Lille Métropole

Note

PUBLIC SPACES ECOLOGY URBAN SERVICES
/PUBLIC SPACES AND ROADS

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Objet

Smart roads for sustainable roads: monitoring utility cuts impacts to conserve pavement

1 THE SUNRISE PROJECT

The "roads/networks" demonstrator is being developed on the Cité Scientifique Campus near Lille, as part of the SunRise project consisting in transforming the campus into a demonstrator of a smart, sustainable city. The campus covers some one hundred hectares with training (20,000 students), research (2,500 personnel, teachers and researchers), housing (4,000 permanent residents), culture, sports and recreation activities. The 140 buildings on the Campus (representing almost 320,000m^2) are served by almost 100km of urban networks: roads, drinking water, sewer systems, electricity, public lighting and urban heating (Figure 1). The campus also has a heat production source.

The purpose of the SunRise project is to employ technological and non-technological innovations to improve the living environment on the Campus, cut water and energy consumption and make users genuine stakeholders in the sustainable development of their Campus. The project also aims to provide stakeholders in the city with a full-scale experiment addressing all the issues of technologies, user interaction and governance. The experiment concerns the various utility networks (electricity, urban heating, public lighting, drinking water, sewers, roads, etc.), building energy performances and the interaction between buildings and urban networks. It has several objectives: achieving optimal use of resources, improving the operating security of urban systems, establishing interaction with users and setting up an academic, innovation and transfer platform.

The SunRise project is supported by the local authorities (Lille Métropole and the Regional Council), water and energy operators, international partners and start-ups. It is one of 4 European Smart Water Network demonstrators (London, Caceres in Spain, Leeuwarden in the Netherlands and the Cité Scientifique in France) financed under the European SmartWater4Europe project. The work with our partners has served to establish the initial diagnoses and define a strategy for rolling out the concept of smart networks. An urban information system is under construction in order to combine information on the assets and working of the various urban networks and buildings in a single system. An initial set of instrumentation is being used to collect data on the various types of consumption. This data is then used to develop an expert system for optimal network management.

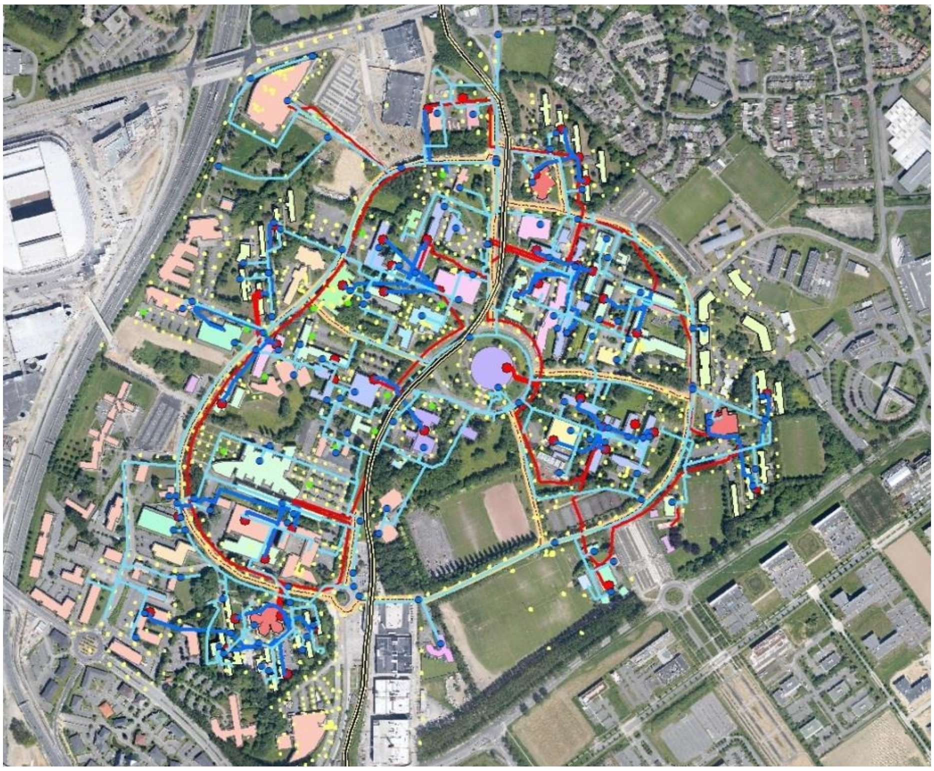

Figure 1: Buildings and urban networks on the Cité Scientifique Campus serving as the basis for the SunRise smart, sustainable city demonstrator (110 hectares, 140 buildings, 320,000m^2 of constructions, 100km or urban networks and 25,000 users)

