Precipitation and road surface information. Is it possible to make a road weather climatology with RWISS data ? A prospective study.

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ABSTRACT

Since a lot of Road Weather Information Systems (RWIS) are installed on the road network for winter maintenance, a lot of informations on temperatures, precipitations and state of surface of the pavement are available. A capitalisation and a centralisation of these data could give informations on pavement solicitations and it could be possible to make a road weather climatology. As a prospective study, the data of about 12 RWIS were studied for one year. After a presentation of the results of the statistical analysis, the limits of such an approach are presented. There is first a discussion on the reliability of the informations given by the RWIS (concerning the storage of data, the importance of the software, the sensors performances), and then a discussion on the extrapolation of the sensor measurements to the pavement. Before combining large amount of data, there is a need of more reliability and standardisation of RWIS data.

INTRODUCTION

Nowadays lots of Road Weather Information Systems (RWIS) are installed on the road network for winter maintenance. These stations collect information on temperatures, precipitations and on the state of surface of the road (dry, moist, wet). From these data, it could be possible to establish a road weather climatology and then to complete the data supplied by meteorological offices (nature, intensity and duration of the precipitation…) which gives no information on the duration of moistness of the road and thus its capacities of adhesion for example.

A capitalisation and a centralisation of the data of the RWIS could give informations on pavement solicitation due to the meteorological factors of exposure (range of daily surface temperature, duration of moistness) that could interest the manufacturers of the civil engineering, the developers of the road and the manufacturers of tyres (pneumatics) …

Then, it would be possible to classify the hardness of a winter due to pavement solicitation and perhaps to explain frost damage. Since RWIS measure time of precipitation and state of the road, a relation between precipitation and moistening of the road could perhaps be found. Different factors could be studied like the effect of solar exposition, altitude and type of pavement.

As a prospective study, the data of about 12 meteorological stations were analysed for one year. Two trademarks of stations were studied. First, we will present some of the available data and the analysis made. Since a critical analysis of the data given by the stations has point out some problems, the second part on this paper will discuss on the limit of such a statistical approach. We will discuss on the reliability of the informations given first, and then on the extrapolation of the sensor measurements to the pavement.

PART 1 : TREATMENT OF 12 METEOROLOGICAL STATIONS FOR ONE YEAR

All these stations are installed on French motorway or national roads. The methodology and some of the results will be presented here to have a general overview of the analysis made[1,2].

1 <u>Methodology</u>

1.1 General information on the 5 stations used

	Localisation	Trade mark of the sensor	Solar exposition	Type of Pavement	Altitude (m)
S01	RN420, PR52,450	Lufft	Sunny	Porous asphalt	
S02	RN52, PR20,000	Boshung	Sunny	Old Very thin asphalt surfacing	391
S03	A72, PR11,950	Boshung	Sunny	Semicoarse asphalt on a bridge	330
S04	A72, PR63,550	Boshung	Shaded	Very thin asphalt surfacing	700
S05	A72, PR72,600	Boshung	Sunny	Very thin asphalt surfacing	550

Table 1 : Localisation and characteristics of the RWIS stations.

All the Boshung stations have a BOSO and an ARCTIS sensor.
The Lufft station has a Opus II GMA sensor.

1.2 Available data

All the RWIS studied give at least the following information

- Precipitation with an IR sensor or a pluviometer
- Air temperature (Ta), Surface temperature (Ts), Dewpoint temperature (Td)
- State of the road (dry, moist, wet and runoff or for other sensors 3 different wet states)

Depending of the trademark of the station there is a stocked measure of all the parameters every 10 or 20 minutes.

There is no information on the traffic, neither on the operational treatments. All the analysis are made with the RWIS data.

1.3 Analysis made

For each month the percentage of available data is computed.

A graphical presentation of Ta, Ts, presence/absence of precipitation and state of the road is made (see Figure 2).

