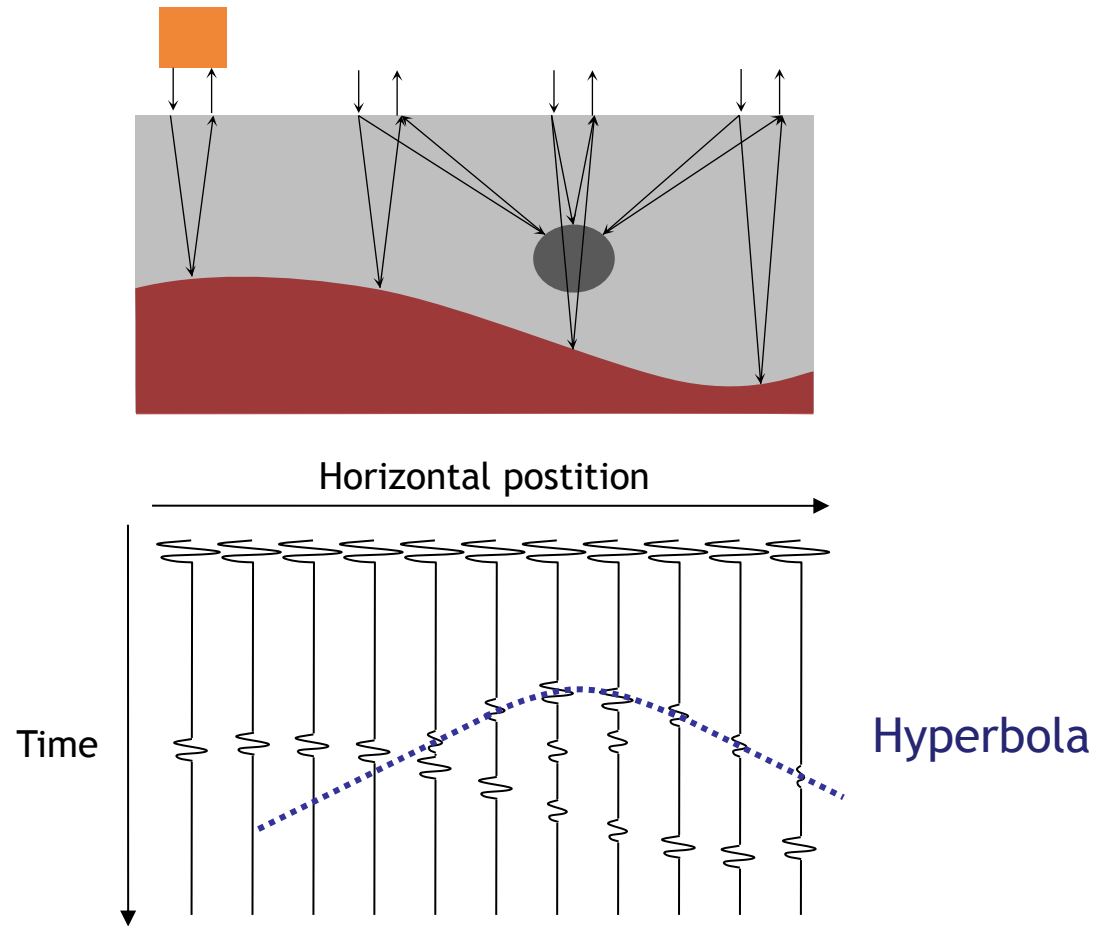


The Ground Penetrating Radar (GPR) is designed to inspect the underground

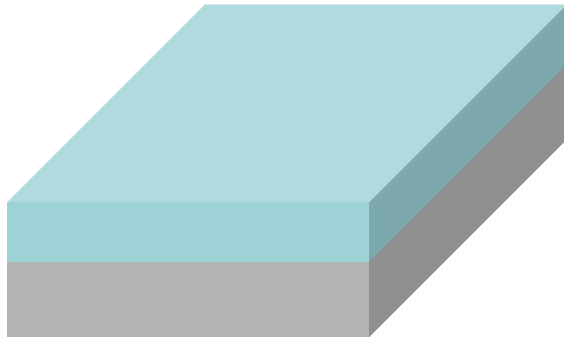
- Electromagnetic waves
 - Frequencies from 0.1 to 3 GHz
- High frequency antennas
 - Designed to inspect civil structures
- Measurements into traffic
 - Up to 90 km/h



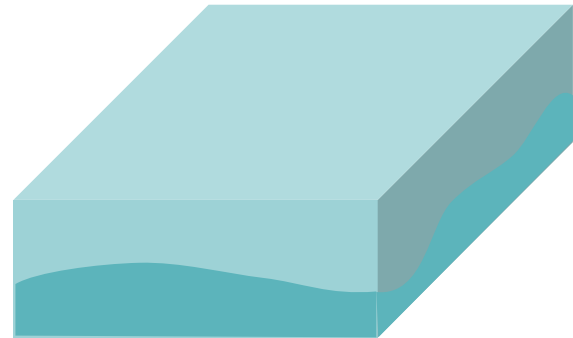
A profile of the underground is created by gathering all the different scans



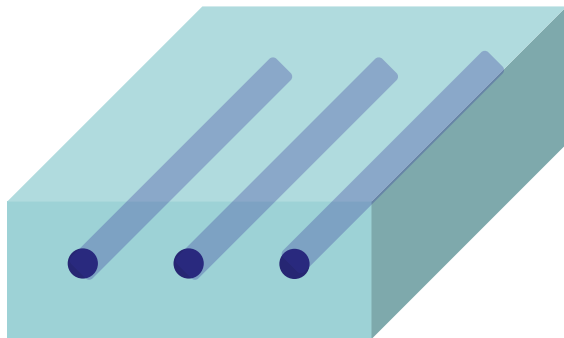
Different types of interfaces can be detected by the GPR