2 THE ISSUE OF UNDERGROUND NETWORKS IN LILLE MÉTROPOLE.

Lille Métropole is a Public Intermunicipal Cooperation Body set up by the law of 31 December 1966 to address the drawbacks resulting from the division of large conurbations into a large number of different municipalities. Lille Métropole encompasses 85 municipalities and over one million inhabitants covering a territory that is both urban and rural, comprising large towns and villages.
Its basic missions, which formerly concerned mainly town planning and public service management, have changed since the law of July 1999 reinforcing the role of intermunicipal authorities.

One of the longstanding missions of Lille Métropole consists in managing and developing over 2,700km of road assets. However, these roads contain a wide variety of utility networks - gas, electricity, water and sewers, etc. – which are essential for modern urban development and life. The concession holders and operators of these different networks must intervene regularly to modernise them, make them safe and develop them to improve service quality for users. However, this requires large-scale operations (cuts) which weaken the component parts of the pavement surface and shorten their life, in particular as state-of-the-art practice is not always applied when filling in the cuts, by ignorance or for economic reasons.

Most of the studies conducted on this subject come from North America. The earliest of them date back almost 20 years. In 2012, for example, Santa Cruz County in California conducted a study to analyse the impact of utility cuts on road rehabilitation (Shahin and Associates Pavement Engineering, 2002). The first part of this study consisted in a bibliographical review. On the basis of visual inspections and non-destructive deflection testing, it was estimated that these cuts reduced lifespan (by a factor of at least 1.64 for the city of Burlington, of between 1.21 and 1.52 for the different roads studied in Los Angeles, 50% reduction in the level of service in a study conducted in San Francisco, etc.).

The deflection measurements in the different studies indicate that the presence of a cut reduces the structural performances of the pavement. This performance can then be converted into a pavement thickness using pavement design software: in this way, the presence of a cut is shown to be equivalent to the loss of several centimetres of thickness of the structure. Nevertheless, this method of inverse calculation incorporating the design deflection is theoretical and does not take into account the immediate compactness defects or quality material leading to compaction or rutting : we therefore should not conclude from North America studies that adding few inches to structural layers of the trench, or even a bit more if the execution is incorrect is sufficient to compensate for a loss of structural quality by 50%.

However, this can be used by the network manager to estimate the loss in asset value on its network. On the scale of the cities that have studied these phenomena, the costs amount to several million or even tens of millions of euros a year.

For the road assets of Lille Métropole, where some 12,000 to 15,000 cuts are made on average each year, the annual impact amounts to several tens of thousands of euros in asset losses. It is therefore particularly important to quantify the value of this loss accurately and draw all the consequences for the operations carried out by concession holders in public spaces.

3 ROADS/NETWORKS DEMONSTRATOR DEVELOPMENT

As part of the Sunrise project, the idea of a roads/networks demonstrator emerged with the aim of carrying on the work conducted in North America, with the benefit of certain technologies which are now mature (sensors, transmissions, etc.), to conduct a scientific analysis of the structural and functional impact of cuts on a pavement and convert their mechanical consequences into economic terms.

As an infrastructure manager, Lille Métropole decided to start a project to assess the recommendations made to concession holders, in particular in its General Road Regulations, and to modify these rules if appropriate. It should be remembered that this document is referred to in the French Roadway Code and is the local regulation established by a local authority and defining the terms of any operations by third parties on its roads.

