Belgian Road Research Centre
Together for sustainable roads

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

Ground Penetrating Radar and ultrasonic tomography

Non-destructive auscultation and monitoring techniques for concrete pavements

Audrey Van der Wielen

22 May 2024

GPR and ultrasonic tomography

Methods description

Physical principles

Antennas types

Speed estimation

Applications to concrete pavements

Pavement thickness

Rebars positioning

Voids/Humidity detection

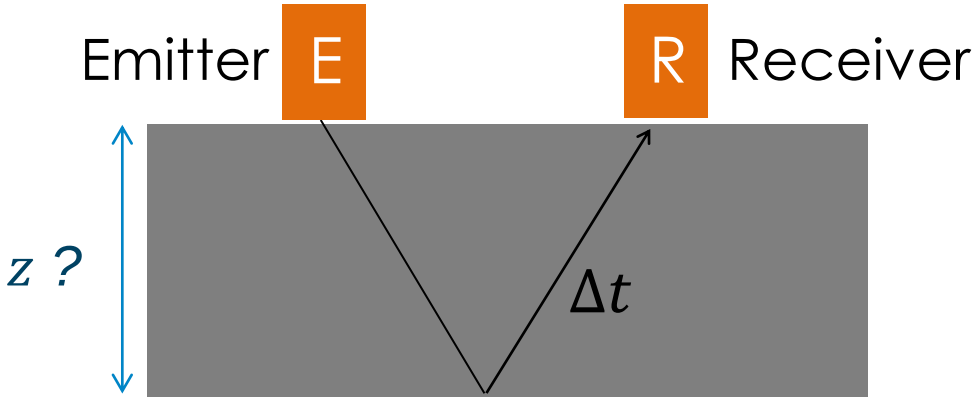
Case study: new JPCP

Dowels positioning

Pavement thickness

Performances comparison

Both devices send waves and deduce the structure from the measured reflections

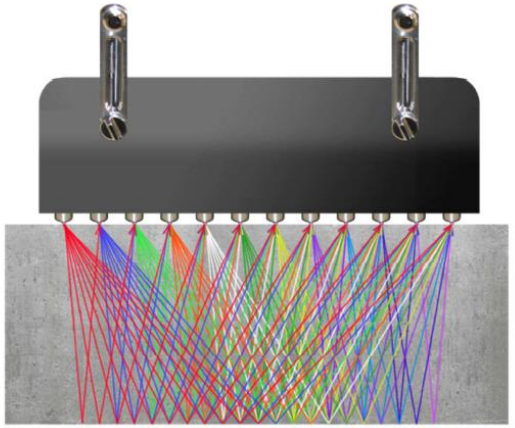


$$z = \frac{2\Delta t}{v}$$

The thickness can be deduced if the speed is known

ULTRASONIC TOMOGRAPH

- Acoustic shear waves (+- 50 kHz)
- 66 simultaneous measurements
  ➔ 25 cm-long tomography
- Dry point contact (DCP) transducers

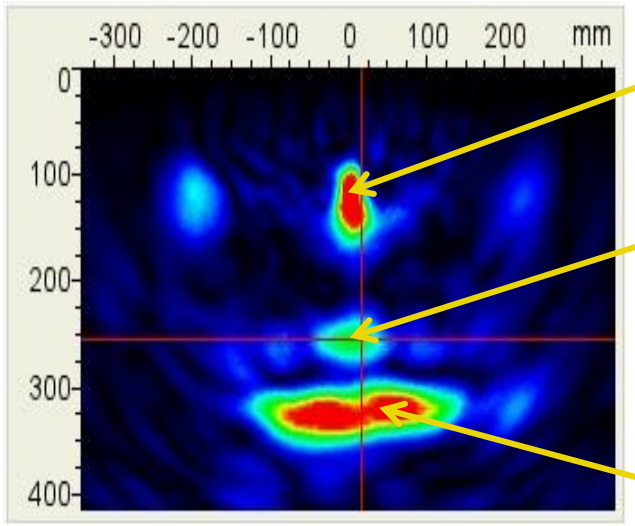


GROUND PENETRATING RADAR

- Electromagnetic waves
- 400 MHz to 2 GHz
- Measurement at regular intervals
  ➔ Profiles

ULTRASONIC TOMOGRAPH

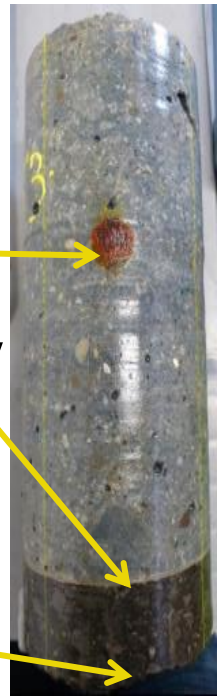
- First concrete layer (up to 1m)



Rebar

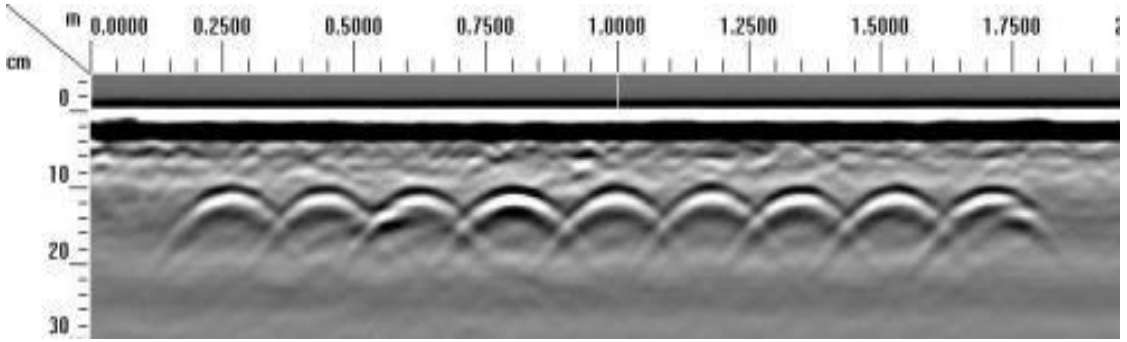
Concrete/ asphalt interface

Asphalt base



GROUND PENETRATING RADAR

- Visibility through serveral interfaces



Rebars ➔ Hyperbolas

Ground Penetrating Radar: Antenna selection

Horn

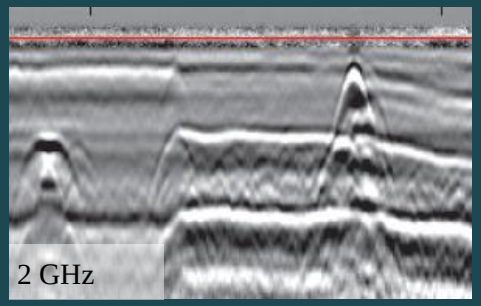
- Higher testing speed
- Surface reflection
  ➔ information about the material

