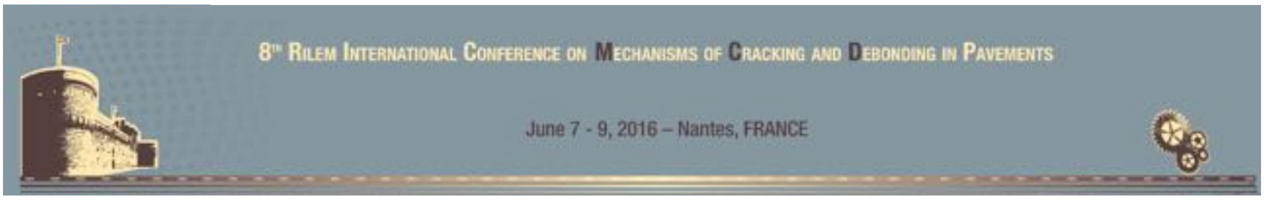


Roads of the Future : Towards Durable and Multi-functional Infrastructures

Introduction – First part

Dr. Nicolas Hautière – IFSTTAR
R5G Project Manager

IFSTTAR

Lessons from history

- 1st generation – The track
- 2nd generation – The paved road
- 3rd generation – The smooth road
- 4th generation – The motorway
- What's next?

THE CHALLENGES ARE HUGE... | 1

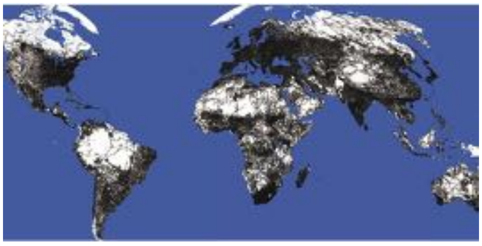
Global Grand Challenges

- Health
- Water
- Energy
- Education
- Environment
- Security
- Poverty
- Food

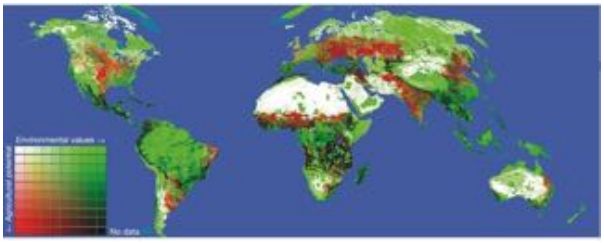
- The road embeds all these challenges !

Territories Sharing

› According to IEA (2013), 25 millions km of new roads are foreseen by 2050.



Roads are indicated in black; white areas lack mapped roads. The quality of road maps varies greatly among nations, with many smaller and unofficial roads remaining unmapped.



Shown are priority road-free areas (green shades), priority agricultural areas (red shades), conflict areas (dark shades), and lower-priority areas (light shades).

A global strategy for road building. Laurance et al. *Nature* (2014)

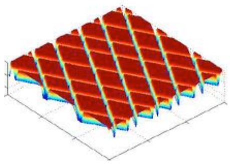
…BUT OPPORTUNITIES ARISE | 2

Innovative Materials

- Progress in materials science allows envisaging a new generation of pavements with novel properties
  - Modular
  - Prefabricated
  - Long-life
  - Self-cleaning
  - Silent
  - Recycled
  - Depolluting
  - Biosourced

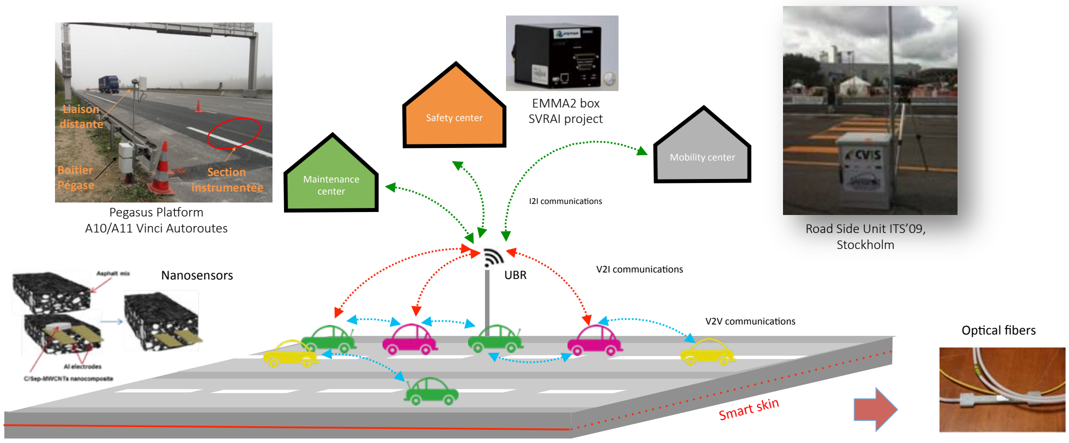
ANR CLEAN
RD117 St Philbert (CG 44)
Long-lasting and depolluting concrete pavement
2x2 lanes at 110 km/h