3.1 Objectives

The objective of the demonstrator is to quantify the change in the structural characteristics of a pavement after cutting a trench, meaning to characterise:

a. the mechanical properties of the pavement and the cut by installing an adequate measuring system
b. the zone of impact and influence of the cut
c. any loss of the structural capacities of the pavement, expressed as a structural equivalent (equivalent layer of material)
d. the impact on the residual life of the pavement (via design methods)
e. methods for restoring the structural properties of the pavement
f. the cost of restoring the structural properties of the pavement

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The study will also serve to assess the recommendations made on cut filling in several guides dating back to before 2000, at least to put into perspective the results with these recommendations.. The aim will be to question the minimum period of time defined in these guides before any cuts are made in a new pavement.

3.2 Methodology

The methodology applies the concepts of the Smart City and the 5th generation road. The idea is to take account of investment and sustainable development in transport and energy infrastructures, based on the principle of careful management of natural resources and efficient, integrated use of new information and communication technologies.

The first sets of pavement instrumentation have been installed. Among others, mention can be made of

Lille Métropole

- an experimental section on the A75 motorway for studying hydric, thermal and mechanical phenomena on a motorway network, with the objective of providing a better evaluation of the impact of climate conditions on road pavements, in particular that of the freeze-thaw cycles that are particularly aggressive for infrastructures.
- - The crossing of BUC (Yvelines) achieved in 2010, with a view to self-diagnosis of the road by measuring
- o Internal pavement temperatures
- o traffic related aggression (VL / PL , axle load)
- o deformations
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The first stage consisted in choosing an experimental site. Avenue Henri Poincaré, in Villeneuve d'Ascq, seemed to be a particularly suitable site for the experiment:

- The pavement was initially in very poor condition and a reconstruction operation was therefore required
- Although overall traffic volume is that of an inter-district road (less than 5,000 vehicles/day), the traffic is relatively aggressive (over 300 heavy vehicles per day, on account of a very large number of bus routes along this road), corresponding to a t3+ traffic class.
- It is a section of less than 50 metres in a straight line with a pavement width of 3m, channelling vehicles down a relatively narrow course
- The site is located near Lille 1 University

The experiment consisted in:

- Reconstructing the whole of the pavement, representing about 150m², applying the usual design rules used by Lille Métropole (adapted from national road design recommendations) for this class of traffic (Lille Métropole, 2000) and represented below in Figure 1: Pavement structureFigure 1
    a. 75cm of 0/31.5 unbound gravel (see product technical specification sheet – annexe 1), classe D21, which means a insensitive to water and non clayey soil
    b. 2 x 10cm of class II 0/14 high-modulus asphalt (see product technical specification sheet – annexe 2), 0/14 mixture of limestone aggregates and bitumen 15/25 class (hard bitumen) constituting the base and binder course of the road. (see product datasheet - Appendix 2) This type of structure is adapted to the aggressiveness of the traffic (number of trucks) measured on this route

    c. 6cm of class III 0/10 AC – semi-coarse bituminous concrete (see product technical specification sheet – annexe 3) consisting in a 0/10 mixture porphyry aggregates and bitumen class III (35/50) (see product data sheet - Annex 3). in accordance with the traffic class of the considered road

The implementation was carried out with the following tools and materials :

EARTHWORK	Cold Milling Machine ,mechanical shovel , 15 T
Backfill	Mechanical shovel, road roller PV3
Sub – Base	Mechanical shovel, road roller Mixte CB525 (VX2P1) et 1 PV3
Base	Mechanical shovel, trembling tandem VT2, et 1 PV3
Binder course	Finisher, trembling tandem VT2, et 1 PV3
Surface course	Finisher, trembling tandem VT2, et 1 PV3

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d.