Contact

- Better penetration
- Higher horizontal resolution
- Less interferences

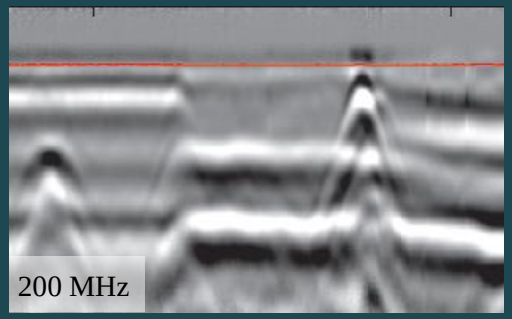
High frequency

- High resolution



Low frequency

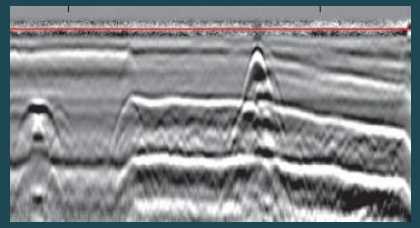
- High penetration depth

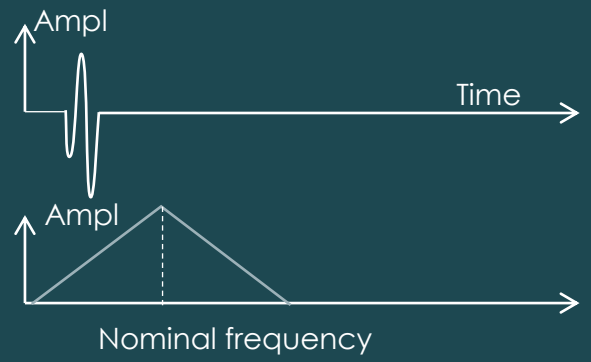


Ground Penetrating Radar: Antenna selection

Time domain

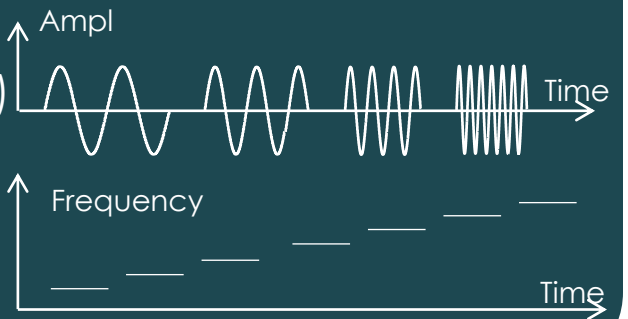
- Direct visualisation of the structure





Stepped frequency

- Large frequency range (100 MHz-3 GHz)
- Increased processing possibilities

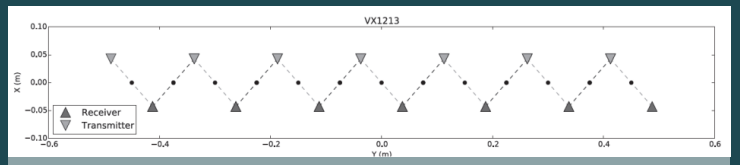


One antenna

- Visualisation of one profile

Multiple antennas

- Multiplication of profiles/frequencies

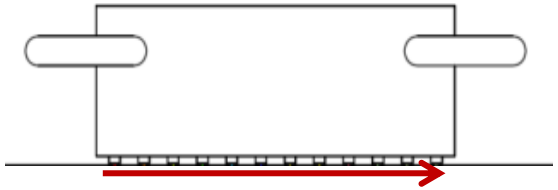


3D-Radar ➔ up to 40 antennas / 3 m wide

Nondestructive speed evaluation

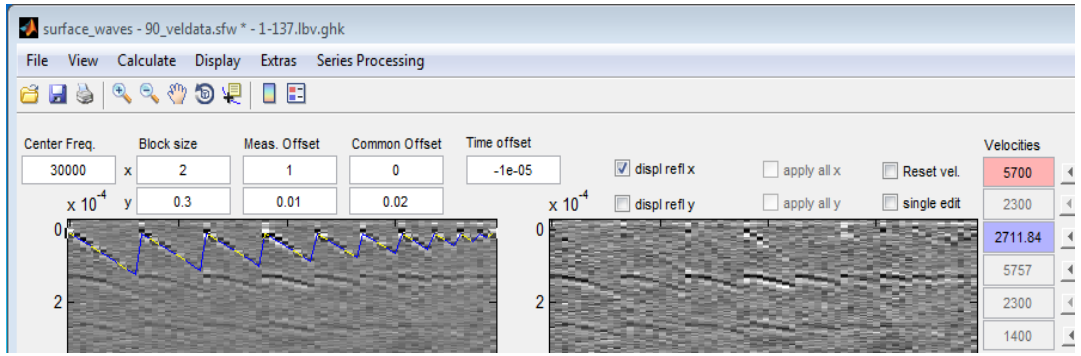
ULTRASONIC TOMOGRAPH

- Speed estimation based on surface wave propagation



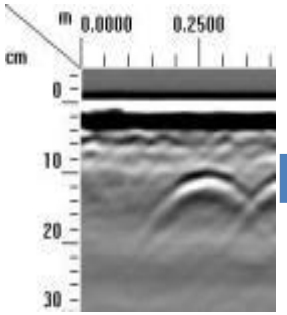
➔ Automatic

➔ During post processing (*Kassel collection* software)

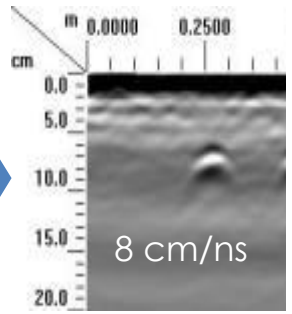


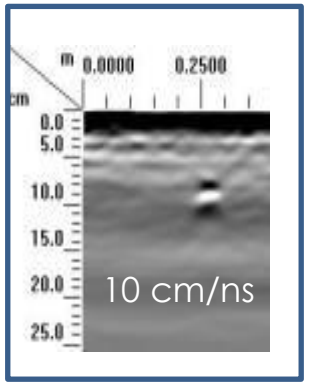
GROUND PENETRATING RADAR

- Surface reflection coefficient
  - ➔ Speed deduced from the energy reflected at the surface (horn antennas)
- Migration
  - ➔ Speed deduced from the shape of the hyperbolas

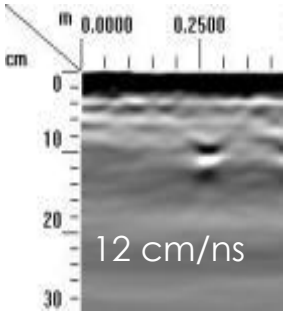


Original signal (2.6 GHz)





After migration



GPR and ultrasonic tomography

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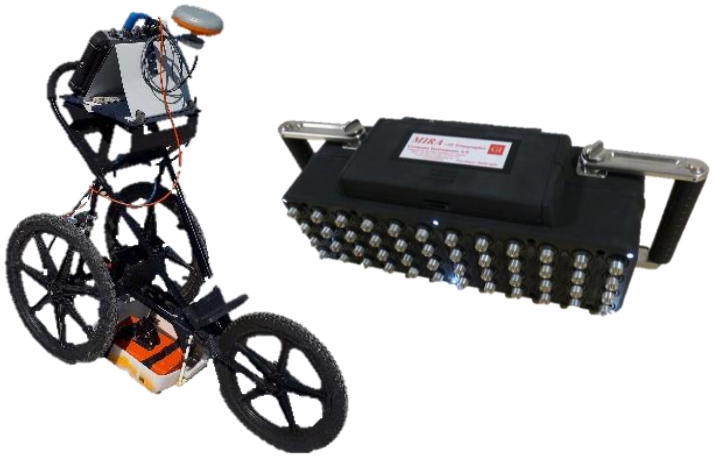
Speed estimation