Material change



Humid zones

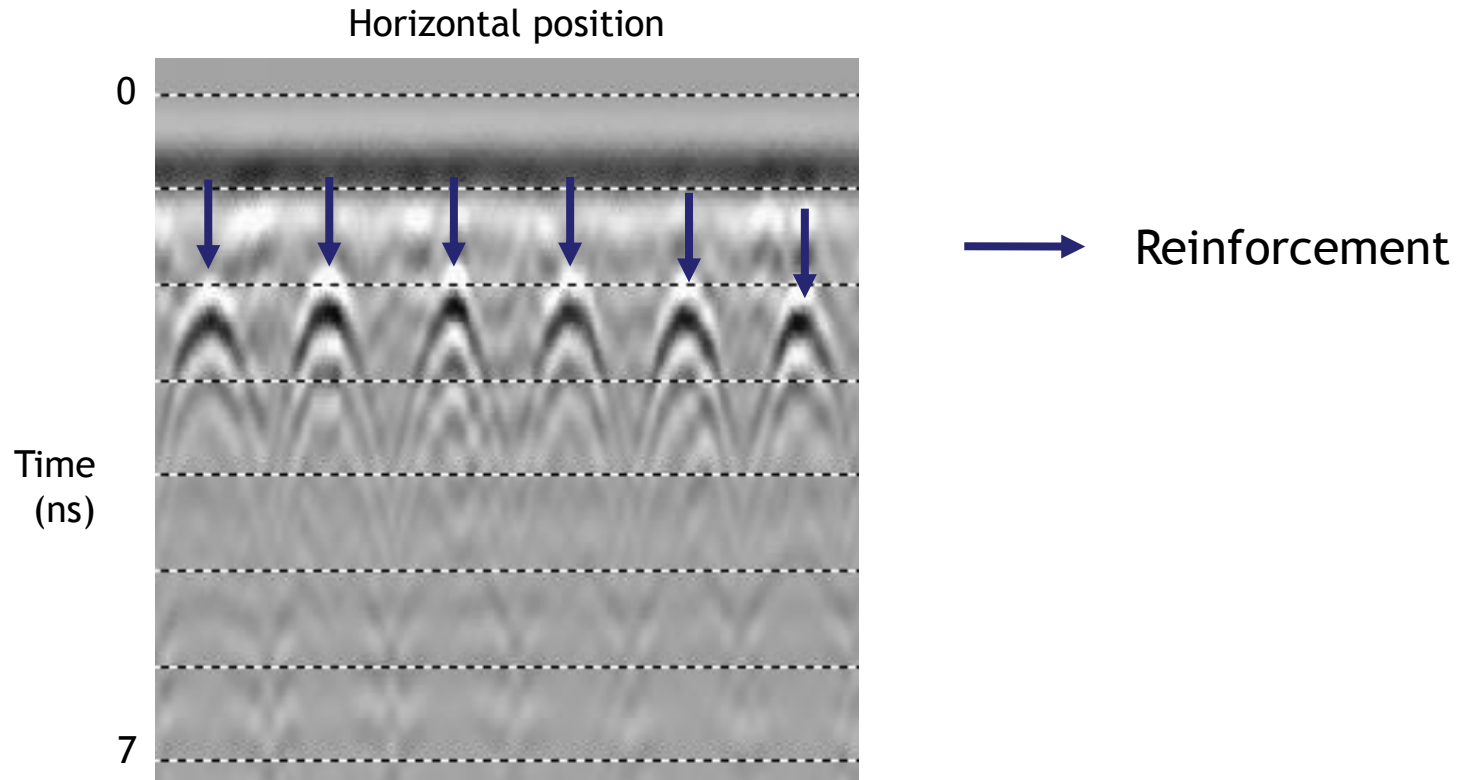


Metallic rebars



Voids

A grey scale is often used to represent the amplitude

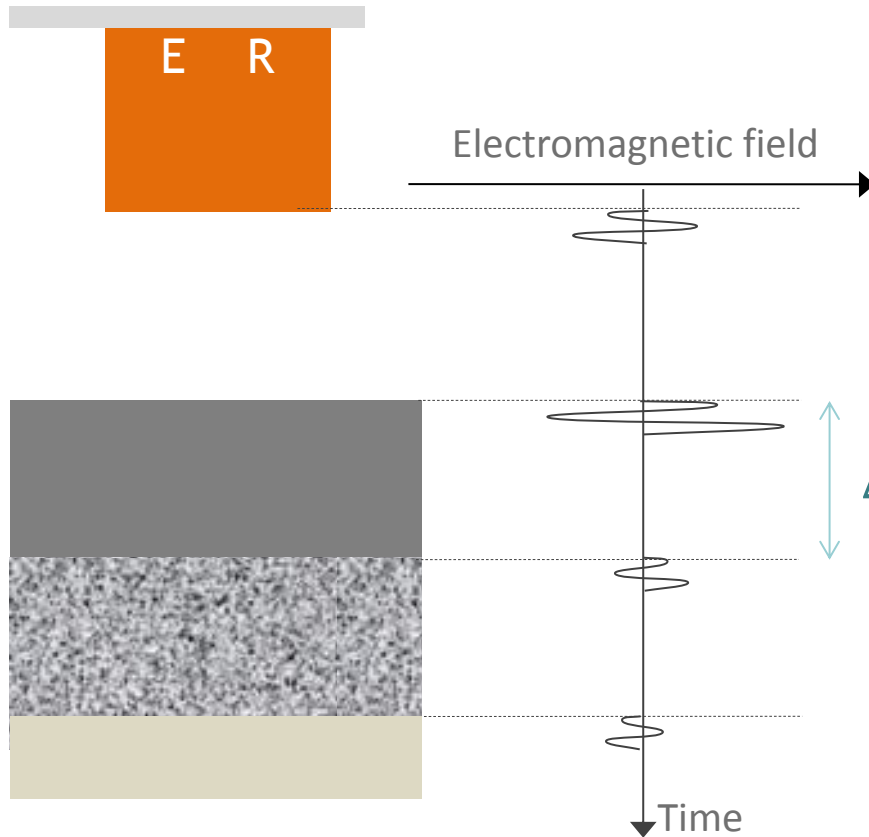


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The wave speed is required to estimate the layer thickness



$$z = \frac{v \cdot \Delta t}{2}$$

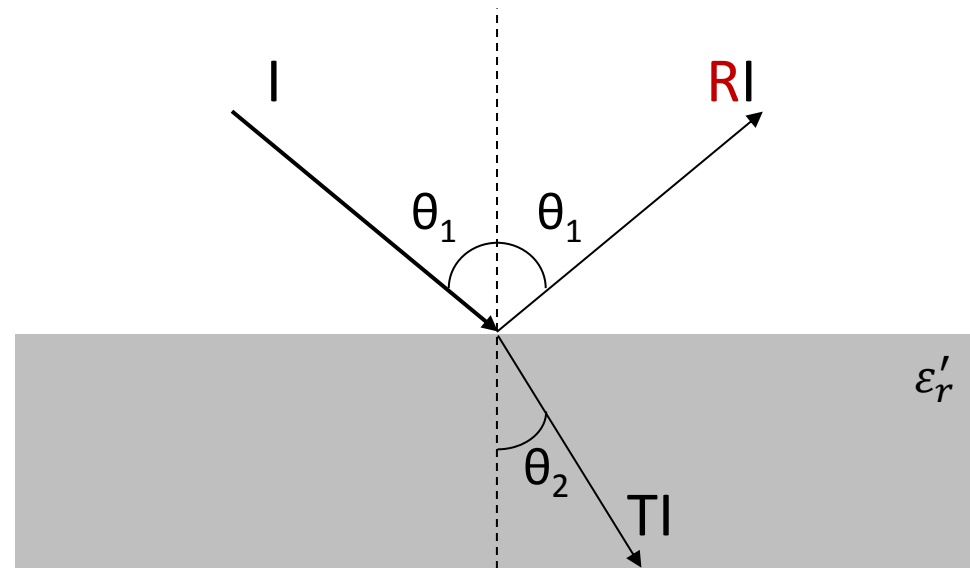
$$v = \frac{c}{\sqrt{\epsilon_r'}}$$

Speed of light

Dielectric permittivity



The reflection coefficient is the proportion of the wave reflected by an interface



$$\epsilon_r' \cong \frac{(R - 1)^2}{(R + 1)^2} .$$



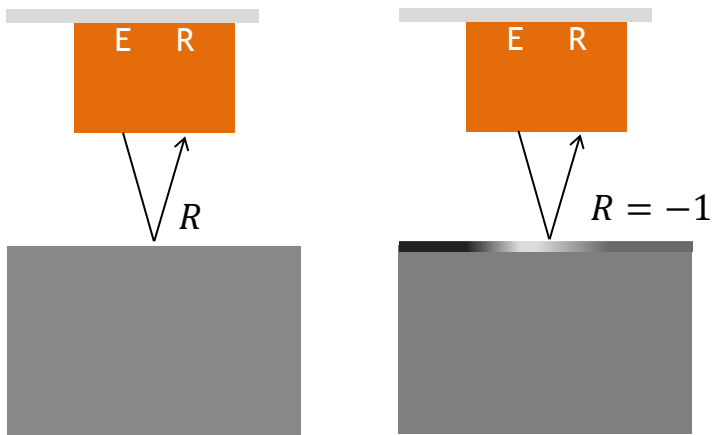
The GPR sends electromagnetic pulses that are reflected by the interfaces

$$R = -\frac{A_{meas}}{A_{calib}}$$

ε_r'