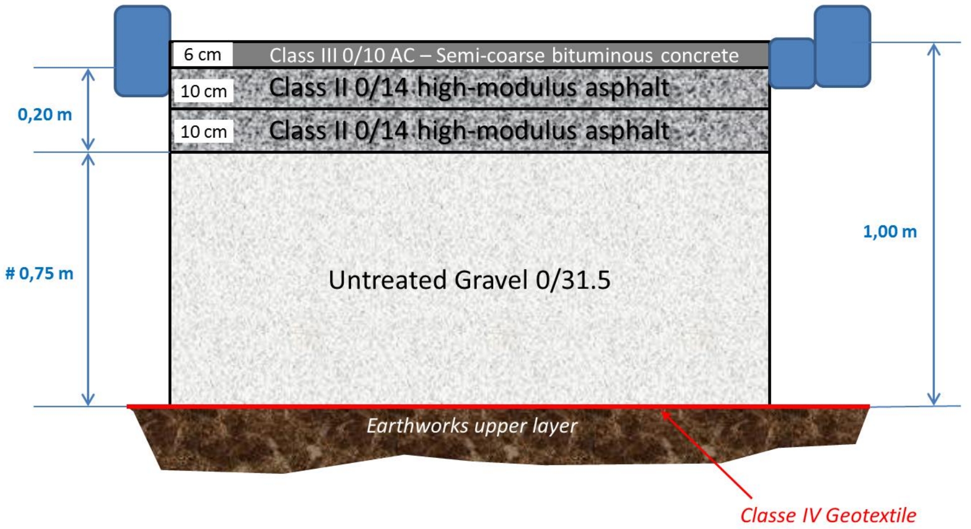


Figure 1: Pavement structure

- Installing the pavement sensors according to the plan below, as the pavement is being built (see Table 1)
- Digging and filling in a cut in this pavement applying state-of-the-art practices (SETRA, 2001) and according to the cross-section illustrated in Figure 2

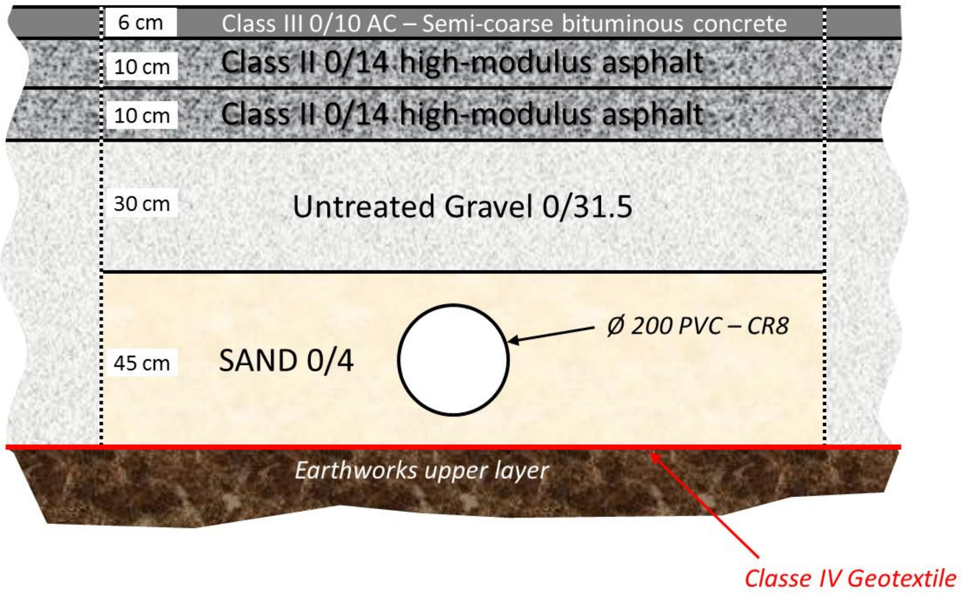
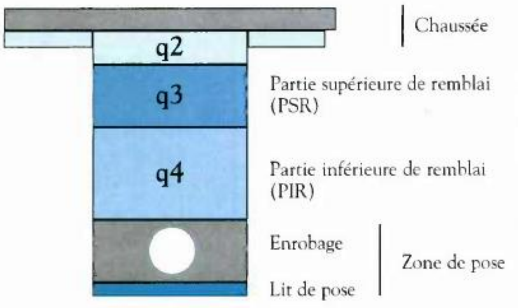


Figure 2: cut structure

The bottom of the trench was compacted by mechanical to ensure its stability and flatness. The pipe was subsequently surrounded with sand (0/4) to a height of 45 cm

