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Introduction

The 5th Generation Road and Sense-City in the starting blocks!

In April 2014, Paris hosted the 5th TRA conference. Almost 2800 people attended the major meeting place for European research and development – manufacturers, researchers, representatives of public institutions and students. With more than 650 scientific papers, almost 50 exhibitors and 11 associated events the conference was a success and an important vehicle for promoting European land transport research. It provided an opportunity to draw attention to various examples of innovative research, such as the 5th Generation Road. This project has made real progress this year, and in November 2014, IFSTTAR signed a framework agreement with the General Council of the Seine-et-Marne Département and EPA Marne for the provision of a test site for the 5th Generation Road. This agreement will make it possible to deliver the first demonstrator between 2015 and 2020.

The Institute is awaiting a number of new landmark events in 2015. The first will be the commissioning the mock-up of the “Sense-City” climate-controlled city in March. This will be located at the Bienvenüe site, which is IFSTTAR’s head office located within the Descartes complex in Marne-la-Vallée. This mock-up will provide an idea of what the facility that is due to be delivered in 2016 will be like. “Sense-city” will bring together a number of stakeholders from the research sector and academia with a view to tackling the many environmental issues that confront sustainable cities and, like the road of the future, is part of the major plan for the energy transition which the Minister for the Environment launched in 2014.

Between 30 November and 11 December, France is due to chair the Climate Change conference and has committed itself to conducting the negotiations in a transparent and inclusive manner. Agreement among the relevant stakeholders is essential for the conference preparation strategy. IFSTT and therefore be working with the Ministry of the Environment, Sustainable Development and Energy to bring its expertise to bear on the challenges we must face. Whether we consider reducing our carbon footprint by means of projects such as the carbonation of concretes or harmonising the certification of European roads through the ECOLABEL project, research carried out by IFSTTAR teams sets out to meet society’s needs, of which sustainable development is one. Issues to do with adapting to climate change are therefore fully integrated in the Institute’s research goals.

Last, slightly more than two years since IFSTTAR’s staff started to arrive at Bienvenüe, the Institute is able to announce that its Head Offices will probably be opened in spring 2015! This opening will mark the beginning of a series of open days which will run until 2016 that will enable the general public will be able to visit IFSTTAR’s sites.
Reducing our environmental footprint
The MURE and IMPROVMURE Projects

Multi-recycling of asphalt mixes for sustainable roads

The industry has adopted two main approaches in response to the challenges of sustainable development in road construction. These are, first, recycling, which makes it possible to limit the consumption of natural resources (aggregates and asphalt) and the production of waste, and second, lowering manufacturing temperatures, which reduces energy consumption and emissions of gasses that are liable to damage the environment or health. While, in isolation, each of these processes is fairly well understood, their combined use or repetition (multi-recycling) raises technical, material, health-related, environmental, societal, standardization and regulatory issues. These aspects are of concern to project managers, consulting firms and contractors. The goal of these projects – the national MURE project (Muti-Recycling of Mixes) and its close cousin the ANR IMPROVMURE project (Innovation for Materials and Processes for Improving the Multi-Recycling of Mixes) is to investigate all these issues in a collaborative framework that brings together all the stakeholders in road construction (at the end of 2014, the national project counted 23 partners).

The research principle applied is to combine pilot worksites with laboratory studies in order to validate knowledge and know-how as rapidly as possible. The experimental conditions, recycling rates, and types of warm techniques, foams and additives, are selected in view of the production capacities of the mixing plants that are operating at the present time. This means that the conclusions of the project could be implemented without any need to radically change the existing equipment. Three cycles of recycling are performed for each experimental variant.

IFSTTAR’s involvement in the project is particularly focussed on understanding damage processes (how the processes affect durability), the representativeness of the laboratory studies and the impacts on health and the environment.

Website: [www.pnmure.fr](http://www.pnmure.fr)
The ECOLABEL Project

Harmonisation of the quality labelling and certification of European roads for sustainable development

In order to create a quality labelling and certification methodology for European roads, a number of players from the roads sector have joined forces with the European Commission to found the ECOLABEL project. Its goal is to improve our infrastructure with regard to all aspects of sustainable development. The methodology ECOLABEL has developed has been validated after application to a variety of road projects that have been chosen from all over Europe. This internationally harmonised quality labelling/certification system aims to integrate life cycle engineering concepts for the appraisal of new and existing roads in order to improve their performance in terms of the precepts of sustainable development.

The scope of this appraisal covers different types of roads and road construction materials such as asphaltic mixes and cementitious materials (concretes and treated soils), using either new or recycled materials. The proposed approach is based on the selection of a set of global and local indicators that make it possible to make a combined evaluation of their technical, environmental and socio-economic performance and their resilience to climate change. This approach is applied in the framework of multicriteria project evaluation.