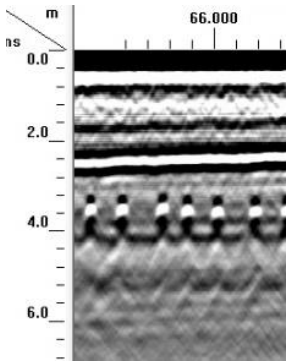


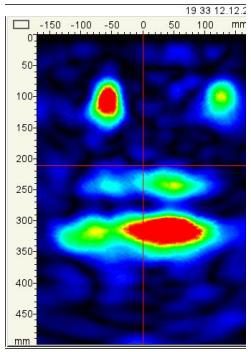
Applications to concrete pavements

Pavement thickness

Rebars positioning

Voids/Humidity detection





Case study: new JPCP

Dowels positioning

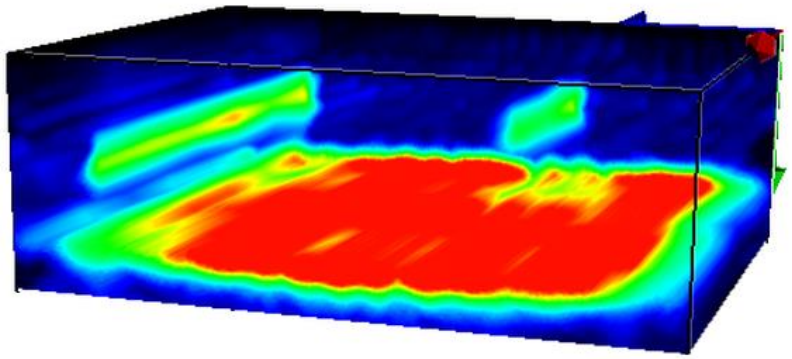
Pavement thickness

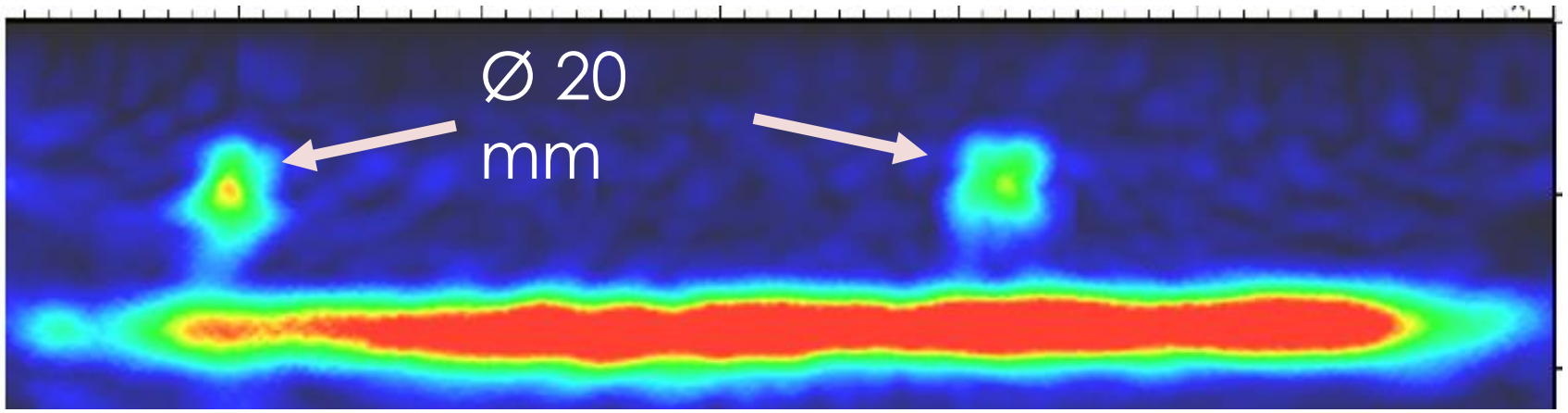
Performances comparison

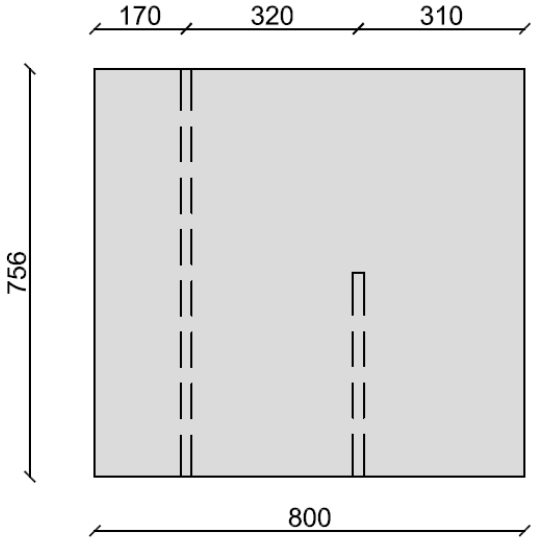
Applications to concrete

ULTRASONIC TOMOGRAPH

- Thickness estimation
- Rebars detection