Then the different layers were implemented in accordance with the state of the art for compaction material (thickness and homogeneity, linear flow , number of passes and speed, depending on the material and the compactor) , to achieve the density targets defined by a minimum value of average density , and a minimum value of density layer depth to be achieved for each layer (cf above)

q2 1)	pdm ≥ 97 % pdOPM pdfc ≥ 95 % pdOPM
q3	pdm ≥ 98,5 % pdOPN pdfc ≥ 96 % pdOPN
q4	pdm ≥ 95 % pdOPN pdfc ≥ 92 % pdOPN



- Unbounded gravel 0/31.5 (top backfill), class D21 soil

- 2 x 10cm of class II 0/14 high-modulus asphalt, 0/14 mixture of limestone aggregates and bitumen 15/25 class (hard bitumen), in accordance with the base and binder course of the initial pavement

- Surface course in BBSG 0/10 sur 6 cm,

  All materials were set with the following tools :

EARTHWORK	Cold Milling Machine , Mechanical shovel, 15 T
PIPE D 200 CR8	Mechanical shovel, pilonneuse Pn3
SURROUND TO PIPE	Mechanical shovel, pilonneuse Pn3
Top backfill	Mechanical shovel, pilonneuse Pn3, Plaque compactorPQ4
Base	Mechanical shovel, Plaque compactorPQ4
Binder course	Mechanical shovel, Plaque compactorPQ4
Surface course	Mechanical shovel, Plaque compactorPQ4 et 1 PV3

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- Installing the sensors in the cut as it is being filled in and as the pavement is being constructed (see Table 1)

- Installing a data collection and transmission system. Sensors measure physical parameters continuously but data recording is triggered on event corresponding to the passage of heavy vehicles of more than 3.5 kN. The data are then transmitted by connecting GSM / 3G on a hosted server in the Eurovia research center

All the work was carried out in August 2014 by Eurovia. Different inspections and tests were conducted to check that state-of-the-art practice was applied when constructing the pavement and filling the cuts.

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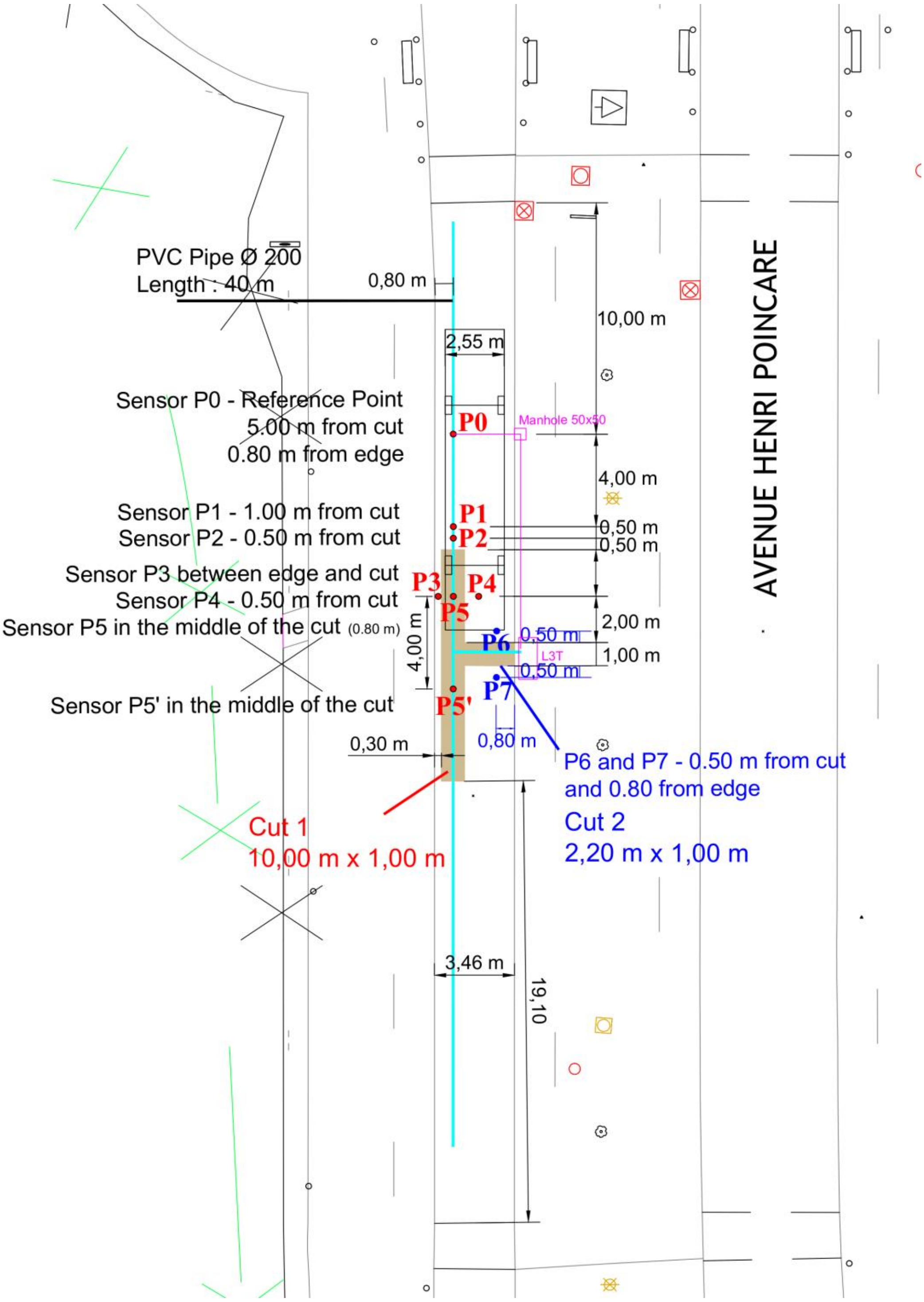