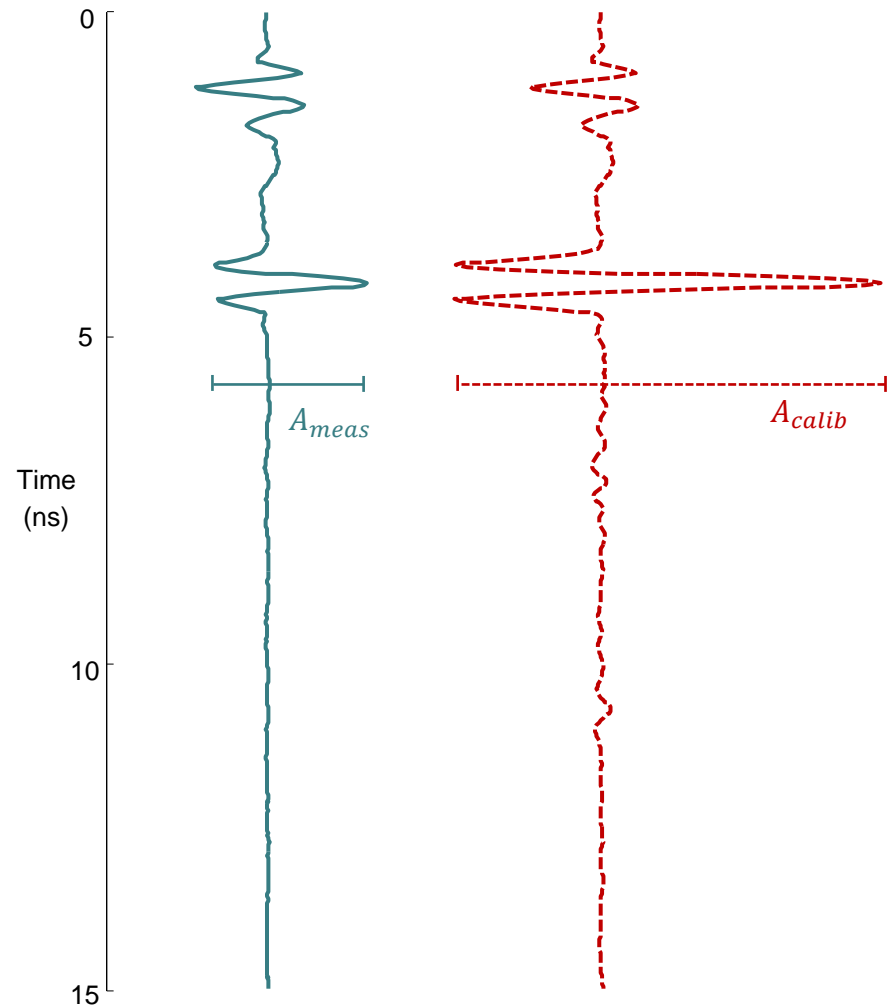
v

z

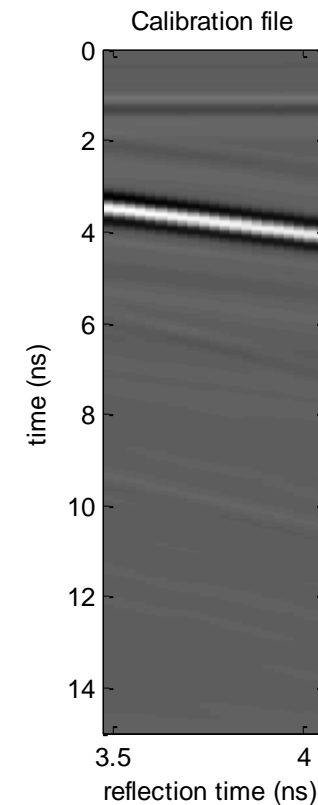
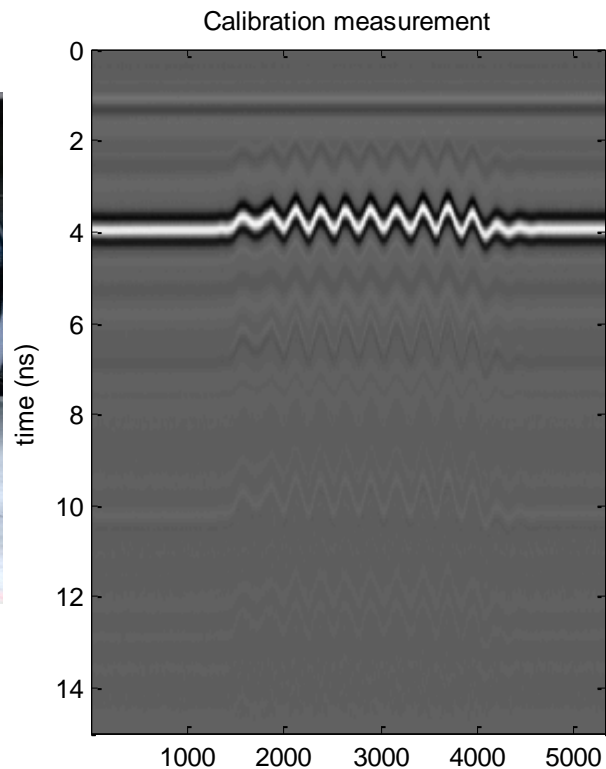