In addition to producing useful performance indicators, the quality labelling/certification methodology, which has been developed jointly by the partners working with the originating institutions and road construction firms, will be applied in each country on the basis of a road quality guide. A multicriteria evaluation tool will also be included to make the application of the label possible once the indicators have been calculated. This may include making recommendations to the players involved in road projects. For more than a year now, the partners' work is more specifically focused on the attempt to produce certification for the entire life cycle of projects; i.e. their preliminary design, construction, maintenance, use and end of life. The life cycle of a road project begins with its design, after the public decision-making process. This certification would apply either to new projects or to existing ones that are undergoing maintenance or rehabilitation.

1 Plan, design, operate
2 Build, maintain, recycle
3 Evaluate the products used in the road project
4 Evaluate the services provided by the roads department

The methodology builds on existing international and national labelling systems and the evaluation practices applied in European countries. In particular, it is the outcome of the rigorous selection of indicators that has been made in the course of the project and an examination of how they can be combined. Indicators that apply at different levels (local, regional and international) were considered when the methodology was developed and this methodology is also based on the analysis and pooling of available data and the output from existing incomplete evaluation tools. New indicators based on the results of evaluation may be developed in the course of the project in addition to those.
The ECOLABEL Project

that have already received much attention at the European level. Although the development of an original quality label or certification process is seen as the principal deliverable of the ECOLABEL project, recommendations for improving and adding to this quality label may also be made.

The project stakeholders:
Acciona (coordinator), BASi, CIRCE, Chalmers, ERF, FEHRL, IECA, IFSTTAR, TNO, KGM, AENOR, INVESTEKO, NAPE SA

IFSTTAR is in charge of Work Package 1 “Setting the scene: labelling approaches and Key Performance Indicators”, and coordinating the drafting of several of the project deliverables. It is also helping to inform stakeholders and the international scientific community about the project.
Using carbonation to improve Recycled Concrete Aggregate

Aggregates are the principal constituents of concrete, making up approximately two-thirds of its mass, and consequently the manufacture of concrete accounts for about 40% of today’s total aggregate consumption. Aggregates are also a non-renewable resource and becoming increasingly difficult to obtain. The Paris region imports almost half the aggregates it consumes (about 13 million tonnes per year) according to a white paper published by the National Union of Aggregate Producers (UNPG) and it has been estimated that this figure will increase by 5 million tonnes per year (source: DRIEE Ile-de-France) as a result of the Grand Paris project. Under these circumstances successfully manufacturing concrete using less aggregate is crucially important.

At the same time, the volume of waste produced by the deconstruction of end-of-life buildings and infrastructure is increasing and will continue to do so in years to come. The buildings that were constructed between 1950 and 1980 are about to reach the end of their service life, and when they do so they will generate very large amounts of concrete for recycling.

In the Paris Region such waste is currently treated in one of two ways: either it is put in landfill, or it is recycled as low cost fill for road earthworks. The road construction sector will be unable to cope with the arrival of large amounts of waste in the near future and the environmental cost of processing it will significantly increase.

In France, the national Recybéton project, which brings together industry and research centres such as IFSTTAR, aims increase the re-use of materials from demolished concrete by using them as aggregate for new constructions.

However, existing methods for recycling concrete aggregates in concrete are still affected by technical problems. The recycled concrete aggregate produced by crushing concrete is more porous than natural aggregate and its mechanical properties are inferior. Another major problem is due to the manufacturing process used to make concrete with Recycled Concrete Aggregate (RCA). RCA absorbs large amounts of water (between 5 and 10 %) and does so slowly, over about twenty minutes. The workability of concrete conventionally mixed made with RCA decreases markedly during transport.

IFSTTAR has therefore investigated the possibility of improving the characteristics of demolished concrete by using carbonation. This is a natural process by which the material absorbs CO₂ through the carbonation of cement hydrates contained in the crushed waste. It occurs because when Portland cement is manufactured from limestone and silica, the limestone and silica are kilned together which decarbonates the limestone releasing large amounts of CO₂. During concrete manufacture, water is added to the resulting cement resulting in hydration and the creation of hydrates, which are responsible for the concrete’s mechanical strength. However, these compounds are not stable, just metastable: in the presence of atmospheric CO₂, the hydrates are naturally carbonated, reabsorbing CO₂ and slowly retransforming themselves into limestone and silica gel, thereby completing the mineral cycle.

During the service life of a reinforced concrete structure this reaction is harmful as it lowers the pH of the concrete leading to the corrosion of the steel reinforcement. However, after the end of a structure’s service life it can be put to good use, in particular for the purposes of recycling. Thus, the first outcome is the improvement in the quality of the RCA obtained from demolished concrete. The second is CO₂ sequestration. This improves the environmental footprint of concrete. Our research shows that carbonation of the cement matrix in concrete produces a material that absorbs less water at a faster rate than the
material obtained from non-carbonated concrete, which makes it much more suitable for conventional concrete manufacture.
The use of carbonation to improve recycled concrete aggregate

We have two techniques at our disposal in order to bring about this carbonation process: natural and accelerated carbonation.