Figure 3: instrumentation diagram

Temperatire	Humidity	Longitudinal distortion	transverse distortion	pressure	Subsidence meter	strain gauges	Fibre Optique

T22							
T15	H13	D13 D14	D15 D16				
T8	H4			P4			

T23							
T16	H14	D17 D18	D19 D20				
T9	H5			P5			

T28							
T27							
	H20	D29 D30	D31 D32				F2
	H19						
	H18						
T2	H17			P8			

	Temperatire	Humidity	Longitudinal distortion	transverse distortion	pressure	Subsidence meter	strain gauges	Optical fiber

Surface								
- 6 cm								
- 16 cm	T22							
- 26 cm	T15	H13	D13 D14	D15 D16				
- 46 cm								
- 66 cm								
- 86 cm	T8	H4			P4			

Surface								
- 6 cm								
- 16 cm	T23							
- 26 cm	T16	H14	D17 D18	D19 D20				
- 66 cm								
- 46 cm								
- 86 cm	T9	H5			P5			

Surface								
- 6 cm	T28							
- 16 cm	T27							
- 26 cm		H20	D29 D30	D31 D32				F2
- 50 cm		H19						
- 75 cm		H18						
- 100 cm	T2	H17			P8			

	Température	Humidité	Déformation Longitudinale	Déformation Transversale	Pression	Tassomètre	Fissuromètre	Fibre Optique

P 5'

Surface								
- 6 cm								
- 16 cm								
- 26 cm						-		
- 50 cm						-		
- 75 cm	T4				P10	-		
- 100 cm	T3				P9	-		

P 6

Surface								
- 6 cm								
- 16 cm	T24							
- 26 cm	T17	H15	D21 D22	D23 D24				
- 46 cm								
- 66 cm								
- 86 cm	T10	H6			P6			

P 7

Surface								
- 6 cm								
- 16 cm	T25							
- 26 cm	T18	H16	D25 D26	D27 D28				
- 46 cm								
- 66 cm								
- 86 cm	T1	H7			P7			

Table 1: pavement and cut sensor layout tables

3.3 First Results

The sensor survival rate was remarkable. Over 80% of them work and are providing coherent measurements.

As an illustration, the image 1 provides the measurements recorded by the three distortion sensors (D1, D10, D29) located at the measuring points respectively P0, P2, P5, located respectively 5 m, 0.5 the trench and on the trench to P5).