Measured trace

Comparative calibration trace



The calibration is measured by moving the antenna over a metallic plate



Method limitations

Approximations

- Incidence angle assimilated to 90°

Speed estimated for the surface material only

- ! Gradient
- Sufficient thicknesses

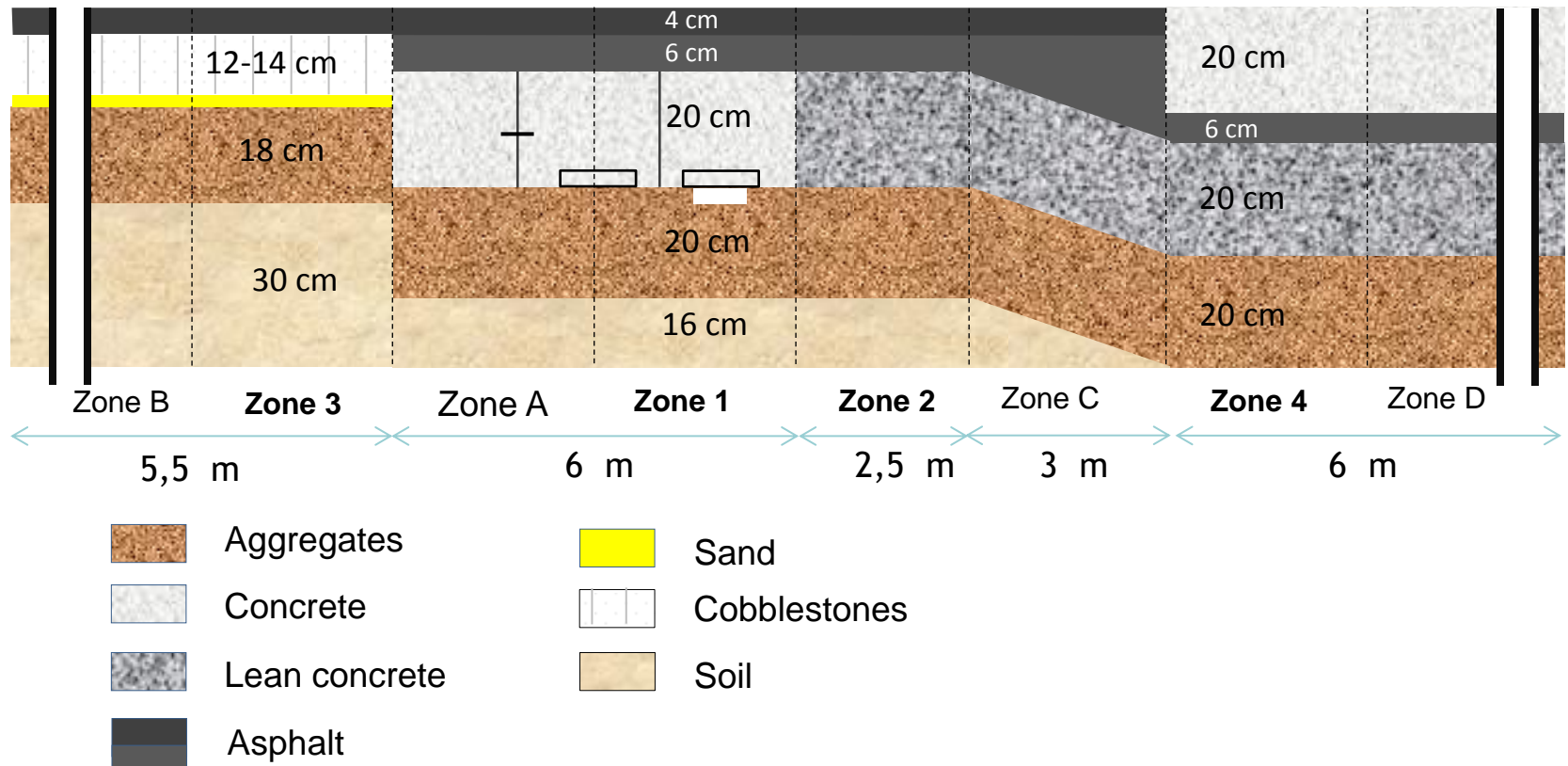


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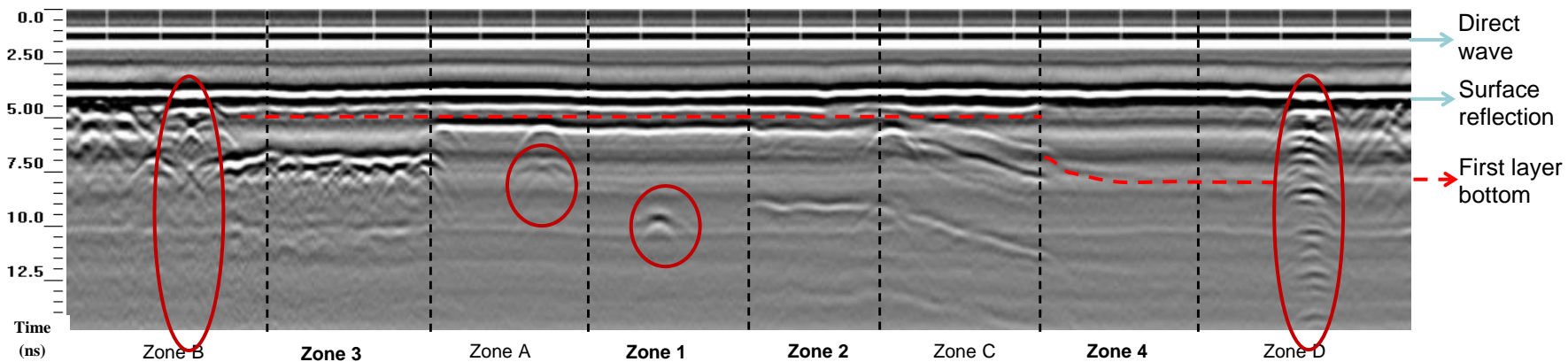
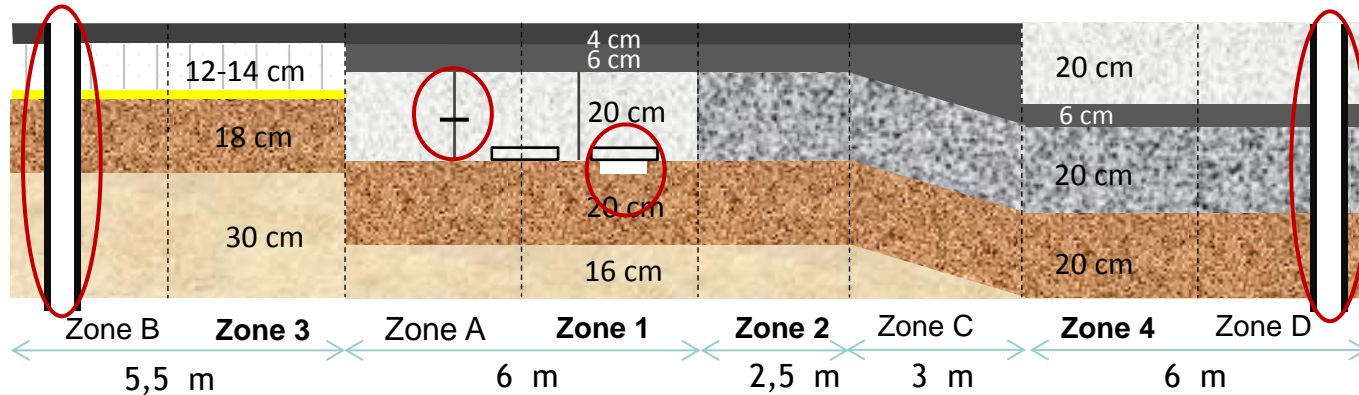
- Ground Penetrating Radar principle
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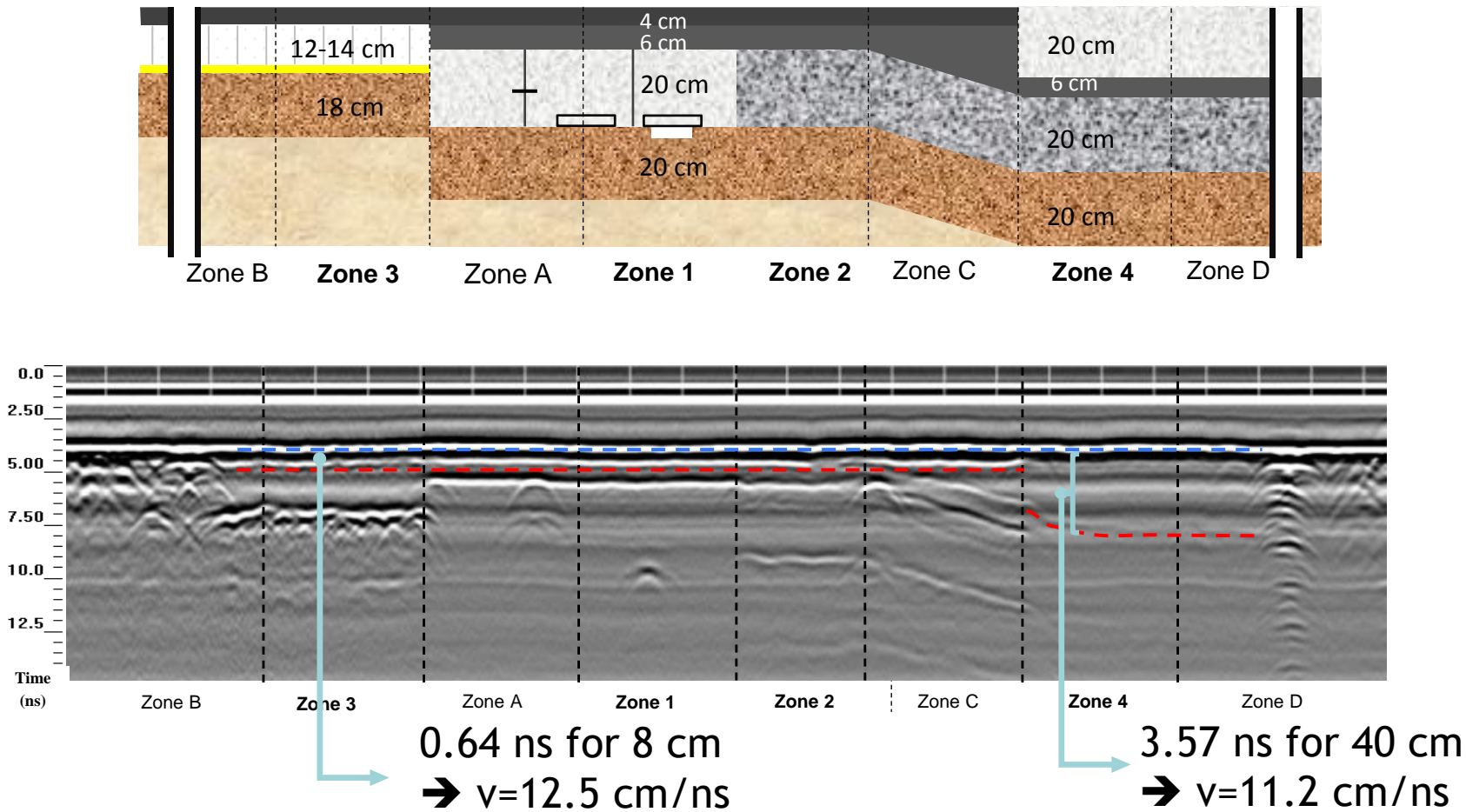
The method is tested on a trench containing four different road structures



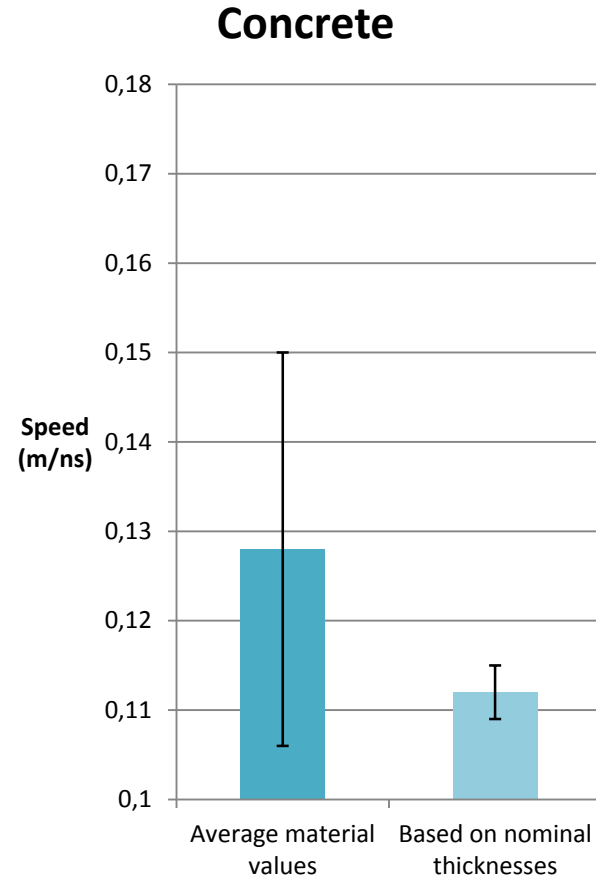
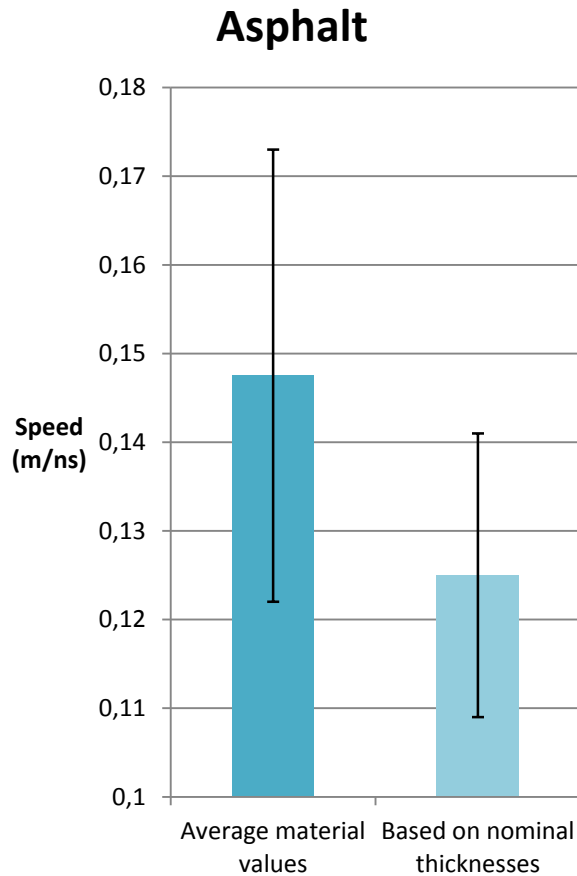
The different section can be observed in the structure radargram