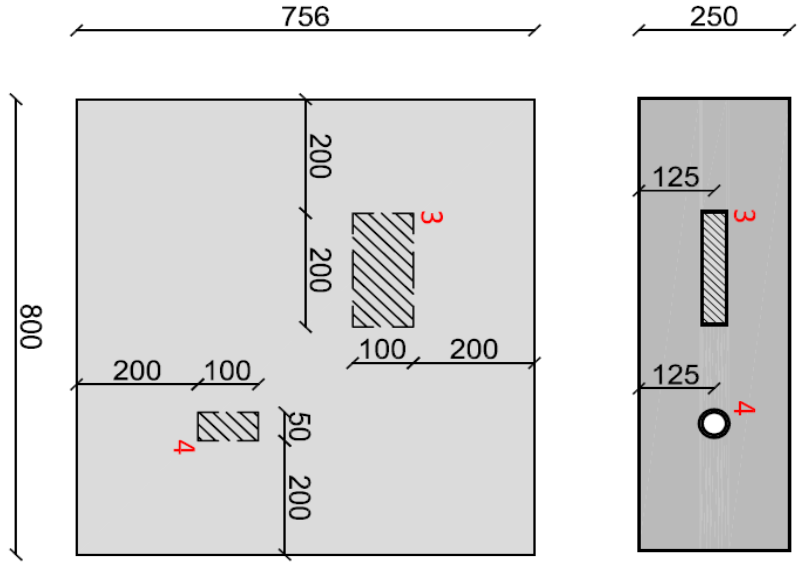


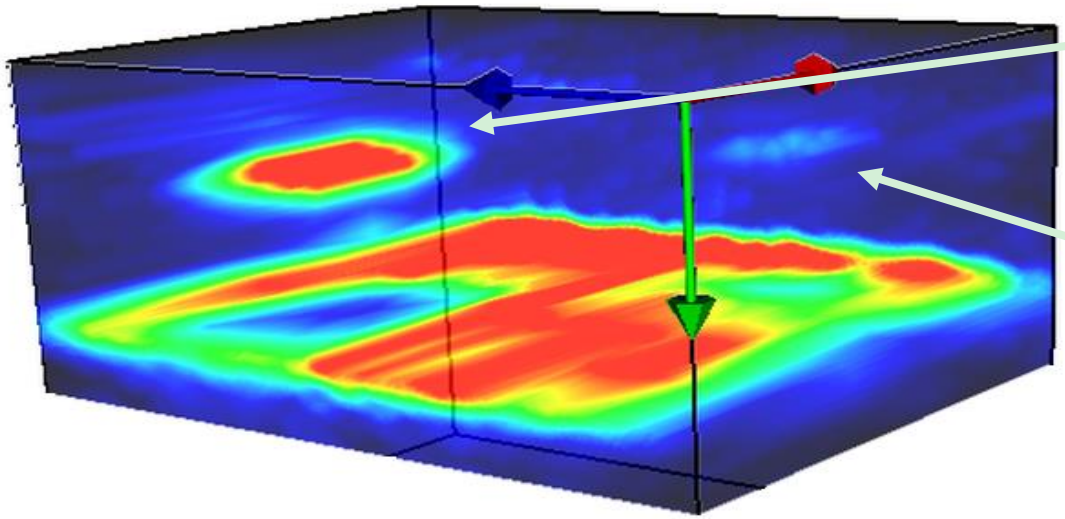


Applications to concrete

ULTRASONIC TOMOGRAPH

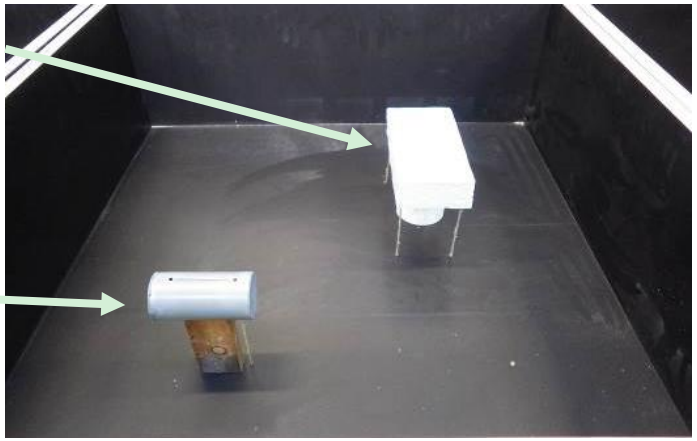
- Thickness estimation
- Rebars detection
- *Voids detection*





Expanded polystyrene d = 40 mm

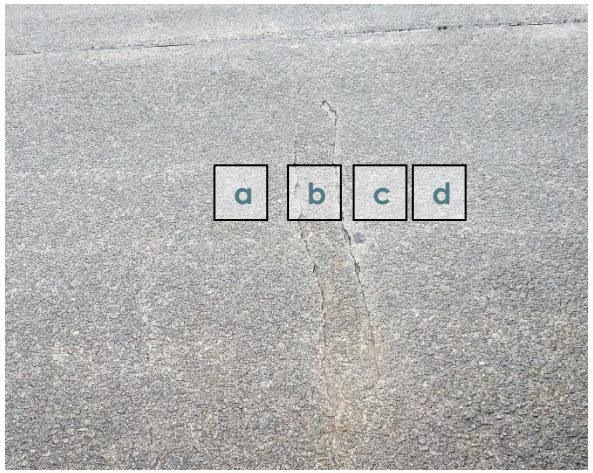
Void Ø 50mm



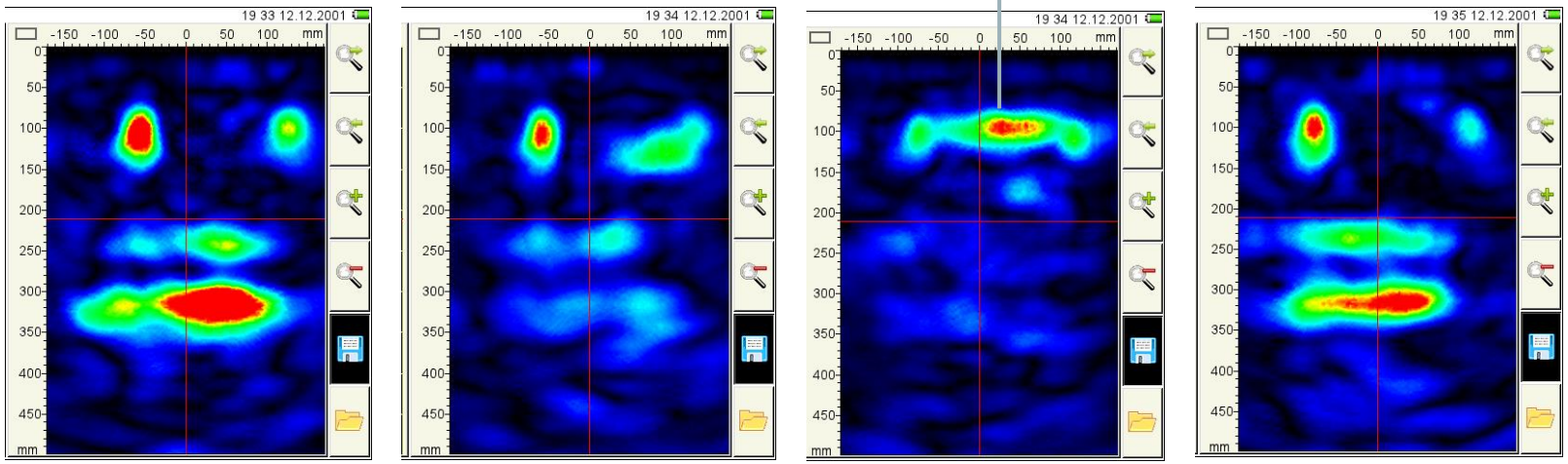
Applications to concrete

ULTRASONIC TOMOGRAPH

- Thickness estimation
- Rebars detection
- *Voids detection*
- *Cracks detection*