To compare the stations, different calculations are made :

- mean, maximum and minimum of Ta and Ts, range of daily surface temperature (max-min)
- duration of precipitations and percentage of the different state of the road.
- A mensual moist index I_M is calculated with the following formula :

$$I_M = \frac{\sum_{duration} State(moist + wet + runoff)}{\sum_{duration} precipitations(rain + snow)}$$

2. <u>Results</u>

Only some of the results are presented here to illustrate the use of RWIS information[1,2]. Of course, well known and logical phenomenons were confirmed.

2.1 Surface temperature

In summer the pavement is hotter than the air and the range of daily surface temperature of the pavement can be above 35°C.

In winter the daily fluctuation of Ts is between 5 and 20°C (see Figure 1).

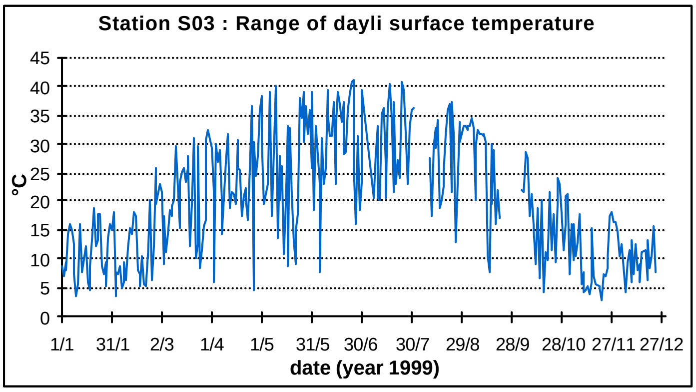

Figure 1 : Range of daily surface temperature (max-min) in 1999 for the station S03

2.2 Descriptive analysis of temperature, precipitations and state of the road

A graphical representation combining air, surface and dewpoint temperature with the detection of precipitation and state of the road is interesting (see Figure 2) and is important for the understanding and interpretation of statistics since we have no information of traffic neither on operational treatments.

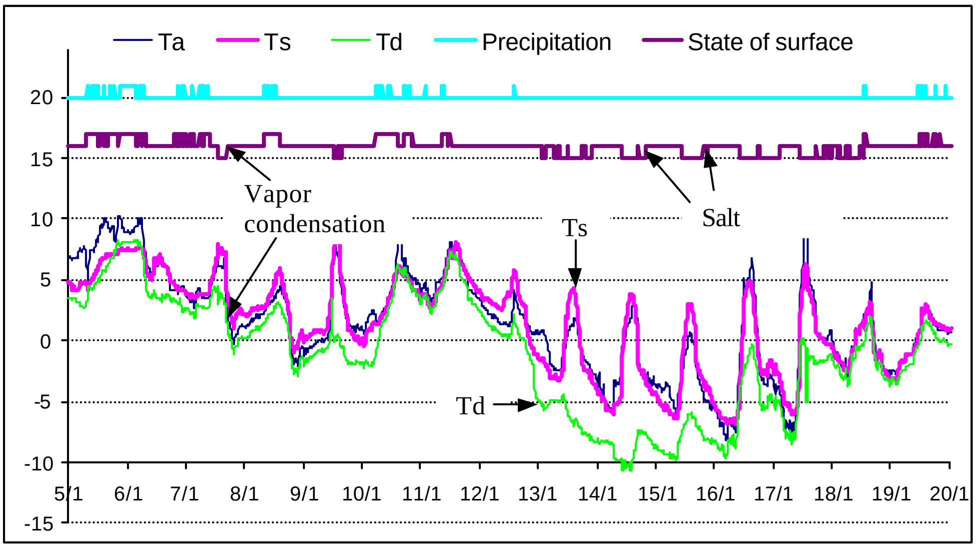

Figure 2 : Graphical representation of the RWIS measurements made on January 2001 for station S02.

- **Air (Ta), surface (Ts) and dewpoint (Td) temperature in °C.**
- **Precipitations (20: no precipitations, 21: presence of precipitations)**
- **State of the road (15 : dry, 16 : moist, 17 : wet, 18: very wet)**

For example, different phenomenons explain the moist states of surface observed on the station S02 during January 2001.