The material speeds can be deduced from the nominal thicknesses



The results compatible with the reference speeds

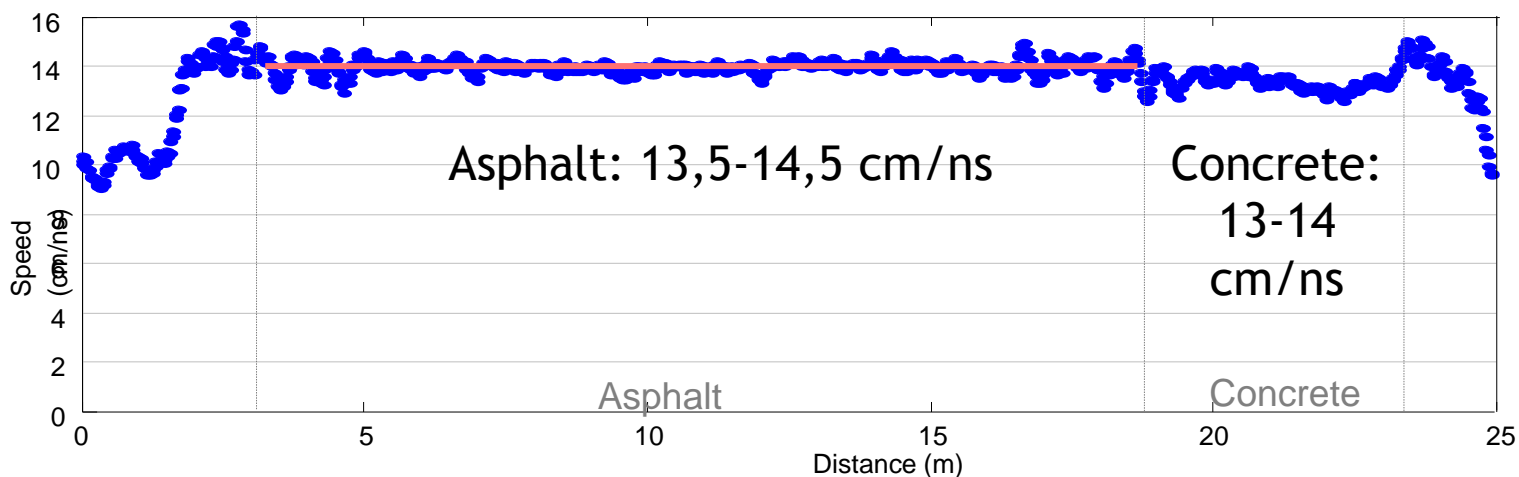
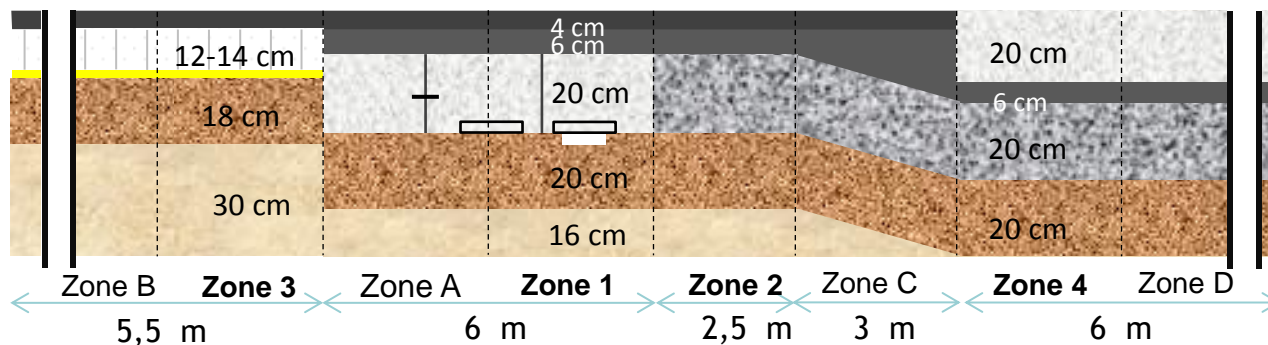


Parametric study

Analysis method

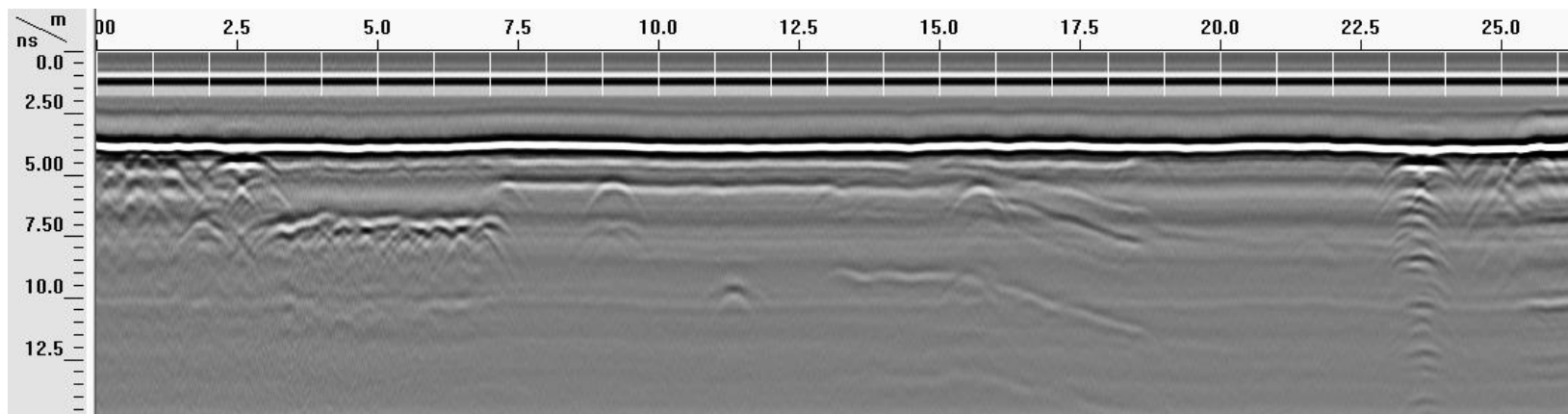
Reflection equations → Matlab

Commercial software → Radan

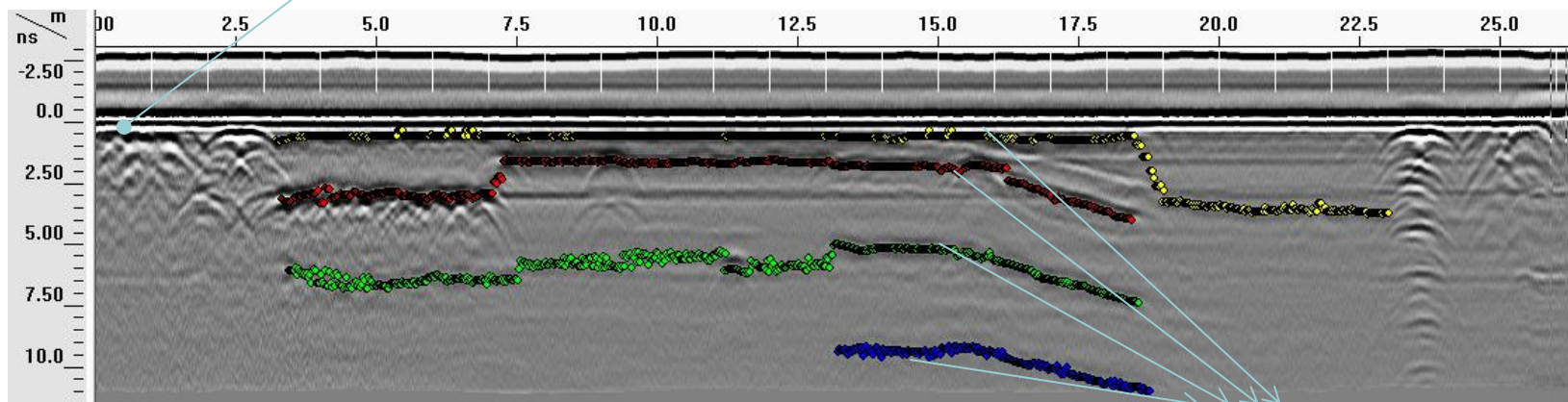


Parametric study

Commercial software → Radan



Surface aligned on 0

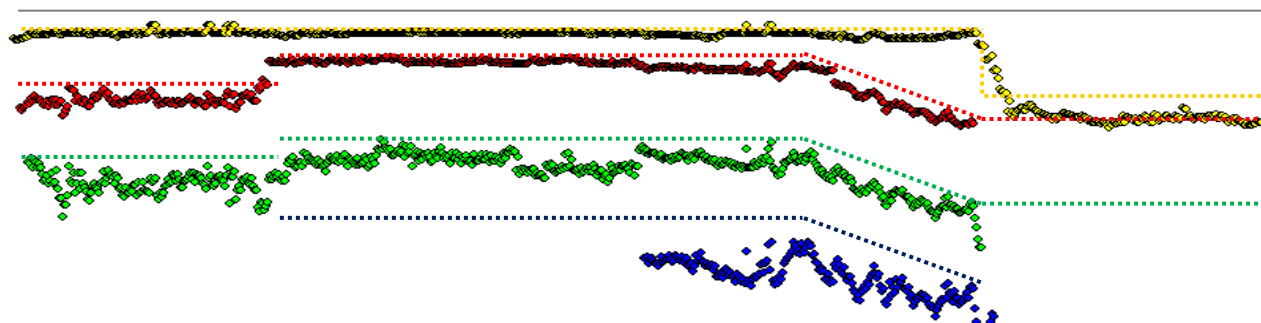
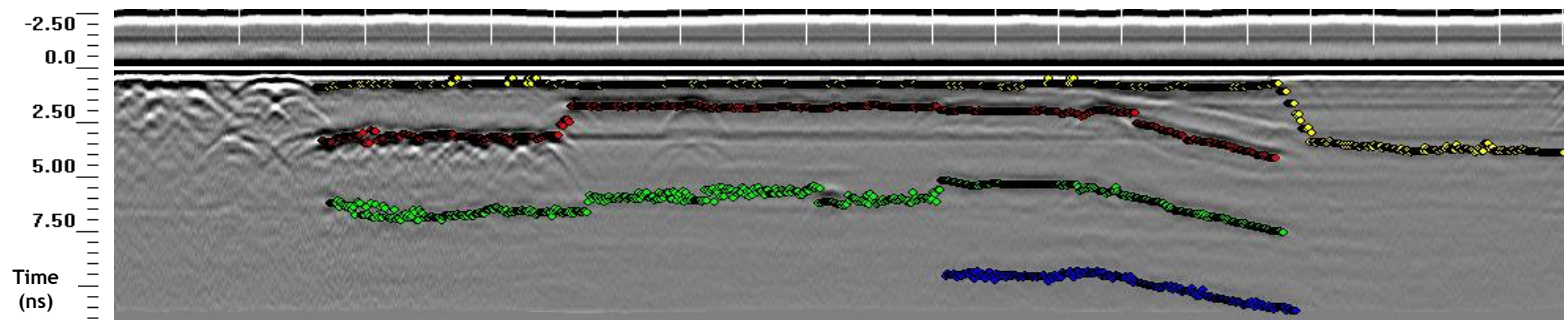