1. Natural carbonation
   This process is based on contact between atmospheric CO₂ and the cement. The simplest way of improving the carbonation kinetics is to increase the contact surface by crushing the demolished concrete. For example, transforming a reinforced concrete slab with a thickness of 20cm into aggregate of roughly 1cm increases the contact surface available to atmospheric CO₂ by a factor of about 1000. Our findings show that it is possible, in the case of traditional concrete buildings dating from the 1950s to the 1980s, to capture between 50 and 60 per cent of the CO₂ emitted during the carbonation of the limestone. If we include the energy used to crush and transport the material we have shown that this process is able to save between 15 and 20kg of CO₂ per cubic metre of processed concrete. This carbonation process is, however, slow and means the aggregate must be stored for a long time (several months) before it is re-used. It also requires a considerable amount of space which may make it impractical.

2. Accelerated carbonation
   The process can be accelerated by working at higher pressures, or even with supercritical CO₂. A supercritical fluid is one that has been heated above its critical temperature and then compressed above its critical pressure. The physical properties of a supercritical fluid (density, viscosity, diffusivity) are between those of a liquid and a gas. CO₂ becomes supercritical at a temperature above 31°C and a pressure of over 73 bars. It is therefore relatively easy to manufacture, safe (not inflammable or toxic) and is already used successfully in the agrifood industry, to decaffeinate coffee grains, extract the aromas from perfume plants and remove the nicotine from tobacco.

Preliminary tests conducted with the chemical engineering laboratory at Toulouse University have shown that cementitious materials can be carbonated under supercritical conditions to a depth of 1 cm in ten minutes or so. This treatment has the advantage of also being effective in the case of fine fractions (sands) produced during recycling which have a high potential for carbon sequestration. Currently these are not used to remanufacture concrete because of their excessive porosity. However, the procedure still needs a socio-economic appraisal. There is a danger that the high technological cost will mean it will not achieve equilibrium. The verdict will also depend on the price per tonne of CO₂ and the implementation of a carbon tax.

Research has also considered a simpler and less expensive alternative. This consists of placing the aggregate in a CO₂ enriched atmosphere at atmospheric pressure. In this way a 10 cm thick layer of concrete can be carbonated in a few days. One can imagine that a high partial pressure of CO₂ obtained by bubbling CO₂ through a
The use of carbonation to improve recycled concrete aggregate

“big bag” of recycled aggregate, could treat it in 2 or 3 months.

At the same time we have developed a carbonation model that can be applied to granular materials. This models the processes described above, and is, in particular, able to take account of the moisture content of the aggregate, which is a very important parameter for the carbonation process (the CO$_2$ penetrates the concrete as a gas but in order to react it must be dissolved in the interstitial water). The model will make it possible to optimise the duration of contact between the recycled aggregate and the CO$_2$ and the concentration of CO$_2$ according to the moisture content of the materials and their microstructure.

References:
Gobert et al., Accelerated carbonation of hardened cement samples using supercritical CO$_2$, 14th European Meeting on Supercritical Fluids Marseille, 2014
Thiery et al., Cinétique de carbonatation d’un lit de granulats concassés de matériaux cimentaires, Journées ouvrages d’art, Marseille, 2011.
Thiery et al., Carbonation kinetics of a bed of recycled concrete aggregates: A laboratory study on model materials, Cement and Concrete Research 46 (2013)
Belin et al., cement paste content and water absorption of recycled concrete coarse aggregates, accepted for publication in Materials and Structures, DOI 10.1617/s11527-013-0128-z
Using bacteria as a binder for road construction materials

Road construction uses large amounts of lime and clinker. However, the carbon footprint of these materials is poor because large amounts of CO₂ are produced during their manufacture. In recent decades the industry has increased the use of mineral additives of varying reactivity such as blast furnace slag (a by-product of metal manufacture) or fly ash to partially replace these constituents, which has led to the development of composite cements and hydraulic road binders.

It is planned to carry out further research to find greener alternatives. One possibility could be to use bacteria that precipitate calcium carbonates. The precipitation of calcium carbonates is a natural phenomenon that is used by many organisms in order to form an internal or external skeleton. For example, some bacteria hydrolyse urea to create ammonium and calcium carbonate. This process was first applied to repair stones and is increasingly used for cementitious materials in various applications. Studies have demonstrated an improvement in the durability of mortar made with Portland cement and fly ash when bacteria that hydrolyse urea are added. This durability is explained mainly by an increase in resistance to water and impermeability.

The purpose of this research is to develop a binder that is made from cementitious materials, industrial by-products and biological formations and thereby reduce the environmental impact of the use of cement or lime for pavement construction while nevertheless conserving a long service life.
Giving priority to positive energy roads

In France, energy considerations are of prime importance in the sphere of road freight and passenger transport. The road system transports 90% of the country’s freight (in tonne-kilometres) and 80% of its passengers (in passenger-kilometres). The energy transition for roads themselves, which are part of a transport system that is omnipresent in the day-to-day lives of the nation’s citizens, is consequently unavoidable.