- On the afternoon of the 7th January, there are no precipitations but air, surface and dewpoint temperature are very close. So the moisture on the road is due to vapour condensation.
- Between the 13th and the 16th for example, there is no precipitation and the dewpoint is under the air and surface temperature. The observed moisture on the road is not due to a vapour condensation but probably the consequence of salting.

This example clearly shows the contribution of salt on the pavement moisture in winter. This moisture can be a consequence of spreading brine, wet salt or of the hygroscopic property of rock salt.

2.3 Statistical analysis of precipitations and state of the road

Monthly statistics show that duration of precipitation is short compared to the duration of moisture and wet pavement. However, the duration of detection of a very wet pavement is scarce (see table 2). A seasonal study shows that in the winter season (typically from October to March) there can more than 50% of the time a moist pavement (due to humidity and use of salt). The "wet index" is a good indicator of seasonal variation.

		jan-feb-march	apr-may-june	july-aug-sept	oct-nov-dec
Percentage of Data (%)		96,4	78,4	75,4	99,7
Precipitations (%)	None	92,4	90,3	95,6	85,5
	Rain	7,0	9,7	4,4	13,7
	Snow	0,6	0,0	0,0	0,8
State of the road (%)	Dry	40,0	79,7	91,5	52,2
	Moist	52,4	11,9	4,9	33,4
	Wet	6,4	7,1	3,1	12,5
	Runoff	1,2	1,4	0,4	1,8
Wet index		7,8	2,1	1,9	3,3

Table 2 : Seasonal analysis of the station S02 for the year 1997

The utilisation of this index enables the comparison of different stations.
There is less seasonal variation of the wet index for a shaded road (see Figure 3).

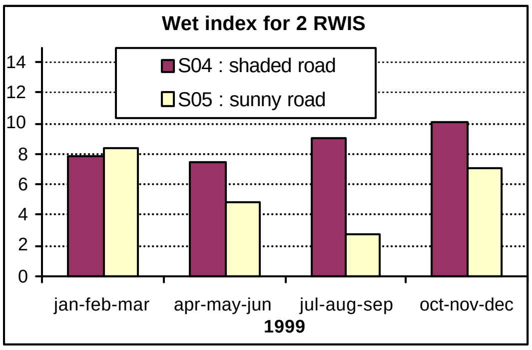

Figure 3 : Seasonal calculation of the wet index for two RWIS placed in very thin asphalt surfacing concrete

The effect of the nature of pavement was not studied because there were two many factors of influence (exposition, altitude…).

3. <u>Conclusion on the results</u>

These graphical and statistical analysis of RWIS data are interesting and give different informations.
For example it points out that the intensive use of salt in winter decreases the road temperature, produces moister on the road so the skid resistance decreases. On the other hand, frost must be avoided. So considering the security aspects, it is important to use salt only when necessary.
The seasonal analysis shows the well-known importance of sun.
With the analysis of more stations and more years of data, it could perhaps be possible to make statistics, compare pavements and perhaps to establish a road weather meteorology.
But a closer look on the data and a critical analysis have shown different problems that will be presented in the second part of this paper. Problems on the reliability of the informations given by the sensors first, and then problems for the extrapolation of the sensor measurements to the pavement.

PART 2 : CRITICAL ANALYSIS

1. Reliability of the information given by the sensors

In a first statistical approach, the technical aspects of the RWIS were not taken into account, the system was a sort of black box giving information. However, before combining large amount of data, it is important to have a critical analysis. This analysis was made by looking on the tables of available data. The following problems were seen.

1.1 Shortage of data

For some stations, a lot of data are missing (sometimes more than 50% for a month). Several reasons can explain this shortage of data :

- There can be technical failure due to the RWIS sensors themselves or due to problems in the data transmission.
- There is not always a close following of the data by the operational services (especially in summer) and the maintenance intervention are not always made immediately (after a storm for example). Moreover for economical reasons, some stations are completely stopped in summer.