ODSURF
Modelling and building the Optimal Dense low noise Surface



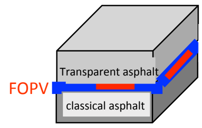
IFSTTAR imagine the post-oil launching the **ALGOROUTE** project on bio-bitumen

Information and Communication Technologies

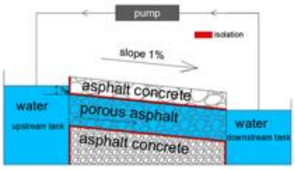


Energy Management

- Energy harvesting
- Energy supply to vehicles



OPV Road



Self-tempered road

Hybrid solar road

EU Project FABRIC
Vedecom (+Ifsttar) © TRL

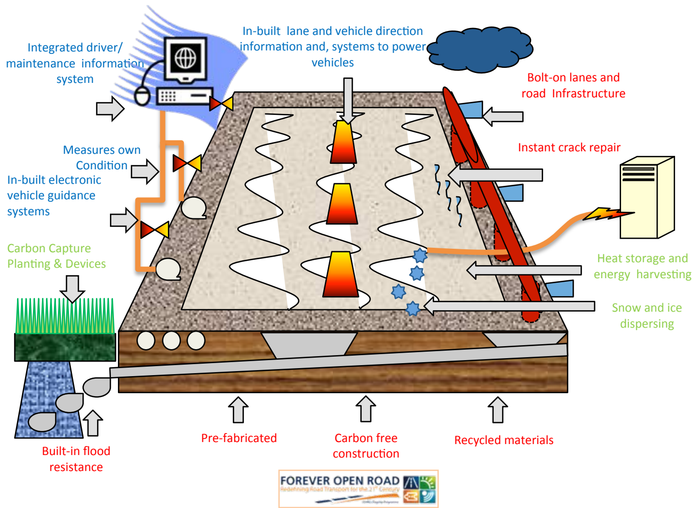
eHighway Siemens

APS Alstom

Primove - Bombardier

THE ROUTE 5ÈME GÉNÉRATION – R5G | 3

The Forever Open Road



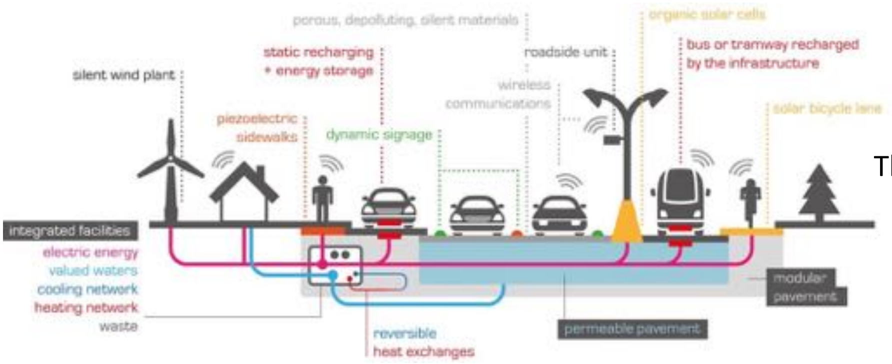
FOR - An international Alliance

- An alliance led by TRL (UK) and RWS (Netherlands)
- An alliance around national innovation programs
  - Die Strasse im 21. Jahrhundert led by BAST (Germany)
  - Ferry Free E39 led by Norway
  - Exploratory Advanced Research led by FHWA (USA)
  - Route 5^{e} Génération led by IFSTTAR (France)

35

R5G Concept

- R5G aims at integrating the different components of the Forever Open Road following a system approach to build full scale demonstrators of the next generation road and allows developing a next generation of living labs