Suspected horizontal crack at reinforcement level



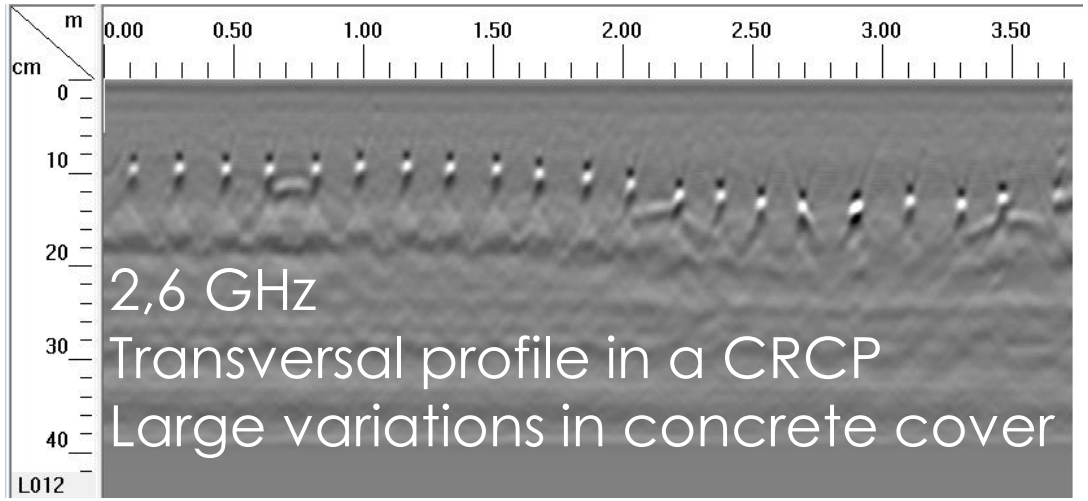
a b c d

Applications to concrete

GROUND PENETRATING RADAR

- Rebars detection

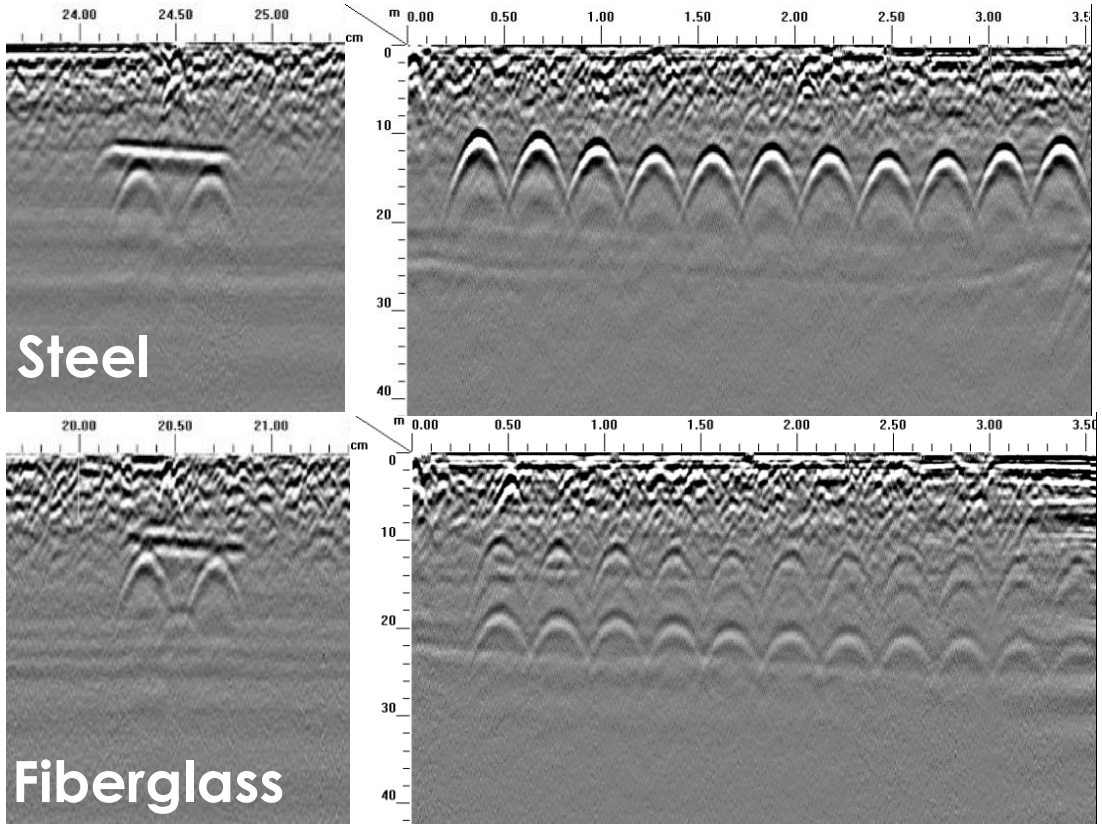
Rebars



Dowels

Longitudinal profile

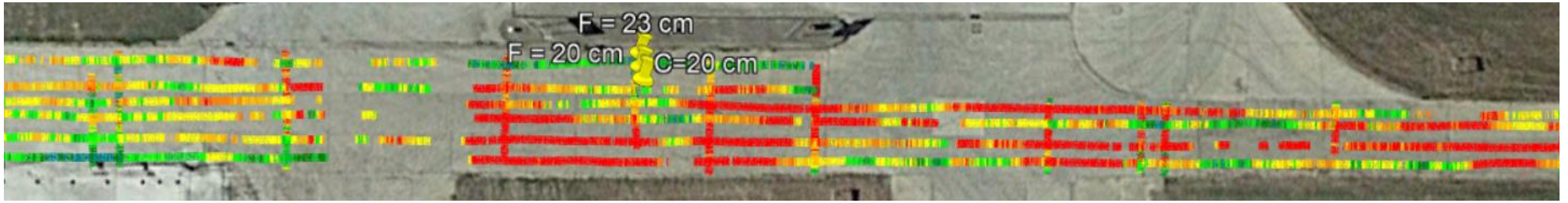
Transverse profile

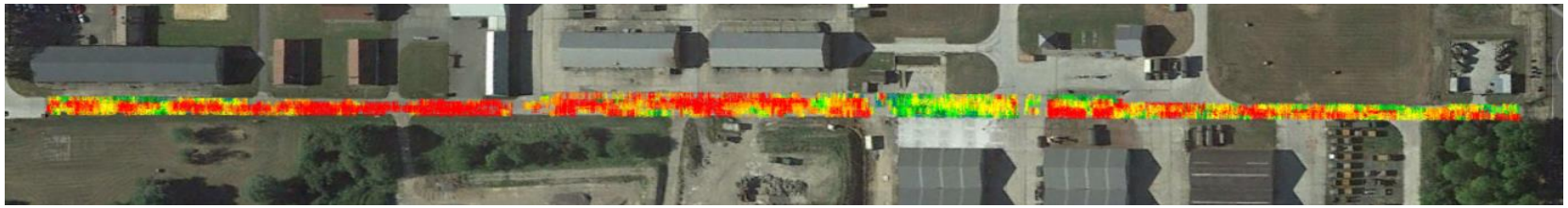


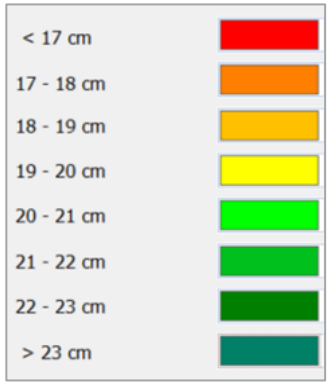
Applications to concrete

GROUND PENETRATING RADAR

- Rebars detection
- Thickness estimation





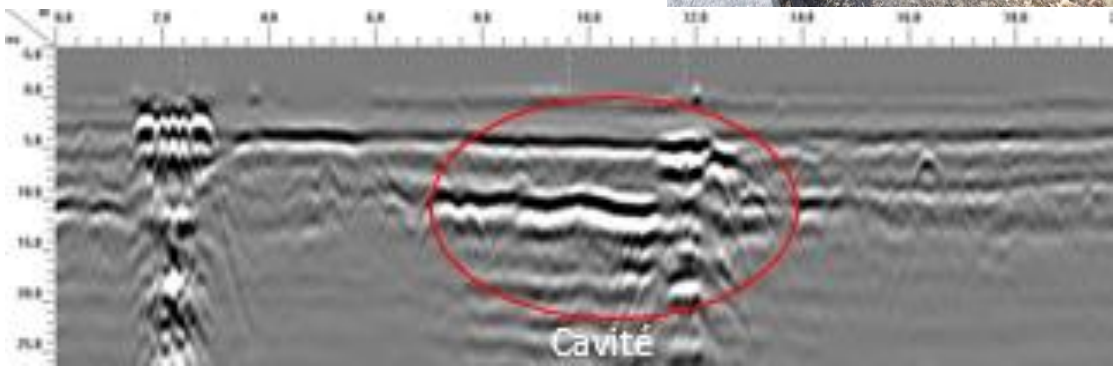


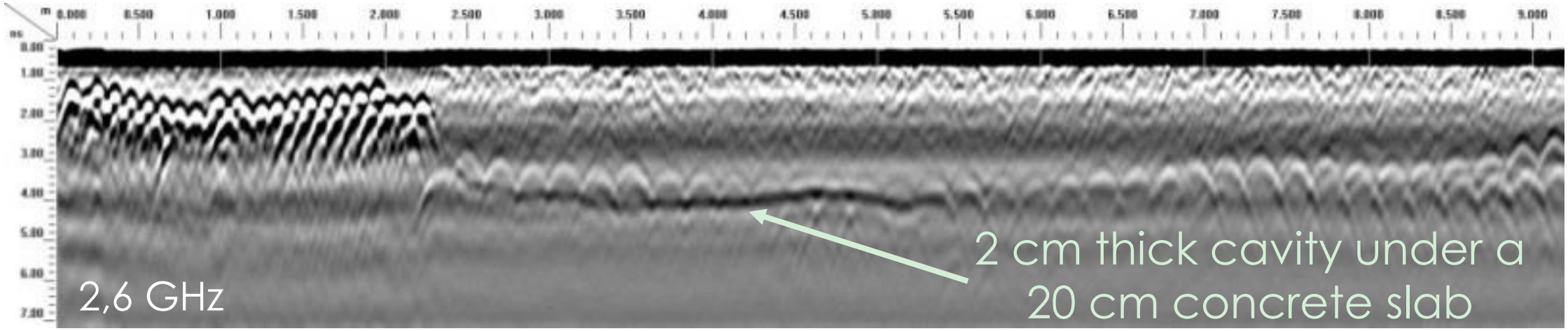
Applications to concrete

GROUND PENETRATING RADAR

- Rebars detection
- Thickness estimation
- Voids detection

Large cavity under a kerb channel





Applications to concrete

GROUND PENETRATING RADAR

- Rebars detection
- Thickness estimation
- Voids detection
- Humid zones detection