R5G clearly states its aim of making a medium-term contribution to this goal. It fosters innovative engineering solutions with the aim of making considerable reductions in the amount of external energy required by the transport system. It attempts to provide energy to vehicles more efficiently and sees roads as a potential source of energy, as has long been the case for buildings with systems such as photovoltaic panels and solar water heaters, etc.
An efficient energy supply for vehicles

The first step to take in order to improve the efficiency of the energy supply to vehicles lies in the development of electric vehicles. The most conventional way of recharging the batteries is, of course, a dedicated socket: R5G should therefore be equipped with high performance recharging stations that are fast and reliable. This is the purpose of the MOV’EO TREVE project, undertaken with ADEME. The goal is to design a dedicated demonstrator for evaluating and conducting applied research into infrastructure for recharging electric vehicles. It also provides back-up for the “urban electric service station” concept.

But the most efficient solution is without doubt the large-scale development of dynamic, contact-free, recharging facilities that can be used by vehicles of any type: private, public transport and freight. The European FABRIC* project will make it possible to build a demonstrator for the contact-free recharging of moving vehicles (up to 80km/h), for private electric vehicles on the Versailles-Satory test site. For urban public transport systems, such as buses or trams, several experiments to insert such technologies into pavement structures have already been carried out at IFSTTAR’s Nantes site.

Dynamic recharging by induction
The FABRIC project in collaboration with the VEDECOM ITE
(©Ifsttar)
Infrastructure that produces hot water?
Pavement surfacings are usually black and they therefore absorb energy from the sun’s rays. Their surface temperature may be several tens of degrees higher than the ambient temperature. The idea of turning them into a “solar water heater” is not a new one, and has already been trialled on a number of occasions. The thermal energy recovered in this way can be used to heat buildings directly or to produce energy. The hot water can also be stored in natural or artificial underground reservoirs. It can then be re-used in the winter for melting snow or ice on the road surface or to help heat nearby facilities. The techniques that have been deployed so far required pipes to be inserted in the pavements, but simpler solutions using specifically developed materials are currently being investigated.

To find out more, consult “À quoi ressemble-ront les Routes de 5e Génération ?” sur www.ifsttar.fr in “Our main themes”.

* FABRIC : FeAsiBility analysis and development of on-road charging solutions for future
Solar roads

Or when roads start to produce energy

Roads have several features that mean they have the potential to be used to heat water. First, their surfaces are perfectly suited to the direct production of electricity by photovoltaic panels. If photovoltaic panels with the usual efficiency of 10% were installed on the million kilometres of pavements that are available in France, the amount of energy produced would equal French energy production, i.e. France’s annual consumption of 500 TWh.

More realistically, the energy produced could certainly be used locally by the transport system itself, in order to power dynamic luminous signage or static roadside communication systems, to light sensitive zones and to power vehicles.

Several international experiments have led to the development of miniature demonstrators. One example is the cycle path built by the Dutch company Solar Road, or the Solar Roadway prototype in the United States. These two projects have shown the feasibility and energy efficiency of the pavement surfacing, which consists of photovoltaic solar panels made with ultra-strong glass to withstand repeated vehicle passages. However, they have not established whether it is possible for the surface to achieve sufficient skid resistance for vehicles to use the road safely. Likewise, damage to the surface caused by traffic and climatic conditions and potential impacts on electricity production have not been dealt with. Finally, the manufacturing costs are very high, of the order to 3 or 4 times those of a conventional pavement.

Research currently being conducted at IFSTTAR takes account of these three problems by attempting to develop a semi-translucent road surfacing that covers a set of flexible photovoltaic cells installed on top of the pavement foundation layers. The surfacing consists of a mix consisting of glass aggregate and a translucent binder made of asphalt, resin and a plant-based binder. This should provide pavement trafficability that is as good as a conventional pavement. The moderate cost of this pavement and the standard photovoltaic cells used should
mean the additional cost compared to a conventional pavement is quite small.

The technical feasibility has been proven (photo). What is now required is the creation of a full-scale demonstrator to test the procedure’s effectiveness and durability.
Designing safer and more efficient infrastructure
The S_VRAI Project

Collecting incident data to foresee accidents

The S_VRAI project deals with incident analysis and provides traffic accident researchers with additional data. The project is being led jointly by CEREMA and IFSTTAR and is based on the development and deployment of vehicle-borne Event Data Recorders (EDR). These completely automatic devices collect information about accident and incident situations. This recorder is known as EMMA (Enregistreur EMbarqué des Mécanismes d’Accidents – On-board Accident Mechanism Recorder) and was developed by IFSTTAR’s Accident Mechanisms Laboratory (LMA) in partnership with the telecommunications company KERLINK. The devices are installed under the driver’s seat and fitted with sensors that make real-time measurements of information about the vehicle’s position (via GPS) and its speed and acceleration. They also collect information about some driver actions such as activating the brake pedal or using an indicator. When the level of certain parameters exceeds a certain threshold that corresponds to an incident situation, all the data collected 30 seconds before and 15 seconds after are stored and then transmitted in a secure encrypted form by GSM to a server hosted by IFSTTAR.