The R5G concept applied to **urban highways**

A Progressive Approach

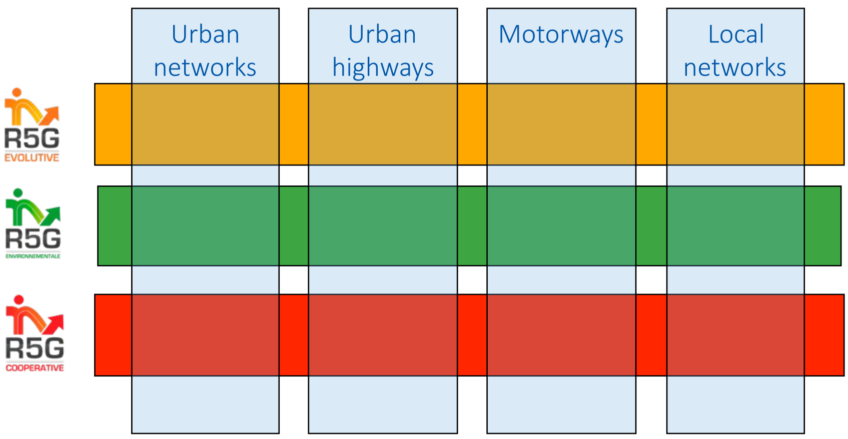
TRL 1-4
2010-2015

TRL 8-9
2020-2030

TRL 5-7
2015-2020

A System Approach

Different networks



Conclusion

- The road embeds all the global challenges, and in particular must contribute to the limitation of anthropization, when building new roads is necessary.
- Current progress in materials, ICT and energy sciences allows redesigning the future of roads
- Future roads have the potential to support a wide range of terrestrial transport modes and to be integrated from an energetic point of view.
- Neglecting the preservation of these assets could prevent the regeneration of actual roads into 5th generation roads. This would be a **choice with regrets**.
- Like other industrial sectors, innovation and upselling are key success factors and must be encouraged by public authorities.

PAVEMENT INSTRUMENTATION AND MONITORING | 4

Introduction

Sensors and data acquisition systems

Examples of applications :

- Geophone measurements
- Strain measurements using optical fibers
- Detection of pavement damage using optical fibers

Introduction

Recent progress in sensor and data acquisition technology

- New sensors : more accurate, smaller, cheaper…
- Increase of data storage and processing capacity
- Generalisation of internet technologies

→ **Increasing possibilities to develop efficient pavement monitoring systems, at a reasonable cost**

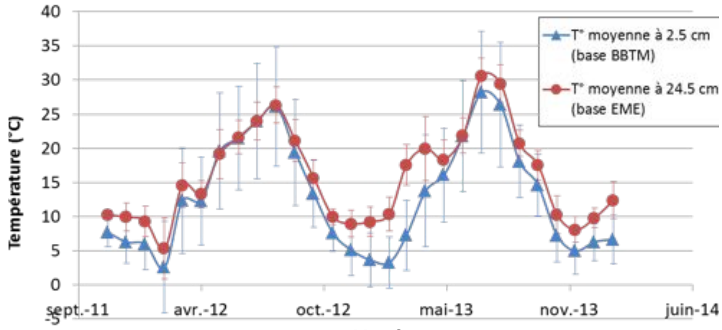
Remaining challenges :

- Less intrusive (wireless) sensors
- Transducer durability
- Distributed measurements

Examples of sensors

Temperature probes

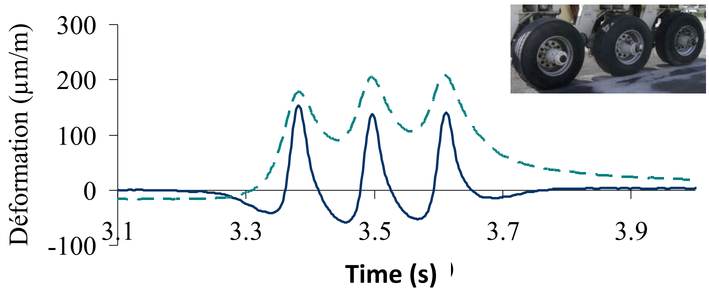
Continuous temperature measurements in asphalt pavement