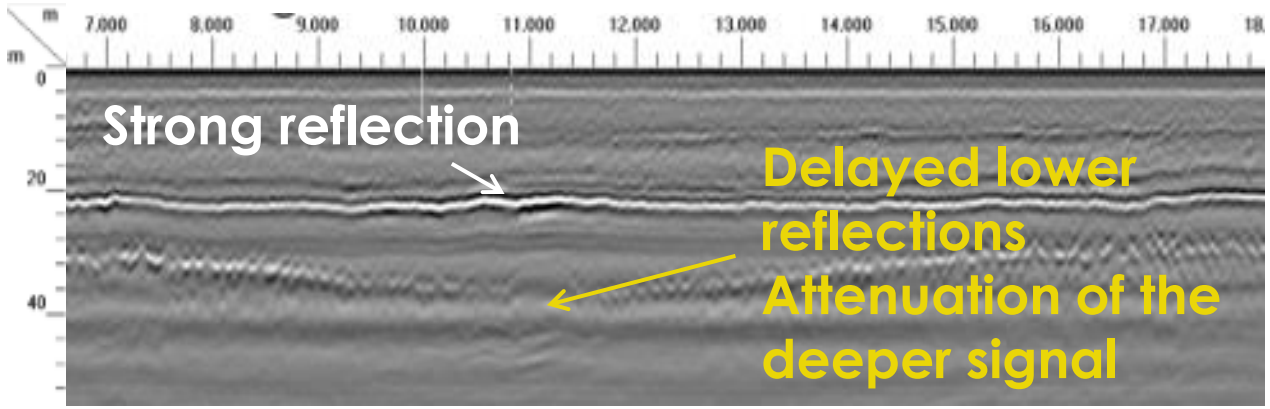
Surface and direct wave

Asphalt / Mastic asphalt

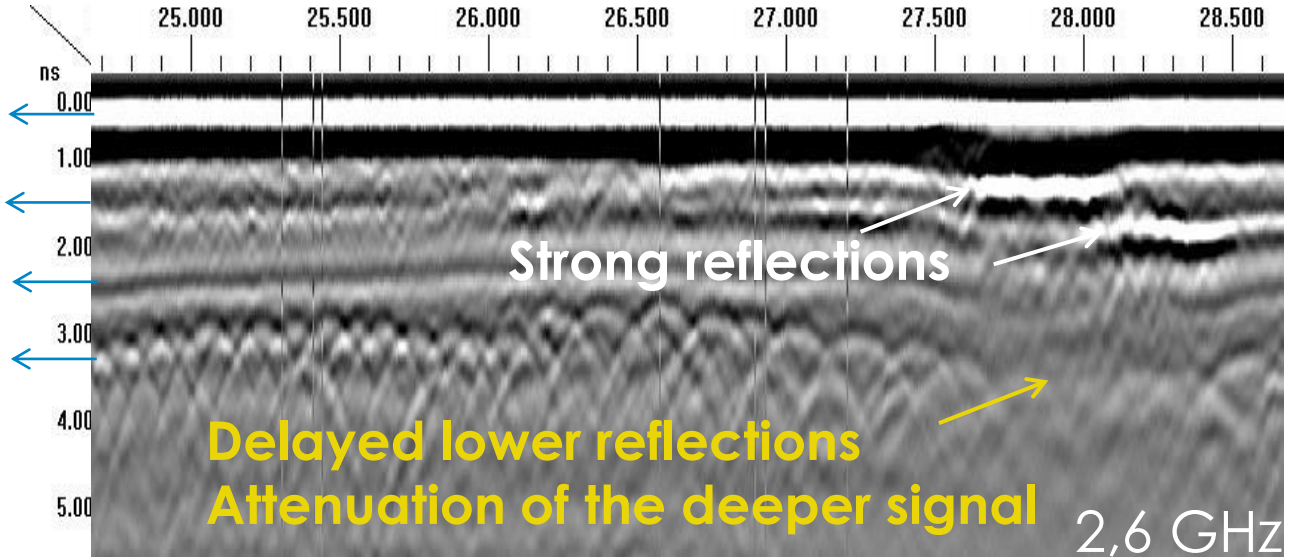
Concrete upper surface

Rebars

Profile measured in a tunnel



Profile measured on a bridge deck



GPR and ultrasonic tomography

Methods description

Physical principles

Antennas types

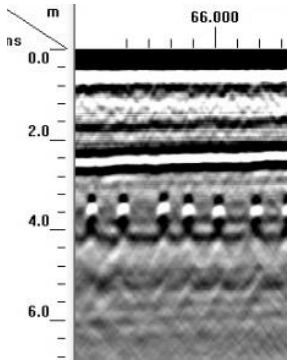
Speed estimation

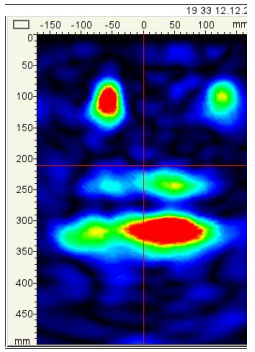
Applications to concrete pavements

Pavement thickness

Rebars positioning

Voids/Humidity detection





Case study: new JPCP

Dowels positioning

Pavement thickness

Performances comparison

The tested section is a newly laid jointed plain concrete pavement (JPCP)

- Dimensions
  - Total length: 250 m
  - Slab length: 5 m
  - Nominal thickness: 20 cm

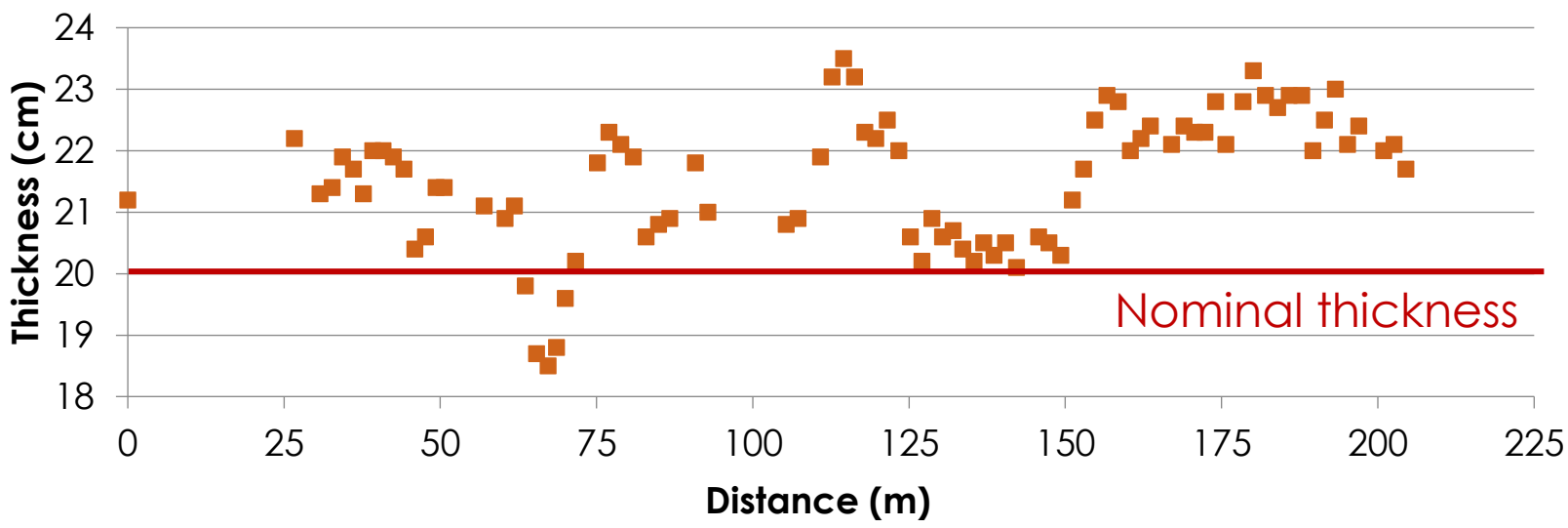
- Fixation of the dowels on an underlying asphalt layer before placing the concrete