2nd generation EMMA recorder 3rd generation EMMA recorder

The first phase of the project was launched in 2011 and came to an end in 2014. It was concerned with the following:

- Development of the EMMA recorders. These devices currently have considerable in-built computing power and advanced communication functionalities and are built to industrial manufacturing standards. The collected data are processed by means of a web server-based operating architecture developed in-house.

- Deployment: the EMMA recorders were installed on fifty vehicles belonging to local and regional government (CEREMA, CG76, DIR) and Départements (numbers 13, 43, 63 and 76). To allow them to collect personal data, IFSTTAR’s Accident Mechanisms Laboratory (LMA) has developed an appropriate legal procedure, which, in particular, has been authorized by the French Data Protection Agency (CNIL). The data collection and processing phases of the project began in August 2012 and lasted 12 months.

- Operational aspects: the collection process provided a total of 3,500 trips that covered a total distance of 100,000 km. More than 1,500 events that included 350 incidents were identified. This data provided the basis for defining and exploring a large number of topics in particular the use of incidents as an indicator of danger, improving our knowledge about accident mechanisms and the links between incidents and infrastructure. Our findings showed that the infrastructure played a role in most incidents and that it is possible to identify the risky zones on a road network using vehicles equipped with on-board EDRs. The other point highlighted by our data collection concerns the characterisation of dynamic driving parameters. The recordings have enabled us to define driving behaviours objectively and analyse
an incident within the context of a journey.
The second phase of the S_VRAI project will consist of increased deployment of the Emma recorders by means of a partnership between the State and local and regional government in order to conduct incident analysis on a larger scale and perfect the methods we have developed. Stakeholders with an interest in road safety (mainly network managers – Département General Councils, Municipalities …) have already shown strong interest in this deployment which has real potential to develop the use of EMMA.
The SCOOP@ Project

From the infrastructure to the vehicle and from the vehicle to the user: a large-scale project to modernise the road sector

The Ministry of Transport is coordinating a French project to trial deployment of cooperative Intelligent Transportation Systems (ITS).

Cooperative ITS allows independent and proprietary applications to communicate with each other using standardised communication techniques, in order to add to the functionalities available to stakeholders, public authorities, operators and users. In particular, this involves developments as regards the road system and two-way communication between the infrastructure and vehicles, on-board devices and roadside beacons.

This project, which goes under the name of SCOOP@F, has the following objectives:
• To radically change the entire traffic intervention, management and information system,
• To replace a large number of dynamic devices (variable message traffic signs, videocameras, vehicle counting loops ...),
• To provide better service to the user and optimise costs for road managers,
• To enable the French vehicle industry to conceive tomorrow’s vehicles.

How does it work?
Roads and vehicles will communicate with each other using wireless networks, by means of:
- roadside and in-vehicle wifi,
- public GSM networks.

Vehicles will therefore be able to inform the road and to other connected vehicles about any obstacles they encounter as well as their position and speed...

Example of data collection and exchange
Warnings will be sent to a tablet on the driver’s dashboard. The data transmitted by the vehicle and received by the roadside unit will be retransmitted to the road managers who will be able to use it to ascertain the state of traffic and intervene more effectively in the case of an incident.

This system will also improve road worker safety. For example, all the connected vehicles will receive a warning in the case of an intervention or roadworks.
The SCOOP@F Project

The system will be tested at a number of sites

Five tests sites :
- Ile de France
- East corridor E50 (Sanef)
- Bretagne
- Bordeaux
- Isère

Equipments:
- 2400 OBU’s (vehicles)
- 300 RSU (fixes stations)
- 100 RSU (mobile stations)
- Data centers, servers

The project partners
The Ministry of the Environment, Sustainable Development and Energy (the coordinator), local and regional authorities (the Bretagne Region, Rennes Conurbation Committee, Bordeaux Urban Community, the General Councils of the Départements of Côtes d’Armor, Finistère, Ille-et-Vilaine via the ITS Bretagne association, the General Council of Isère), managers of the national road (SANEF, Direction des routes Atlantique, Ile-de-France, Ouest), vehicle manufacturers (Renault, PSA, LAB - GIE RE PSA Renault), research centres, research institutes and universities (CEREMA, IFSTTAR, Université de Reims, Institut Mines Telecom).

The total budget of approximately €20 million, will be provided in part by INEA (the Innovation and Networks Executive Agency). The aim is for the SCOOP@F project to equip 3,000 vehicles and almost 2,000km of roads.

IFSTTAR’s role
One of IFSTTAR’s five departments, COSYS (Components and Systems), is in charge of the project. The Institute’s researchers will apply their expertise to the technical specifications of the system and its validation. They will also take part in the studies that will investigate the organisational, legal and regulatory impacts such innovative systems will have for stakeholders, the public sector, road operators and users.

Website: www.developpement-durable.gouv.fr/SCOOP-F-Projet-de-deploiement.html
Research and innovation for railways
Towards the use of satellite positioning technology in the French railway sector

Satellite navigation systems are already widely used in the railway industry. Currently, all TGVs, freight trains and some regional trains have GPS receivers that they use mainly for “non safety-related” applications. SNCF offers passengers an application of this type known as “SNCF Maps” which enables them to geolocalise trains in real time. Other applications exist which are used for infrastructure maintenance or fleet management.