Strain sensors

TML, KM100 strain gages
Length 100 mm, range ±5000 µdef

Longitudinal and transversal strains

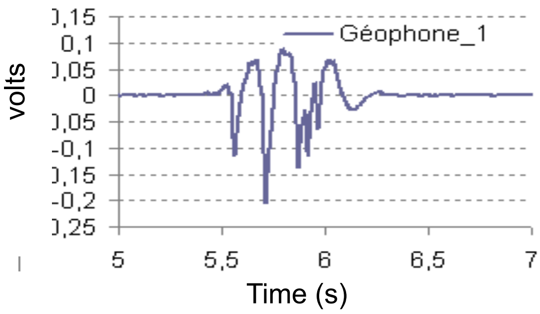


Examples of sensors

Geophones

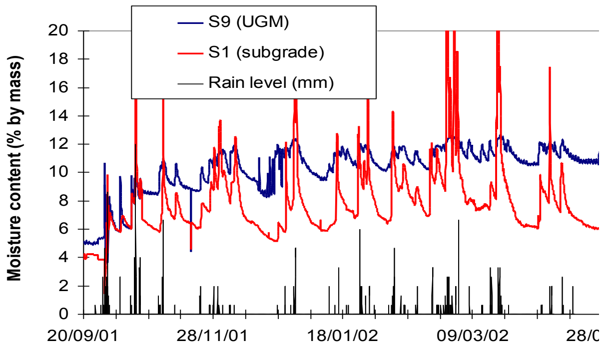
Measurement of vertical velocity

Geophone signal – 5 axle truck



Moisture probes

TDR probes
Measurement of volumetric water content – accuracy ≈ 1 %



Examples of sensors

Optical fibers

- Measurement of strains and temperatures
- Passive sensors - Small size, low cost, durability

Fiber Bragg gratings

- Local strain measurements
- High measurement frequency (several kHz)

Continuous fibers (Raileigh)

- Continuous strain measurements over whole fiber length (up to 70 m) – spatial resolution : 1 cm – strain resolution : 1 μstrain
- slow measurements : 1 to 10 seconds per measurement

Data acquisition system

PEGASE system : Modular, wireless data acquisition platform

- Analog Device Blackfin BF537 low power processor
- Wireless WIFI communication
- Small and low-power GPS receiver to ensure localization and absolute time synchronization
- uClinux embedded operating system
- Association with different sensor conditioners

Advantages of the PEGASE platform:

- On board processor
- Remote programming of the board
- Low power consumption

EXAMPLES OF INSTRUMENTATION RESULTS | 5

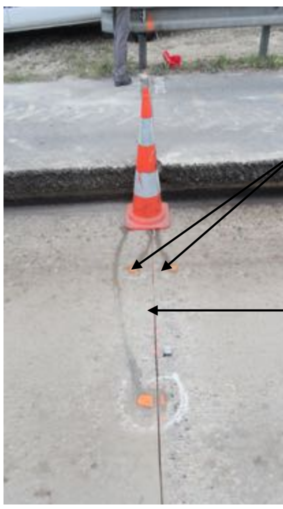
Instrumented site on motorway A10 geophone measurements

Instrumented site

GSM aerial

Pegase platform

Continuous monitoring under real traffic

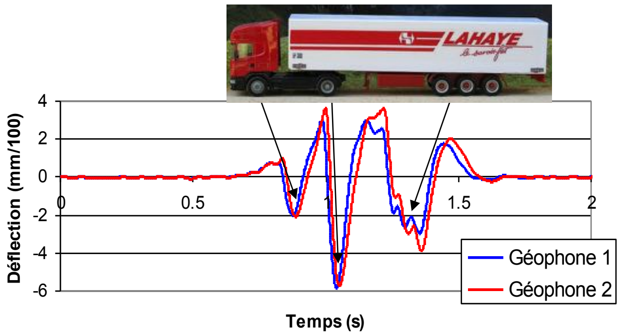


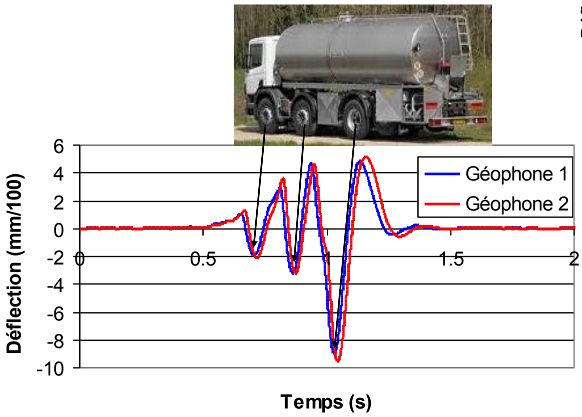
Géophones

Joint in Cement-treated base

Geophone measurements

Integration of geophone measurements ➔ detection of vehicle silhouettes and evaluation of deflections