Semi-automatically picked interfaces



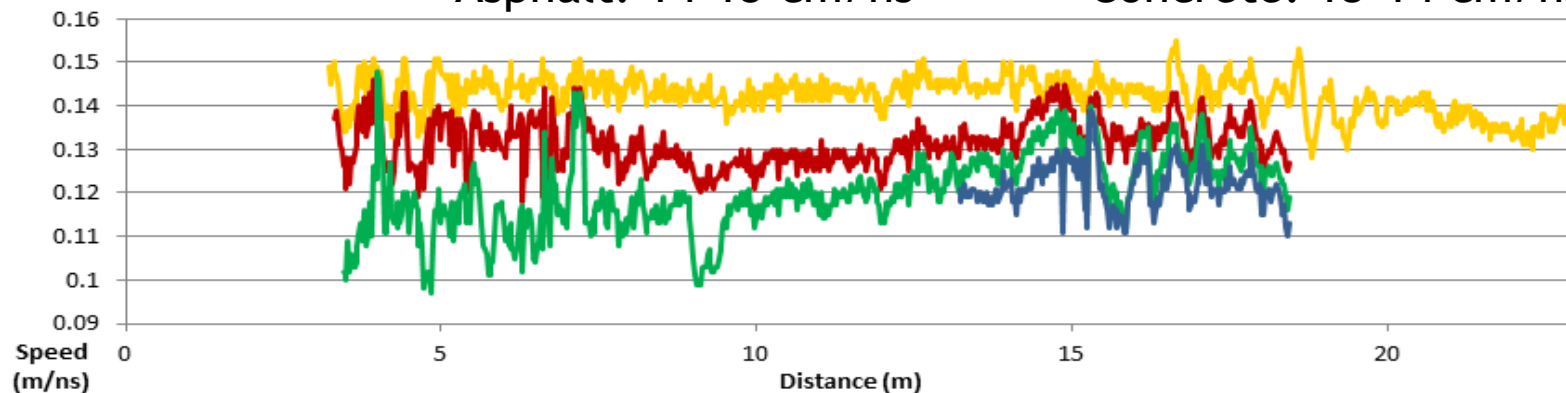
Parametric study

Commercial software → Radan



Asphalt: 14-15 cm/ns

Concrete: 13-14 cm/ns



Parametric study

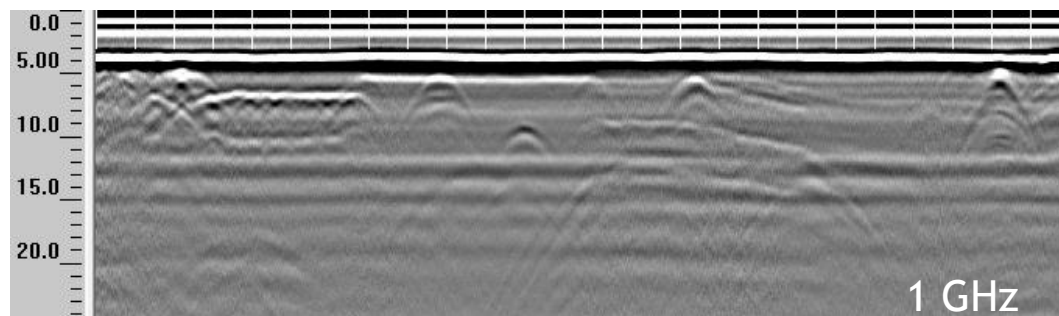
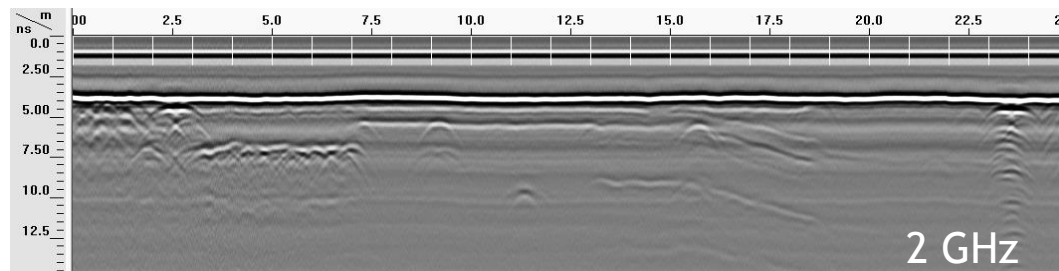
Analysis method

Reflection equations → Matlab

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Measurement parameters

Antenna frequency: 1 GHz / 2 GHz



Parametric study

Analysis method

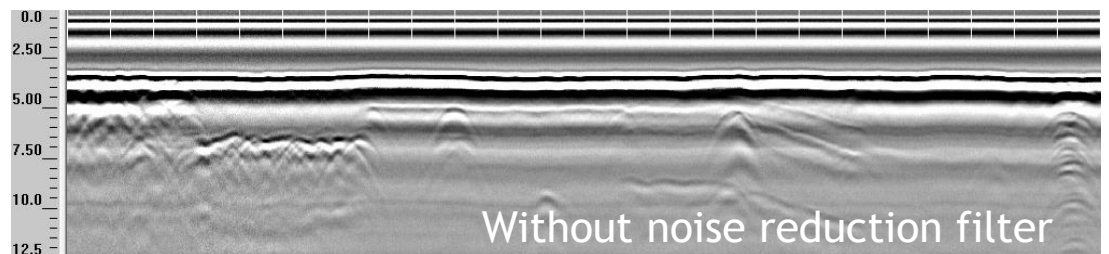
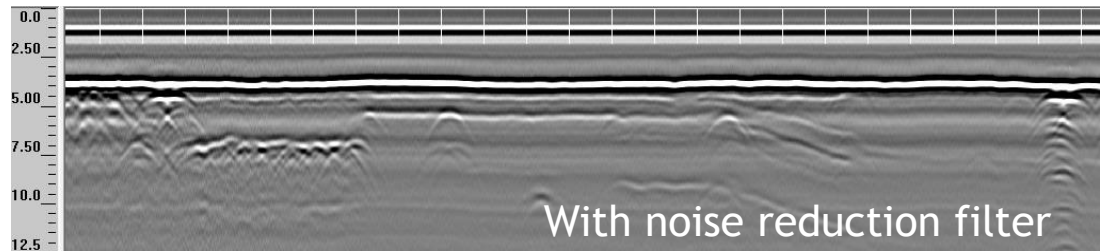
Reflection equations → Matlab