For a number of years, IFSTTAR’s LEOST\(^1\) laboratory has been researching into GNSS\(^2\) for applications that are more demanding, particularly in the area of safety. Examples are its involvement in the European “Locoprol” project (financed by the 5th FPDR) and more recently the “GaloRoi” and “Satloc” (financed by the 7th FPDR). Fifteen years of European Community research in these areas are today bearing their fruit. Research has been stepped up and gained the recognition of the major players in the railways sector and the GNSS space agency. The signing of a “Memorandum of Interest” between the European Commission, the European Railway Agency (ERA) and associations belonging to the European railways sector bears witness to this interest. The document states that “GNSS is able to play an important role in the railways sector”.

France is also engaged in this process through two events that took place in 2014: in July, IFSTTAR signed a framework agreement with the CNES. The application of satellite positioning in the railway sector was one of the priority topics in this agreement. In November a discussion seminar, organized by the MEDDE and the CNES in collaboration with IFSTTAR and Railenium, took place in Lille. This bought together the major players involved in the development of these technologies.

In practical terms, the use of GNSS in the railways sector has many benefits. The first is a possible reduction in the cost of transport infrastructure as the number of trackside beacons, which are currently used to locate trains, could be reduced and replaced by on-train devices. Such a change would mainly involve low-traffic lines such as regional lines where the costs of installing and maintaining equipment are high. This technology has the potential to save some unprofitable lines which are currently under threat.

These changes are part of the deployment of the European Railway Traffic Management system (ERTMS). They will make it possible to increase the efficiency of rail transport, in particular by increasing line capacities without compromising – or even while improving – safety. These solutions will make it possible to modify the size of block sections by making them movable or to adjust braking distances in order to run more trains on a given line, without additional investment in infrastructure.

The issues facing this approach relate to the accuracy of geolocation, the reliability of the information, and the ability to carry out necessary standardisation, normalisation and certification.

IFSTTAR’s involvement in these areas is at a number of levels and harnesses the expertise in its LEOST and ESTAS laboratories in multiple domains such as geolocation, telecommunications, the development of new operating safety methods and the simulation of the impacts of ERTMS.
Research and innovation for railways

At the national level, discussions are under way with the Ministry of the Environment, Sustainable Development and Energy (MEDDE). Their aim is put in place an action plan for developing operational perspectives for application in the more or less distant future, as well as fostering R&D activities and the demonstration of the developed applications. These discussions are being conducted in close collaboration with the Railenium Technological Research Institute (IRT) and manufacturers in the various sectors that are involved.

The secure satellite-based location of trains has European approval and is one of the clearly stated R&D priorities of Shift2rail, a recently created joint enterprise. The LEOST, in collaboration with ESTAS\(^3\), is continuing its research into the analysis and modelling of the errors caused by the railway propagation environment. The aim of this work is to investigate the perception and impacts of obstacles (tunnels, the urban environment, trackside vegetation) which reduce the accuracy of location and adversely affect the operational security of the system and its ability to meet railway safety requirements.

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\(^1\)LEOST : Laboratory on Electronics, Waves and Signal Processing for Transport

\(^2\)GNSS : Global Navigation Satellite System

\(^3\)ESTAS : Evaluation of Automated Transport Systems and their Safety.

The LEOST and ESTAS laboratories are part of COSYS (Components and Systems) which is one of IFSTTAR’s 5 departments.
The INROADS Project

Innovative solutions for self-powered dynamic signage

New roads must take account of the fundamental requirements of improving safety and saving energy. We therefore need to design new generations of dynamic signage that take advantage of new technology, in particular LEDs (Light Emitting Diodes) and the general availability of telecommunications systems.

In order to face these challenges, IFSTTAR is taking part in the European INROADS project (INtelligent Renewable Optical ADvisory System). This is managed by the TRL (UK), and is part of the “Forever Open Road”, project, which is the flagship project of the FEHRL (Federation of European Highways Research Laboratories) that was launched in 2011 and represented in France by IFSTTAR via the 5th Generation Road (R5G) project. INROADS aims to develop a wireless LED road stud that is self-powered by a solar cell and remotely activated and deactivated via a telecommunications system. This communication-based system will in the longer term become part of the road of the future approach in which vehicles will dialogue with equipment on the infrastructure. This type of system, which has only a small amount of available energy, is envisaged for dynamic signage during both the day and night. Possible applications include the signage of pedestrian crossings, danger signs (to prevent wrong-way driving on motorways) or dynamic road markings.

IFFSTAR has designed a dynamic road marking application for bends on unlit roads with low night-time traffic. Luminous road studs positioned along the road markings light up when a vehicle approaches in order to provide the driver with improved visual guidance and improve vehicle control on the bend. The system is deactivated after the vehicle’s passage.

Driving simulator study

In order to investigate the usefulness of this application, IFSTTAR has evaluated the system by observing how it is used and understood. This was done by carrying out experiments on a risk free environment of a driving simulator.