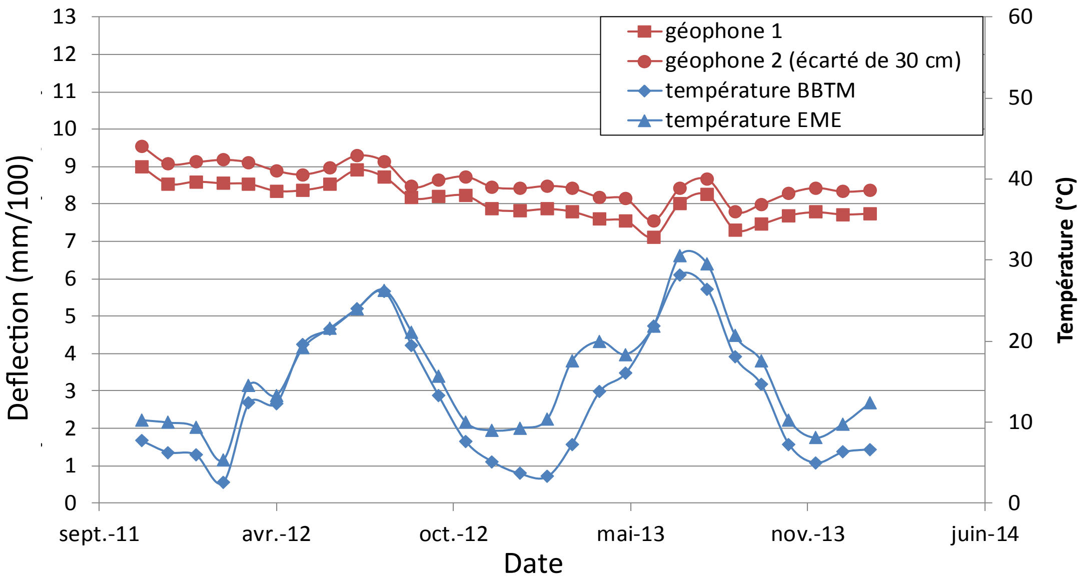




Geophone

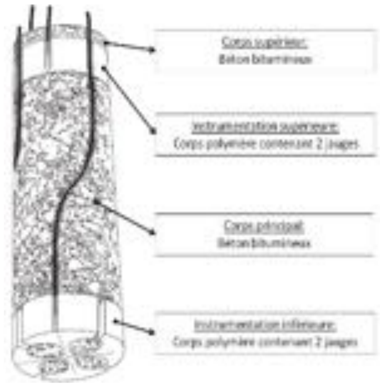
Geophone measurements

Monthly evolution of pavement deflections



Strain measurements using optical fibers

Evaluation of sensors developed at Université Laval for measurement of strain fields in upper pavement layers



Instrumented core

Core taken from site, instrumented, and sealed in place with resin
2 gages (longitudinal and transversal) near top
2 gages near bottom