1.2 Problem of a discontinuous storage of data.

The storage of the RWIS information is made every 10 or 20min depending of the trademark.
It is important to understand the nature of the stored data because if a measure is made every 2 min for example, there will be a loss of data while storing it every 20 min.
For continuous data like temperature measurement and humidity, the stored data is the instantaneous measurement. But for other data like precipitations and states of surface it is more problematic.
When a data is stored every 20 min., it is sometimes difficult to interpret afterwards what happened. For example, for some of the stations, a lot of detection of wet and very wet state occurred in summer without precipitation. Was it a problem of sensors or the consequence of the discontinuous storage of data ?
A short event like 5 min of rain between 2 storages will not appear in the saved data. On the other hand, if there is 5 min of rain corresponding to the storage time it will appear like 20 min. of rain.
When these phenomenon appear regularly it introduces a bias in the statistics.

1.3 Growing importance of the software

For temperature measurements and precipitations, there were no software problems. But for the analysis of the state of the road different technologies are used and the importance of the software is high.

- Problem of the combination of information of different sofwares and trademarks

For some stations, the state of the road is already computed and the sensor information is not given. For Boshung, there is 3 or 4 states depending of the type of RWIS (0:dry, 1:moisty, 2:wet and 3:runoff or 0:dry, 1:moisty, 2:wet1, 3:wet2 and 4:wet3). For Lufft, the sensor measurements are stored and the user can indicate in the software the thresholds of the different states. Both methods have advantages and drawbacks.
For some stations, the state of surface goes to wet only when the precipitation sensor is active and goes back automatically to moist when the precipitation captor is inactive. However in reality the road can still be wet 30 min. after the rain and the road is not always wet immediately after the beginning of the rain. This forcing of wet and moist state behaviour,

due to software, has a logical sense, is not very problematic for winter maintenance use but it can introduce a bias for statistical analysis.

For Lufft system, the user can choose the thresholds between the different state of the road. With this methodology, it is possible to take into account environmental data like the grading of the surrounding pavement, the purity of the raining water… However the winter maintenance service have no time neither knowledge to choose such thresholds. Moreover, the statistical analysis is completely dependent of the chosen thresholds.

- Conclusion

Software interaction and different technical choice are very problematic for statistical analysis because in the same road network, there can be different trademarks of RWIS with different sensors, technique and software. Different upgrades of the software can coexist and since the updates of the software have a cost, they are not always done. Then, the statistics are not always made on the same information.

1.4 Testing of the RWIS

All these remarks show the importance of having information of what is measured and also on the necessary reproducibility and reliability of the measurements. The RWIS sensors of 3 trademarks were tested on their detection of moist and wet state(3).

- Methodology

The water depth necessary for a change of surface state was measured in laboratory conditions with two methods. A controlled quantity of water was spread on the road sensors of the 3 different trademarks until the detection of a different state of surface.

For the moist state since there is always droplet of water, the equivalent water depth was calculated with measuring the weight of absorbing paper.

For the wet states an apparatus called "limnimètre" developed by the LCPC was used(4). This apparatus is composed of 2 parallel conducting electrode that have a vertical motion. The height of the electrical contact corresponds to the height of water.

- Results

All the sensor tested detect the moist state for a height of water between 0,04 and 0,11 and the repeatability was quite good.

For the wet state the results were not so good. For one sensor the limit between moist and wet state is 0,5mm, for another, the sensor needs the activation of the precipitation sensor to detect the wet state and for the last one the wet state was detected but there was no repeatability of the threshold.

- Conclusion

The reliability of sensor is important because more and more operational service rely on RWIS information for their decision of winter maintenance. In France all trademarks of RWIS are tested in laboratory on an independent service to deliver an official approval(5). There are 4 levels of classification of the RWIS performance.

2. Reliability of the extrapolation of the measurement of the RWIS for the pavement .

All the measurements of the RWIS are made on sensors with different physical propriety compared to the pavement. The extension of the measurement to its surrounding is questionable since the introduction of a sensor has an influence. So the introduction of the sensor must follow some rules.

2.1 Position of the sensor

The detection of the state of surface depends on the height of water on the sensor. Since the pavement have roughness macrotexture, the sensor must have a correct position (see Figure 4) to avoid for example water accumulation on the sensor that would not be representative of the surrounding pavement.