Twenty participants were recruited to test the road under different conditions. Initially, the road was unlit (or only lit by the participants’ headlamps), then with street lighting and, last, with the dynamic road marking with the luminous studs. Drivers were observed to control their lateral position better on bends with the dynamic road marking system without increasing their speeds on straight road sections. The conclusions reached about the self-powered dynamic LED road marking system are therefore positive.
Photometric recommendations

In addition to these tests, measurements were made at IFSTTAR’s photometry laboratory. The results were compared to the opinions of a panel of observers. Recommendations concerning the intensity of the luminous studs were issued in order to ensure their visibility under all external conditions without being too bright during the night. Controlling the stud in this way also reduces the amount of energy the system consumes, which is important as the lack of external power supply means that little energy is available.

A luminous stud

The next phase of INROADS

In 2015, the INROADS project will enter the pre-industrial phase. A trial on a real site will be set up in Israel in order to test this technology and the dynamic road marking system under real conditions.

1 INROADS is funded by the Seventh Framework Programme for research and Development. For more information go to www.fehrl.org/inroads

2 TRL : Transport Research Laboratory
Integrating infrastructure within tomorrow’s cities
Sense-City, a miniature climate-controlled city

*An R&D space dedicated to technological innovations for the sustainable city*

Built-up areas, from megapoles to rural municipalities, are systems of an extraordinary human and technological complexity whose equilibrium is threatened by population growth and the increasing scarcity of resources. Massive urbanisation is a danger to the environment and global climate change is a threat to individuals and assets as a result of natural hazards (climatic, hydrological or geological).

Connecting the city, that is to say designing and deploying systems that are able to carry, between the different entities, very large volumes of data that are varied in nature and analysed for a variety of ends, is central to our hopes of making our built-up areas more sustainable – i.e. resilient to climate change, economical in their energy use and participants in the energy transition, attractive to individuals and firms, healthy and environmentally friendly.

While many stakeholders are already aware of this need, progress is slow as, in addition to connectedness, to become a reality the sustainable city requires urban intelligence which will provide it with coordinated capabilities in the areas of perception, decision-making and action: measuring phenomena, analysing their impact on urban sustainability in order to identify improvement strategies; acting effectively on the phenomenon’s cause.

In this rapidly changing context with major societal impacts, the Sense-City project, which is an “outstanding facility” with funding to the tune of €9 million, sets out to boost research and innovation for the sustainable city, in particular in the area of micro- and nano-sensors. The project’s core is a “miniature climate-controlled city”, which is a mobile 400m² controlled environment enclosure environmental which is built to house realistic mock-ups of the main components of a city, namely the buildings, infrastructure, distribution networks or the underground environment.
A preliminary version of this space will become available in January 2015 and be replaced by the definitive version in 2016. It will provide realistic conditions in which the performance of innovative technologies for sustainable cities can be tested, in particular micro- and nano-sensors, after they have been developed in the laboratory but before their industrial production. This R&D platform will be located in the Cité Descartes at the Paris-Est site. Academics, industry and local authorities will be equally welcome to use the facility which is one of the ways the Cité Descartes will establish itself as a major tertiary sector centre for the city of the future. Investigations will be concerned with the energy performance of buildings and districts, the sanitary quality of buildings (indoor air pollution), the quality and sustainability of urban networks (transport, fluids), outdoor air quality, soils and water, monitoring waste storage zones and the safety of infrastructure.
Sense-City, the climate-controlled miniature city

The first Sense-City miniature city, available in January 2015

Indoor air quality
Outdoor air quality

Instrumented biosourced house; Solar road; High strength solar panels; Green district
Intelligent road; Intelligent street furniture; Sustainable water networks
A site for linked trials for the city of tomorrow (250 m² / 10 m x 25 m)

The project partners, IFSTTAR, ESIEE-CCIP, LPICM (UMR CNRS-École Polytechnique), CSTB, INRIA and UPEM, have joint control of the value chain for the development of innovative products for sustainable cities, from the production of prototypes of nano- and micro-sensors to their validation under real conditions, including sensor integration, packaging and deployment as well as data processing, modelling and presentation.

Illustrations: Érick Merliot, IFSTTAR
Biography of Hélène Jacquot-Guimbal
Managing Director
Ingénieur général des ponts, des eaux et des forêts
(Senior Engineer for Bridges, Waterways and Forests)

Education
• École Normale Supérieure (Sèvres, admitted in 1977 with a specialisation in physics, doctorate in physics in 1981)
• École des Ponts et Chaussées (admitted in 1981)