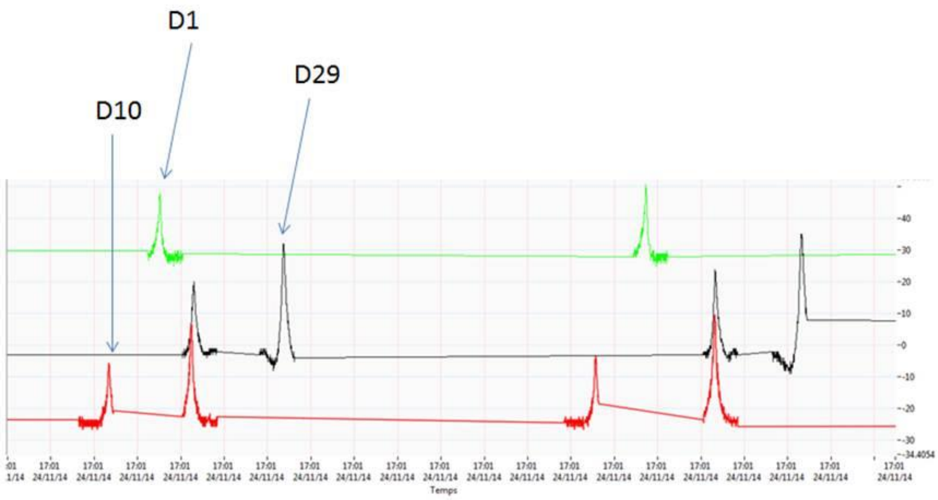
The image illustrates the passage of two heavy vehicles on the road, from P0 to P2 and P5. These vehicles have, each two axles. The first axle is nevertheless always too light to trigger a recording at point P0, which explains the presence of a single signal to P0 (rear axle).

Looking at the signing of the rear axles (second signals at each pass), we can see that they are of increasing amplitude, P0, P2 and P5. While it is too early to conclude that any effect of the trench on the structural characteristics of the road, however, this record suggests that

- -The deformation is more important at the trench that in the pavement

  - In the pavement , the deformations are more important near the trench

and thus seems in accordance with the observations of American studies.



The measurement protocol covers a period of about 2 years (measuring the behaviour of the pavement and cut over two winters) and the conclusions will not be final until the end of that period, The study will consist of an analysis of the different measurement points, their evolution and their behavior under various loads. The results provided by the sensors are then re-injected into the structural design of pavements models to estimate the impact in terms of strength and durability. The study design is given above for information

- Characterisation of theoretical state
  - Pavement (P0 to P7 except P5 and P5')
    - Theoretical materials
    - Theoretical geometry
    - Theoretical modelling / behaviour
  - Cut (P5 and P5')
    - Theoretical materials
    - Theoretical geometry
    - Theoretical modelling / behaviour
  - Theoretical comparison between the pavement and cut

- Characterisation of actual state
  - Pavement
    - Actual materials : properties of gravel, asphalt, compaction ratio, etc.
    - Actual geometry (see As-Built File): actual thicknesses, etc.
    - Actual modelling / design
  - Cut
    - Actual materials
    - Actual geometry (see As-Built File)
    - Actual modelling / design
  - Actual comparison between pavement and cut (at different points if possible or overall otherwise)

- Measured state
  - Pavement
    - Analysis of the initial sensor measurement values
    - Modelling / measurements
  - Cut
    - Analysis of the initial sensor measurement values
    - Modelling / measurements
  - Comparison between different points

4 CONCLUSION

The first results are encouraging, and even if they do not allow to draw conclusions yet, at least they show the methodology used seems adequate.

With this demonstrator, the partners hope to:

- Estimate the loss of heritage value due to the trenches
- Analyze the design rules of urban roads and rules for repairing trench
- make an assessment of the instrumentation protocol, never implemented in urban areas.

Depending on the richness of the results provided by the demonstrator and on the gaps that may exist at the end of this research protocol, it will be to imagine other devices to deepen some issues left unresolved.

5 REFERENCE DOCUMENTS

Lille Métropole. (2000). *Catalogue des structures.*

SETRA. (2001). *Etude et réalisation des tranchées - Guide technique.*

Shahin and Associates Pavement Engineering. (2002). *Analysis of the impact of utility cuts on rehabilitation costs in Santa Cruz County, CA.*

Annexes

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