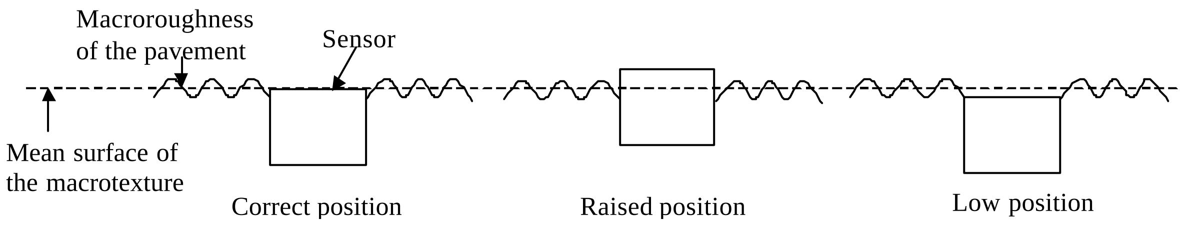

Figure 4 : Positioning of a sensor in the pavement

For the same reasons, the sensor must have the same slope as the surrounding pavement.
Even if traffic has a homogenous effect for the pavement state, the position of the sensor must be correct.
The position of all the sensors tested in this study was checked and was always correct[1,2].

2.2 Influence of the type of pavement surrounding the sensor

The representativity of the measurement of the RWIS for the surrounding pavement depends on the pavement structure and on his macroroughness.

- Influence of the macroroughness

The detection of different wet states depends on the height of water on the sensor. But the height of water on the pavement surrounding the sensor can be different. For example an old semicoarse asphalt has a little macroroughness with an equivalent sensor measured texture depth (measured by sand patch test) of 0,7mm. Another pavement with surface dressing can have equivalent texture depth by sand patch test up to 3mm.
And even if some RWIS trademark are able to choose the detection threshold depending of the surrounding pavement, the macroroughness is always changing with time (deposit of dust…). In the case of porous asphalt it is even more problematic.

- Influence of surface propriety

There is also a bias on the measured surface temperature due to the different physical propriety of the sensor and of the pavement. It is the case for example for radiative propriety (difference of emissivity) …

CONCLUSION AND DISCUSSION

Is it possible to make a road weather climatology with RWIS data ?

Up to now, it seems to be possible to make a climatology with some of the information of the stations (surface and air temperature…) for example. However it is very important to take into account the localisation of the implantation of the stations (like slope of the road, solar exposition, altitude…). Then the effect of the surrounding pavement could be studied.
But for the moment, the reproducibility and reliability of the information on the state of the road are not good enough to make climatology on those data.

Use of RWIS for winter maintenance

This study is a prospective study for the use of RWIS information for making statistics. This approach has point out several problems on the reliability of some of the RWIS measurements. From the operational point of view, some users of RWIS have noticed that there are important differences between the received information from the RWIS and the pavement state of surface. For example: the RWIS system indicates a dry information when the pavement is wet. So the operational service have to take the RWIS information with cautious and to have a critical analysis of the data. Then it would be important to make independent testing of the RWIS. On the other hand the measurement cannot to be perfect. A good solution would be to have a qualification of the stations with the users. The performances must first correspond to their needs.

Some of those points are also important for COST 344[6] (Improvements to snow and ice control on European road and bridges) and Aurora[7] (International program of collaborative research, development and deployment in the field of road and weather information system (RWIS)). The importance of having RWIS communications standards is one of the Aurora project and another task group works on the adaptation of the RWIS information for users. What is the necessary information and what is really used in the decision process ?

A worldwide enquiry was made on the testing methodologies for pavement sensors[8]. This study has shown that there is nearly no independent testing of the RWIS performances and that current practices rely on "good faith" of vendors. Some of the expert interviewed felt that testing procedures were necessary. The importance of having procedure that enables comparison of different trademark is stressed for quality aspect and also to enable exchanges of data. Moreover, the reliability of the system decreases without standard maintenance and since they are scientific instruments, they need calibration.

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