Professional experience
• Department Head, DDE of the Somme Département (Ministry of Infrastructure) from August 1984 to September 1987
• Assistant director of planning and community facilities (Ile-de-France Regional Council) from October 1987 to November 1989
• Assistant Deputy Director of decentralisation at the Directorate for Personnel and Services (Ministry of Infrastructure) from November 1989 to April 1994
• Deputy Director of Human Resources at the General Directorate of Administration and Development (Ministry of the Environment) from April 1994 to November 1996
• Deputy Director of Scientific and Technical Development at the Directorate for Scientific and Technical Affairs (Ministry of Infrastructure) from November 1996 to June 2001
• Deputy Director of Roads (Ministry of Infrastructure) from June 2001 to May 2002
• Budgetary and transportation advisor to the Minister for the Environment and Sustainable Development from May 2002 to February 2003
• General Director of Administration, Finance and International Affairs (Ministry of the Environment and Sustainable Development) from February 2003 to November 2004
• Member of the Minister for Infrastructure’s Office from November 2004 to May 2005, as the future Managing Director of Personnel and Administration
• Managing Director of personnel and management at the Ministry of Transport, Infrastructure, Tourism and the Sea, from May 2005 to May 2009
• Temporary Managing Director of administration at the former MEDD, from October 2007 to May 2008 in addition to her existing post.
• Managing Director of the Laboratoire Central des Ponts et Chaussées, since May 2008, since March 2010 responsible for its merger with INRETS (the National Institute for Transport and Safety Research)
• Managing Director of IFSTTAR (French Institute of Science and Technology for Transport Development and Networks) since 1st January 2011

Officer of the Legion of Honour
Officer of the National Order of Merit
Serge Piperno is IFSTTAR’s new scientific director, replacing Henri Van Dame in April 2014. He began his career as a researcher in 1995 after a doctoral thesis at the École Nationale des Ponts et Chaussées (ENPC) where he was in very good hands: his supervisor was no less than Bernard Larrouturou, the future Director of CEREMA. The young civil engineer and researcher took up a post in CERMICS, the Applied Mathematics Laboratory at the École des Ponts, joining the Scientific Calculation, Modeling and Numerical Analysis team based at the INRIA site at Sophia-Antipolis. In 1999, he became its scientific manager, a post he kept until 2005. The team was involved in investigating fluid-structure interactions, i.e. “the way air flows around an airplane or the effects of wind on a suspension bridge”, he remembers. “We were also interested in applications to do with wave propagation, for example the warming of brain tissue due to electromagnetic radiation from a mobile telephone. It was highly motivating!”

In 2000, Serge Piperno became the Deputy Director of CERMICS and deputy member of the INRIA evaluation commission where he worked alongside many world-renowned scientists, including the famous mathematician Pierre-Louis Lions, winner of the Fields medal in 1994. “It was at this time that I began to develop a taste for managing scientific research” he explains. In 2005, he became the Director of CERMICS, ten years after joining the laboratory as a doctoral student! He nevertheless continued to devote some time to research. “At that time, I worked, for example, on the numerical simulation of free surface flows, such as the breaking of the Malpasset dam near Fréjus, which cost more than 400 lives in 1959”.

A year later he was awarded the Blaise Pascal prize by the Académie des Sciences. The prize was set up by the Society for Applied and Industrial Mathematics (Société de Mathématiques Appliquées et Industrielles), and had previously been awarded to Bernard Larrouturou in 1989. He served as the General Secretary of this society from 2007 to 2010. In 2009 he decided to devote himself entirely to the management of research, becoming the director of research at École des Ponts ParisTech. “In this small organisation that was rather like a small firm engaged in research, I was a jack-of-all-trades in a small department with a wide variety of tasks: scientific management, preparing research contracts, human resources, accounting, etc.”

Serge Piperno, who has been at the head of IFSTTAR’s scientific Directorate since April 2014, has made the following initial observation: “In view of the foreseeable reduction in public funding, we must find how to attract more and more resources from outside, focus on our strengths without neglecting to improve and maintain our expertise and major scientific facilities”. Another challenge that faces the new head of the Scientific Directorate is that of increasing the Institute’s profile. “For this we probably need to refocus our communication with the outside world, and to some extent our activities, and concentrate on a small number of major projects – like the 5th Generation Road – while continuing to combine the physical and social sciences, as this singularity of the Institute is a strength”, he concludes.
“The representatives of the French people, constituted as a National Assembly, and considering that ignorance, neglect, or contempt of the rights of man are the sole causes of public misfortunes and governmental corruption, have resolved to set forth in a solemn declaration the natural, inalienable and sacred rights of man”

Introduction to the Declaration of the Rights of Man and the Citizen, 1789, preamble to the French Constitution.

In memory of:
  Frédéric Boisseau, maintenance technician
  Philippe Braham, marketing executive
  Franck Brinsolaro, corporal in the protection service
  Jean Cabut, known as Cabu, cartoonist
  Elsa Cayat, psychoanalyst and columnist
  Stéphane Charbonnier, known as Charb, cartoonist
  Yohan Cohen, employee
  Yoav Hattab, student
  Philippe Honoré, known as Honoré cartoonist
  Clarissa Jean-Philippe, police trainee
  Bernard Maris, economist and columnist
  Ahmed Merabet, police officer
  Mustapha Ourrad, proofreader
  Michel Renaud, former head of the Mayor of Clermont Ferrand’s Office
  François-Michel Saada, pensioner
  Bernard Verlhac, known as Tignous, cartoonist
  Georges Wolinski, cartoonist