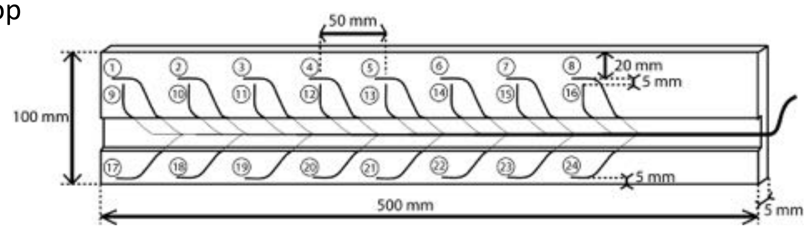
Instrumented plate

Thickness 5 mm

6 to 8 horizontal gages near top and near bottom

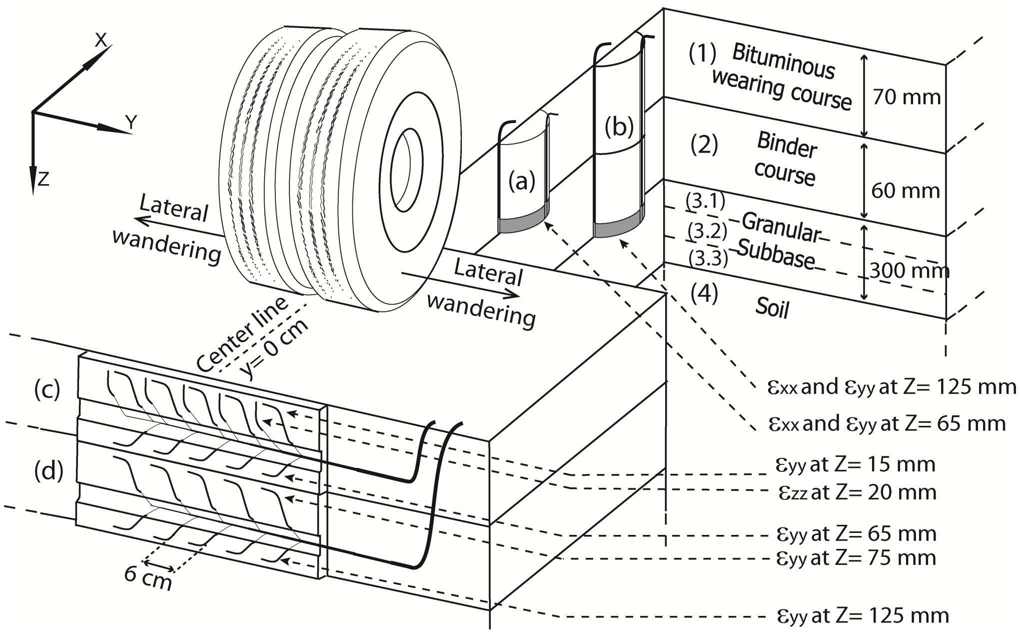
6 to 8 vertical gages

Sealed in pavement with resin



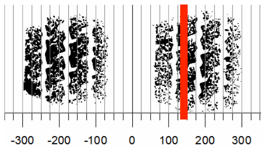
Strain measurements using optical fibers

