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

Introduction – First part

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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...

Global Grand Challenges

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

- The road embeds all these challenges!
According to IEA (2013), 25 millions km of new roads are foreseen by 2050.


...BUT OPPORTUNITIES ARISE
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

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Energy Management

- Energy harvesting

- Energy supply to vehicles

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The Forever Open Road

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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 5e Génération led by IFSTTAR (France)
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

Urban networks | Urban highways | Motorways | Local 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.
Introduction

Sensors and data acquisition systems

Examples of applications:
- Geophone measurements
- Strain measurements using optical fibers
- Detection of pavement damage using optical fibers

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

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

Examples of sensors

Geophones
Measurement of vertical velocity

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
- uLinux 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

Instrumented site on motorway A10 geophone measurements

Instrumented site

Continuous monitoring under real traffic

GSM aerial
Pegase platform
Instrumented section
Géophones
Joint in Cement-treated base
Geophone measurements

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

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

Installation of sensors on the accelerated pavement testing facility

- Bituminous wearing course: 70 mm
- Binder course: 60 mm
- Granular subbase: 300 mm
- Soil

Strain fields:
- $\varepsilon_{xx}$ and $\varepsilon_{yy}$ at $Z = 125$ mm
- $\varepsilon_{xx}$ and $\varepsilon_{yy}$ at $Z = 65$ mm
- $\varepsilon_{yy}$ at $Z = 15$ mm
- $\varepsilon_{zz}$ at $Z = 20$ mm
- $\varepsilon_{yy}$ at $Z = 65$ mm
- $\varepsilon_{yy}$ at $Z = 75$ mm
- $\varepsilon_{yy}$ at $Z = 125$ mm

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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

![Graph](image)

- Modelling of transversal strains with the ViscoRoute software

- Depth: 15 mm
- Speed: 42 Km/h
- Negative strains = extension
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)

Optical fiber installation

Distributed optic fiber sensor

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

Defects
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

Strain measurements along optical fiber under static load

Thank you for your attention

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