The tested section is a newly laid jointed plain concrete pavement (JPCP)

- The investigations had two objectives
  - Evaluate the pavement thickness
  - Check the dowels position

Pavement thickness was assessed using a topographic total station

- 142 measurement spots
- Measurements before and after concreting
- Precision of about 2 mm in estimating thicknesses



Description of the equipment

Ultrasonic tomograph

Static measurements

3 points calibration

Automatic speed estimation based on direct wave

GPR 900 MHz

5 km/h

5 points calibration

Migration

GPR 2 GHz

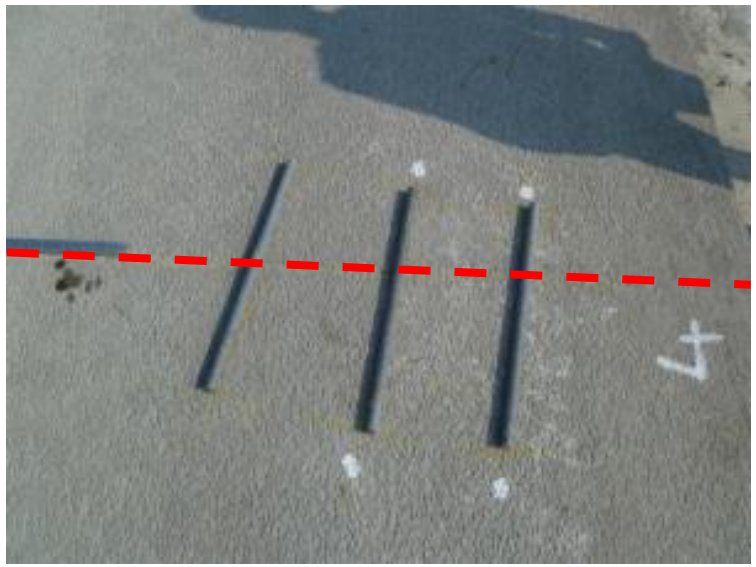
~30 km/h

5 points calibration

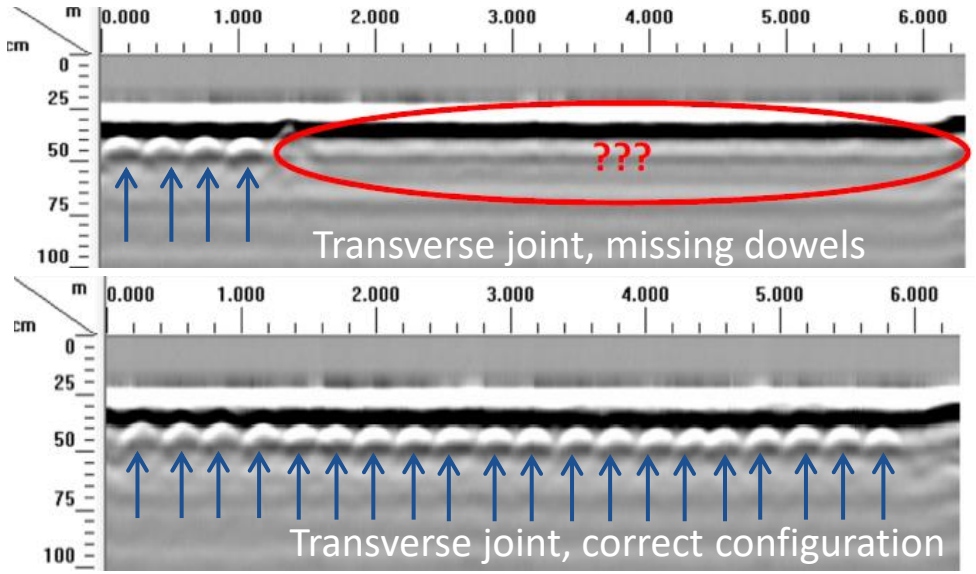
Surface reflection coefficients method

Dowels detection

ULTRASONIC TOMOGRAPH



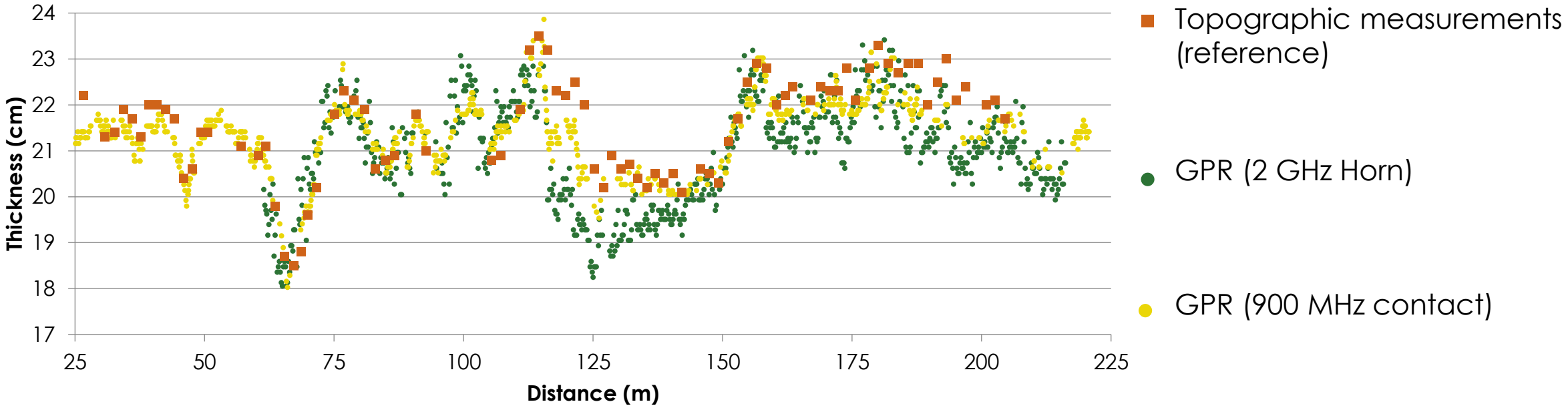
GPR (900 MHZ)



- For 20 joints out of 50, the dowels were misplaced
- Both methods are efficient for the dowel positioning, but GPR is faster (1h40 for 50 joints)