Installation of sensors on the accelerated pavement testing facility

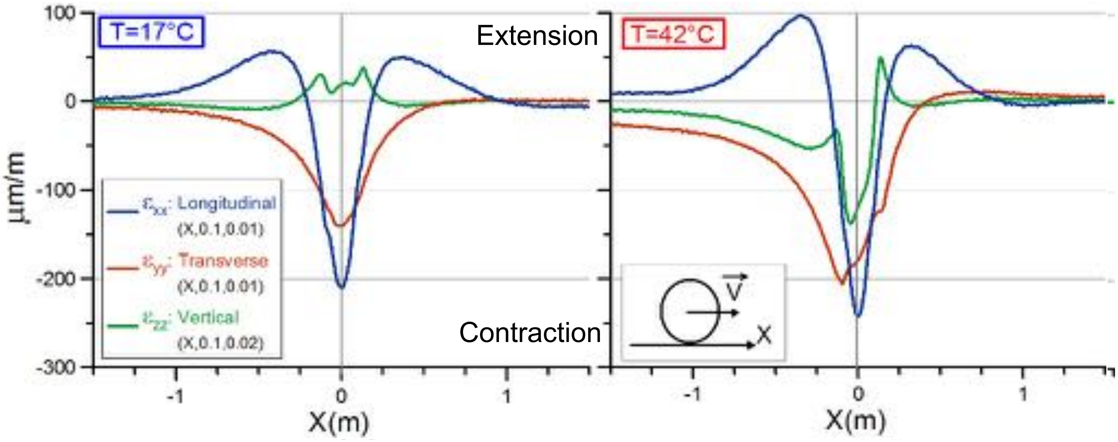


Strain measurements using optical fibers

Strain measurements in 3 directions under dual wheel

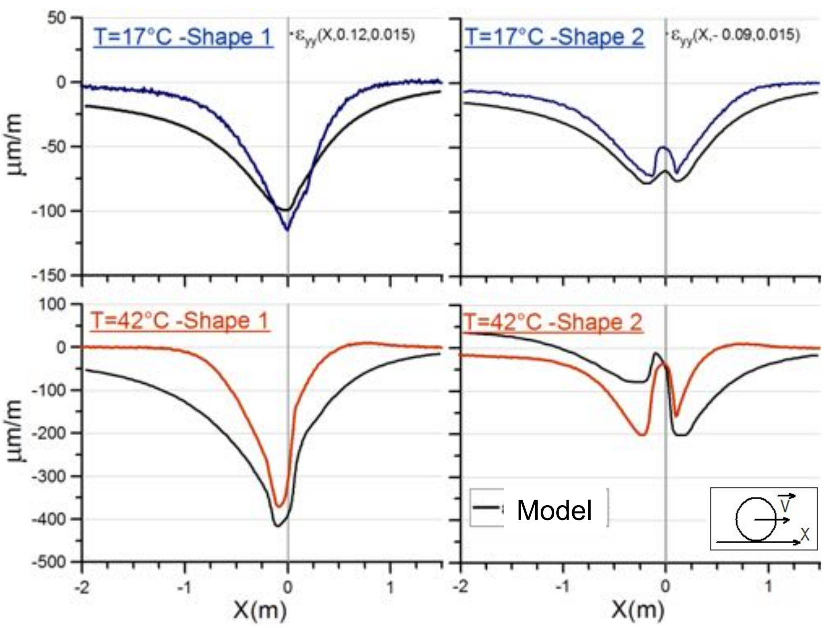


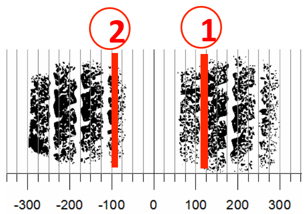
Strains at small depth (10 to 20 mm) under tire sculpture
Strong influence of temperature



Strain measurements using optical fibers

Modelling of transversal strains
with the ViscoRoute software





Depth : 15 mm

Speed : 42 Km/h

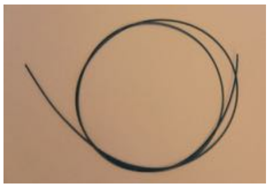
Negative strains
= extension

Evaluation of pavement damage using optical fibers

Experiment performed in the IFSTTAR APT facility

Use of continuous optical fibers for damage detection

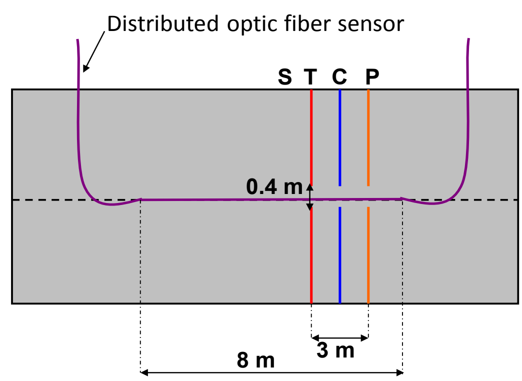
- fibers installed in pavement base
- continuous measurement of strains after different numbers of 65 kN load applications
- objective : detection of high strain levels, indicating the presence of cracks



Evaluation of pavement damage using optical fibers

Pavement Structure

- 8 cm high modulus asphalt mix
- 30 cm UGM (210 MPa)
- Subgrade (95 MPa)

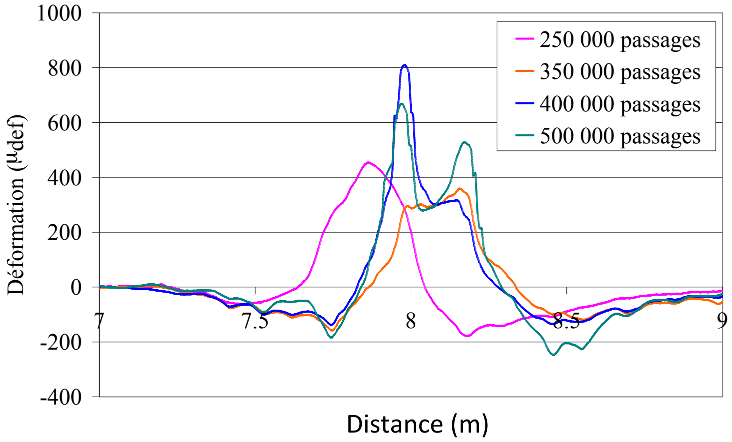


P : flat steel bar (up)
C : triangle steel bar (down)
T : T shaped steel bar (down)
Defects

Optical fiber installation

Evaluation of pavement damage using optical fibers

Strain measurements along optical fiber under static load



Evolution of strain level and signal shape

Detection of cracking before it reaches the pavement surface

Thank you for your attention