Commercial software → Radan

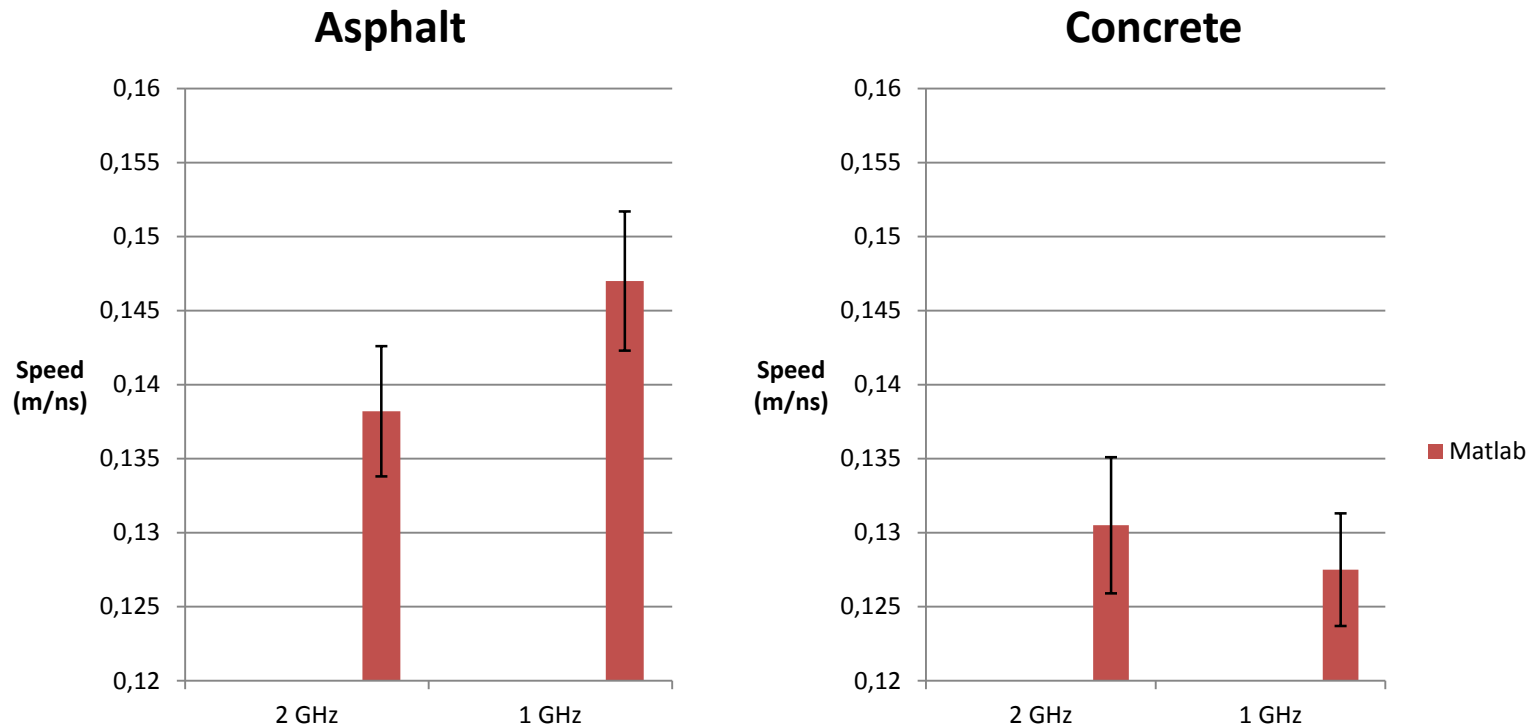
Measurement parameters

Antenna frequency: 1 GHz / 2 GHz

Use of a noise reduction filter



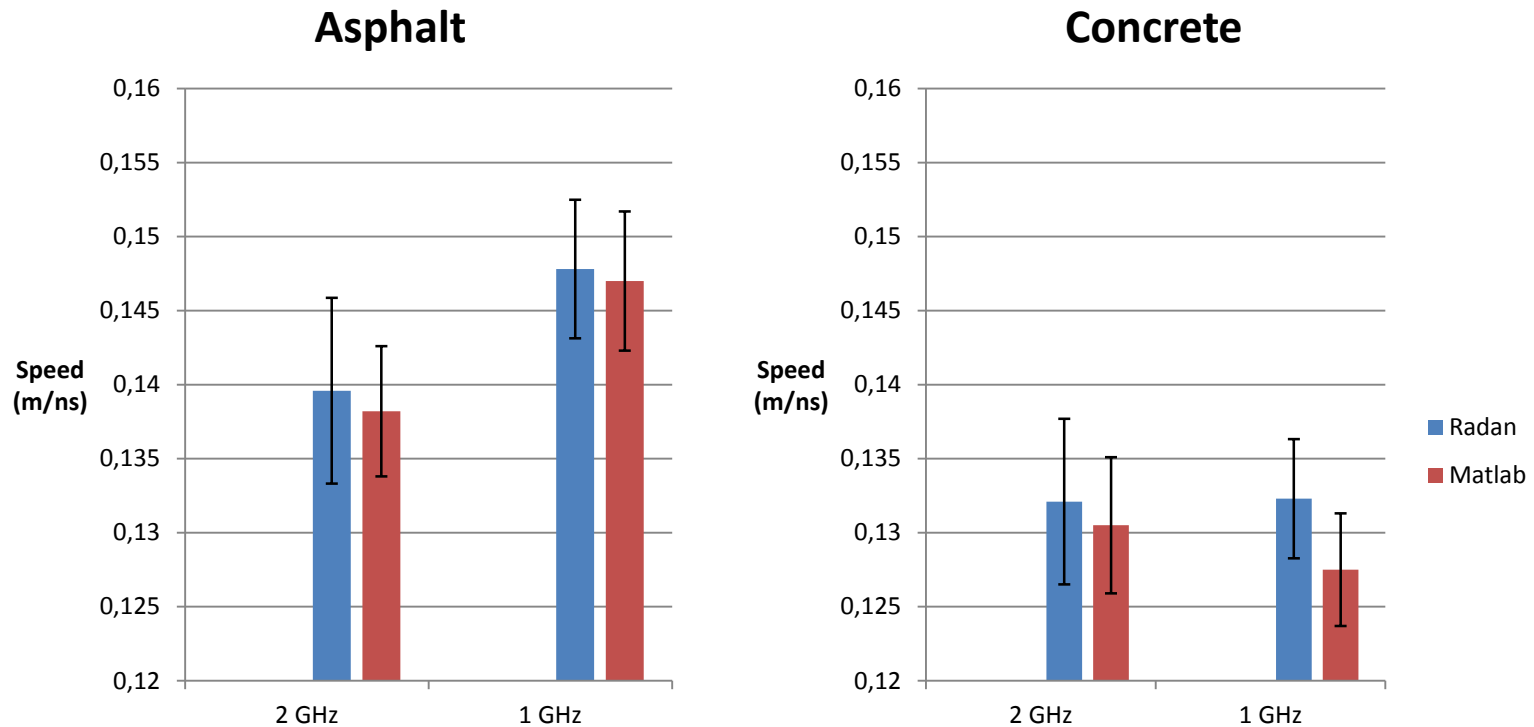
Results



- The speed estimated on asphalt with the 1 GHz antenna is higher

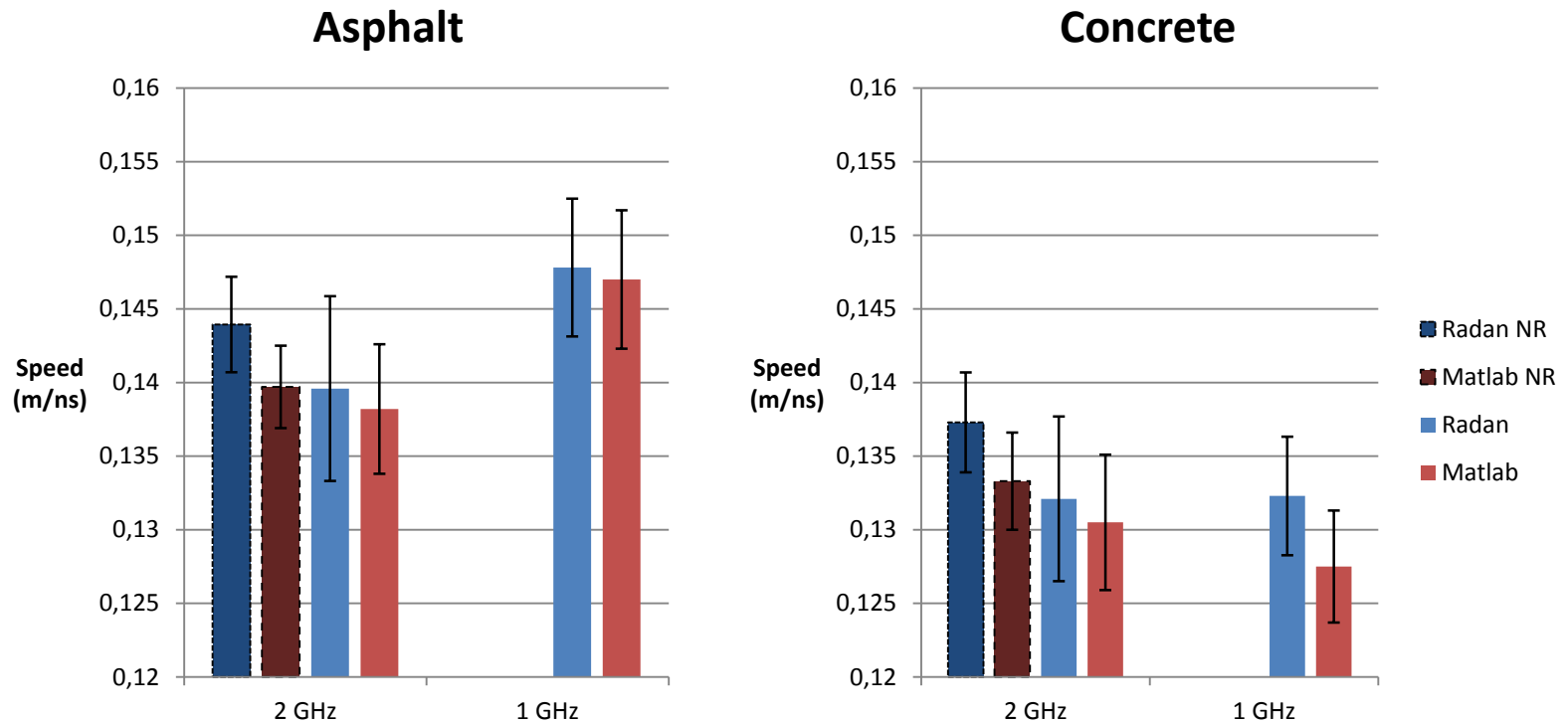


Results



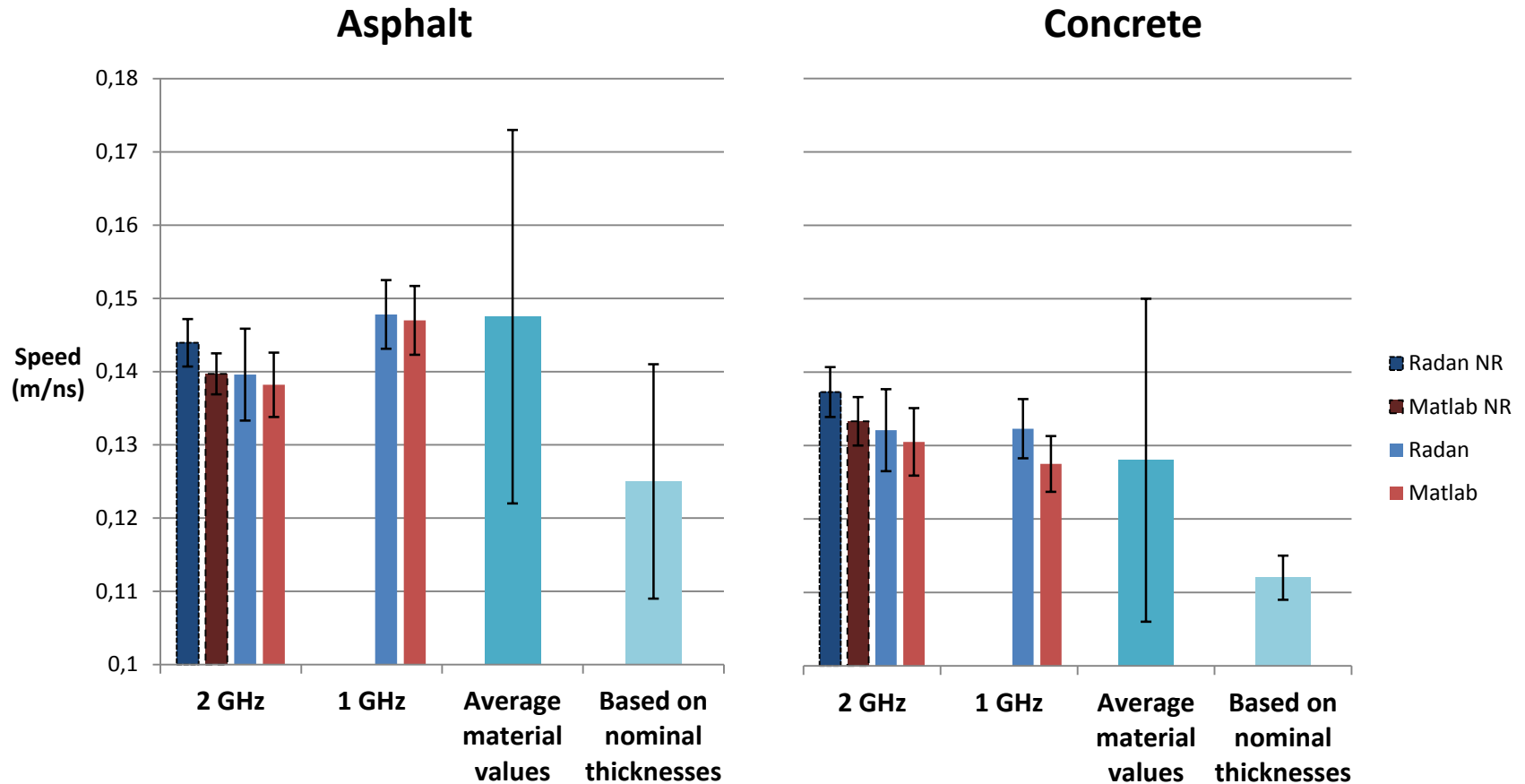
- The speeds estimated with the equations are lower and with a smaller standard deviation





- The noise reduction filter
 - reduces the standard deviation
 - Increases the estimated speeds

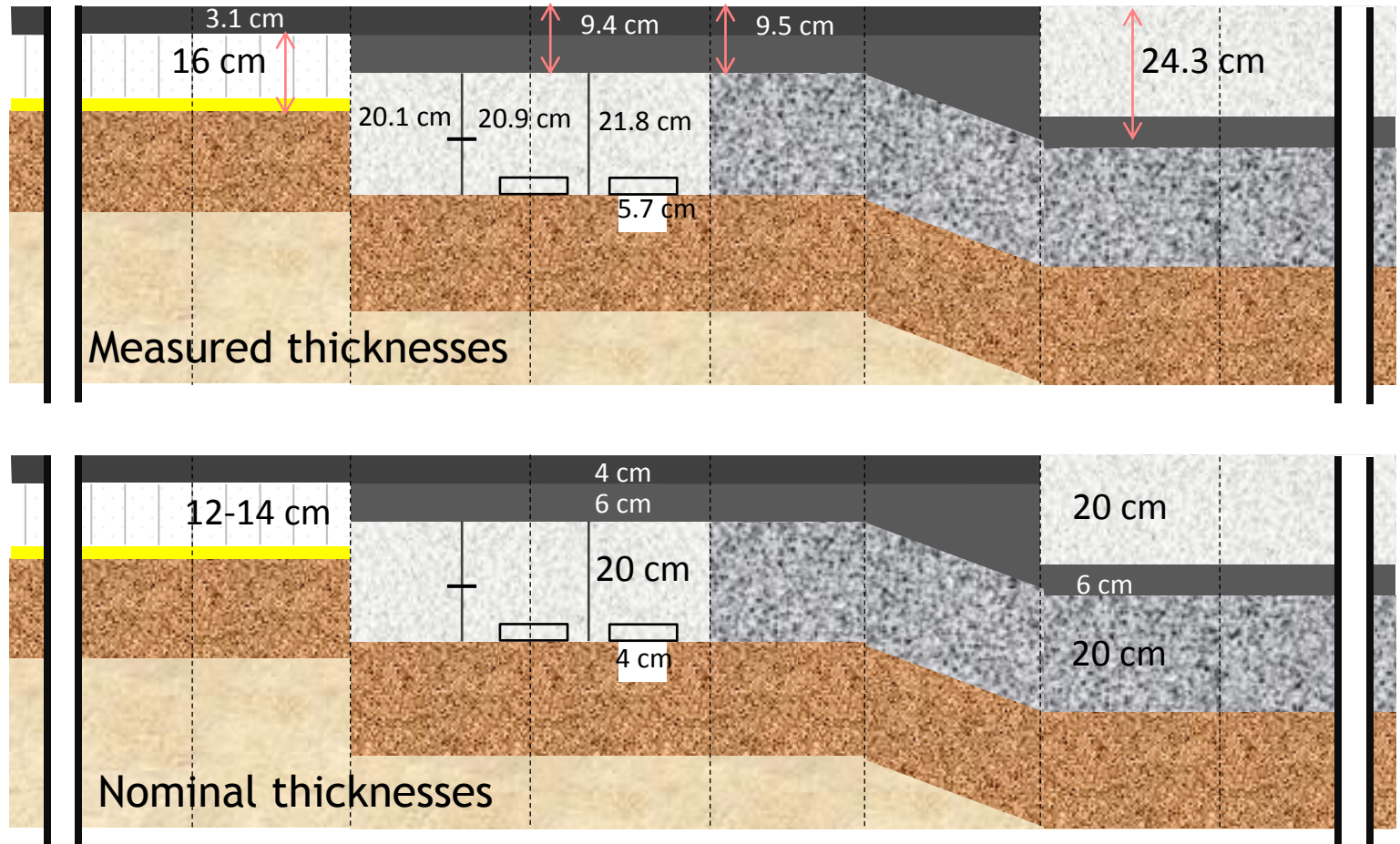
The results are compared to the reference speeds



- The surface reflection analysis reduces the interval of possible values
- Differences are observed with the measured thicknesses



Topographic points were measured during the trench building



The thicknesses variations seem to be more than 0.5 cm

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- Development of a thickness evaluation methodology
- **Method validation and assessment**



Conclusions

- Consistence between reflection equations and commercial program results
 - Speed variation of 1 cm/ns depending on the method
 - ➔ reduction of the variation range for a given material
- The noise reduction filter
 - Reduces the standard deviation
 - Increase of the apparent speed
- Estimated thicknesses < nominal thicknesses
 - Method uncertainties
 - Material inhomogeneity
 - Uncertainties in the layer thickness ➔ Coring for validation?



- Validation through coring
 - On the test trench or on other sites
 - Method extension to lower layers
 - Equations development
 - Comparison with Radan
 - Validation with cores
- ➔ The expected precision remains lower than for the first layer



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Thank you!