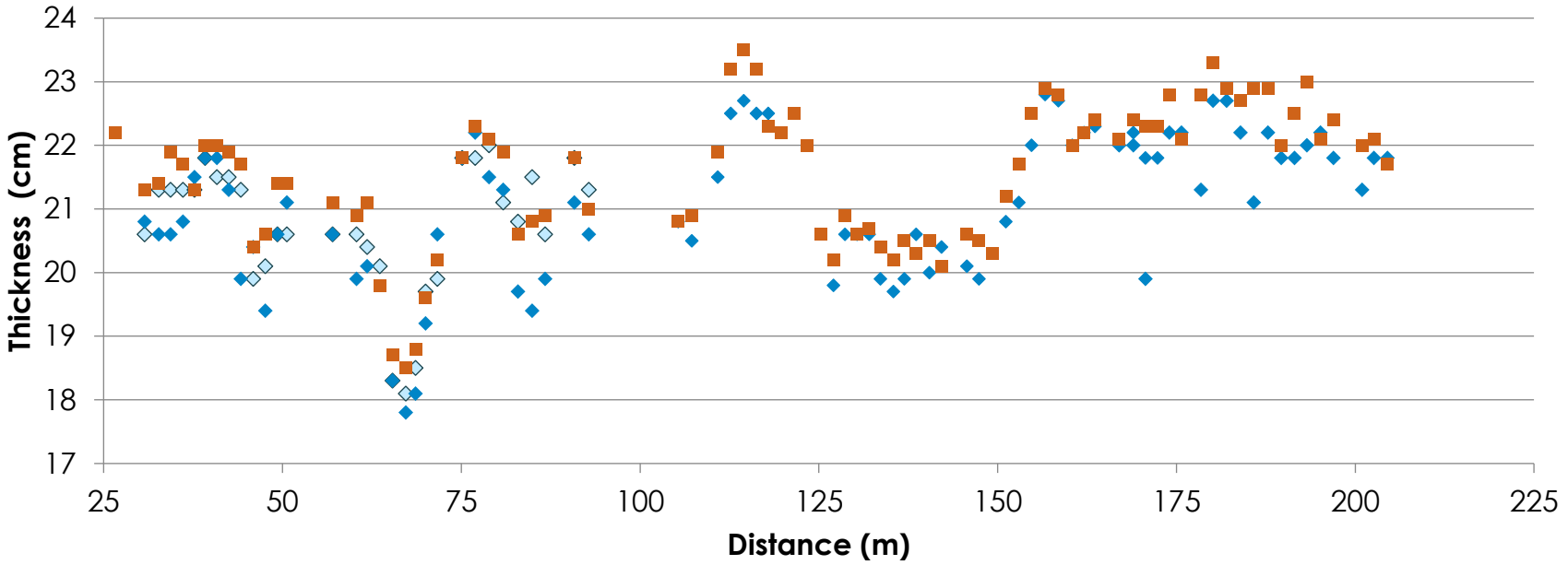
Pavement thickness evaluation: GPR measurements (calibrated)

- Data are missing in the 2 GHz profiles (air noise)
- Better precision for the 900 MHz estimations



Pavement thickness evaluation: Ultrasonic tomography

- Static measurement ➔ less measurement points than with radar
- Nondestructive speed estimation sometimes leads to thickness underestimations

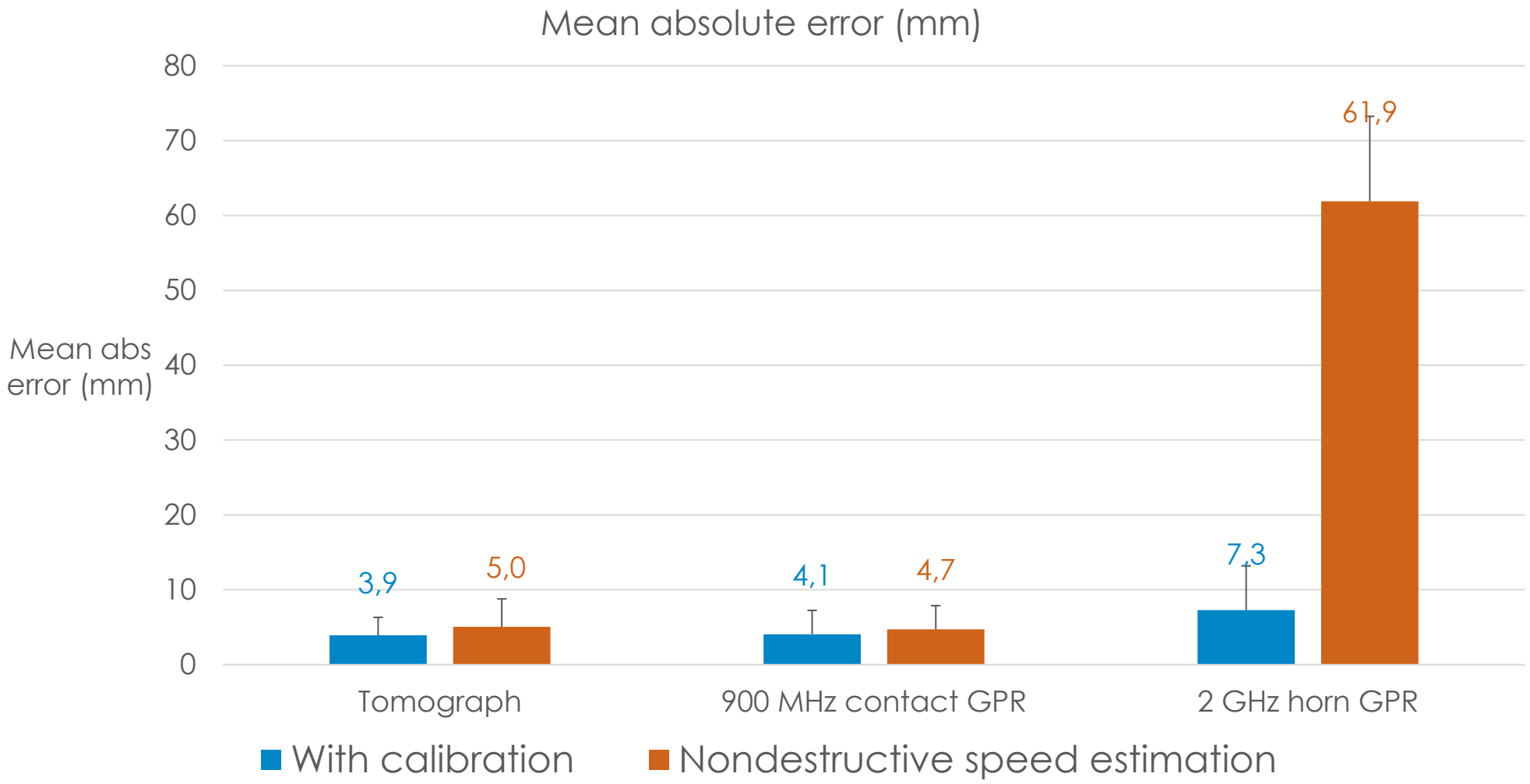


Topographic measurements (reference)

Tomograph – Calibtrated speed

Tomograph – Automatic speed

The totally nondestructive tests lead to variable results



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Conclusions

- GPR and ultrasonic tomography are efficient tools for the inspection of concrete pavements
  - Similar precision in thickness estimation (~2% mean error with calibration)
  - Dowels/rebars positioning
  - GPR is faster but affected by the presence of water

- For fully nondestructive testing of concrete structures, combining GPR and ultrasonic measurements
  - Allows high speed testing
  - Allows differentiating humid zones and actual depth variations

Belgian Road Research Centre
Together for sustainable roads

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