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PAVEMENT PREDICTION PERFORMANCE MODELS AND RELATION WITH TRAFFIC FATALITIES AND INJURIES

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ABSTRACT

This paper presents some results of a study, which aimed at modelling pavement evolution by different methods. In a first part, a database was constituted with data collected on French roads in the last decades. The database contains skid resistance values (Sideway Force Coefficient measured by SCRIM/Sideway force Coefficient Routine Investigation Machine), macrotexture values (Mean Profile Depth), traffic data, pavement characteristics and age.

In a second part, non-linear regressions were used in view of obtaining some evolution laws.

Then, a short bibliographical study allowed the comparison of the results obtained in this study with other pavement prediction performance models proposed in former European studies.

In a last part, the texture data were compared to accidents data in view of finding a relation between them. The difficulty of safety studies lies in the fact that skid resistance data rarely fit to accident data considering the fact that skid resistance is measured each year, each two years or each three years depending on the survey policy applied by the authorities. The evolution laws were used in view of evaluating the skid resistance and macrotexture when accidents occurred. Thus, threshold values for skid resistance and macrotexture were proposed when risk strongly increased.

RÉSUMÉ

Ce papier présente quelques résultats d'une étude qui a pour objet la modélisation de l'évolution des caractéristiques de surface de différents revêtements routiers. Dans un premier temps, une base de données est constituée à partir de mesures réalisées sur le réseau routier national français au cours des deux dernières décennies. Cette base contient des informations relatives à la technique routière, au trafic, à l'âge et aux caractéristiques de surface (Coefficient de Frottement Transversal mesuré par le SCRIM et Profondeur Moyenne de Profil). Dans un deuxième temps, des lois d'évolutions sont proposées. Elles sont basées sur des méthodes de régression non-linéaire en première approche. Cette analyse statistique permet de déterminer les variables explicatives de l'évolution des caractéristiques de surface comme l'âge ou le trafic. Dans un troisième temps, les lois d'évolution obtenues dans le cadre de cette étude sont analysées et comparées à d'autres lois proposées dans des études antérieures.

Enfin, les accidents s'étant produits sur quelques itinéraires sont corrélés aux niveaux d'adhérence relevés. Une des difficultés vient du fait que les mesures d'adhérence (CFT et PMP) sont ponctuelles (tous les ans, deux ans ou trois ans) et ne correspondent pas toujours au moment où se sont produits les accidents. Les lois d'évolution sont donc utilisées pour évaluer le niveau de coefficient de frottement et de macrotexture au moment de l'accident et corrélés ainsi les données entre elles. Des valeurs seuils affinées au-delà desquelles le risque devient très important sont ainsi proposées par les auteurs.

1. INTRODUCTION

Managing road surfaces is an intricate problem for French administration. A method called IQRN, which will be described in §2.1, is currently applied. The method is based on regular measurement of road characteristics in view of detecting deteriorated sections. Considering the fact that IQRN method is used for decades, French administration collected thousands of data. Thus, a database was constituted with a part of these data to study skid resistance evolution and link with accidents.

In a first part, this article describes the methodology of the study. In a second part, the evolution laws obtained with statistical analysis of the database are presented. A short bibliographical study gives some pavement prediction performance models proposed in former European studies. In a last part, skid resistance and macrotexture data were compared to accidents data in view of finding a relationship between them.

2. METHODOLOGY OF THE STUDY

2.1. Data collection

Skid resistance evolution is studied thanks to a database containing data obtained on French national network on 400 km of roads. The study focussed on road with a traffic greater than 10 000 veh./day like rural roads connecting cities or bypasses. This database contains information concerning the following parameters:

- Skid resistance (Sideway Force Coefficient),
- Macrotexture (Mean Depth Profile),
- Geometrical characteristics (radius of curvature, longitudinal and transversal slopes),
- Traffic,
- Pavement surface type (very thin asphalt, asphalt concrete...),
- Age of the pavement surface,
- Accidents.

The management of French national roads is done with a method called IQRN (quality index of national roads). The national network is divided into three batches all around France. Each year, one batch (i.e. one third of the national roads) is characterised with skid resistance and macrotexture measurements, rut depth, cracks... These data are collected to give a global note, which characterize the state of the road. When sections obtain bad notes, French road managers scheduled works to improve pavement characteristics. The whole data are collected in a national database called VISAGE, checked and rectified if needed.

The SCRIM (Sideway force Coefficient Routine Investigation Machine) provides a Sideway Force Coefficient (SFC) at 60 km/h with a water thickness of 0.5 mm each twenty meters. A smooth standard tyre is used for the tests. SFC is measured in the right wheel path and ranges from 0 to 1. This parameter is used to estimate microtexture. A value of 0 corresponds to smooth pavement (like resin for example) without any microtexture and a value of 1 corresponds to pavements with a very high level of microtexture (surface dressings with special aggregates of calcined bauxite for example). Thus, each part of the national network is surveyed at least every three years. On part of the road with high heavy vehicles traffic, measurements are realized each year considering the fact that this traffic leads to rapid polishing of surface aggregates and rapid loss of skidding resistance.

Thus, only sections where SCRIM measured at least three times the skid resistance without any pavement surface changing were included in the database.

Macrotexture is measured with a profilometer called RUGO (device developed by the French laboratory of roads and bridges) composed of a non-contact sensor, which measure the distance between its datum-line and the pavement surface examined. The device consists essentially of a laser transmitter and of an optical potentiometer: the emitted ray strikes the surface of the ground and reflects itself on the optical potentiometer, fit to deduce the height which separates it from the point of reflection on the pavement surface, under an average angle of observation of 30°. RUGO provides a mean profile depth in millimetres, each twenty meters, following the standard EN ISO 13473-1. RUGO is installed on the SCRIM and makes the measurement in the right wheel path, before the SCRIM test wheel.

Geometrical characteristics are measured with POMMAR device and VANI device, which contained gyroscopic station and lasers. The measurements are realized by driving in the middle of the right lane with a speed ranging from 50 to 90 km/h. The sections of the database were selected when skid resistance data were available. Then, POMMAR characterized the chosen roads by given longitudinal slope, transversal slope and radius of curvature each 2.5 meters.



Figure 1 - SCRIM and RUGO devices



Figure 2 – POMMAR and VANI devices

Traffic is obtained with SIREDO stations. The SIREDO network consists of approximately 3 000 devices SOL2 for traffic data collection, which were installed by the State since the early 1990's on the whole National road and motorway network. Using inductive loops mounted in the pavement and linked to a recorder, the SIREDO stations detect metallic masses running on the road. Thus, the station can deduce the class of vehicles, the speed and the weight. These data are merged to create histograms of traffic. The average daily traffic is calculated each year on the sections.

Lastly, accidents that occurred between 2000 and 2006 on the selected sections are included in the database. These data are obtained by using software called CONCERTO and an extraction of the French national database called BAAC. This database contains a

description done by authorities of each accident that occurred on the national network in France. The BAAC database contains the location of each accident (road, geometrical characteristics,...), weather conditions (wet, snow,...), manoeuvres (turn right,...), vehicles involved and injuries/deaths. Software Concerto allows statistical analysis of the data and provides selected data following criteria chosen by the users.

2.2. Analyses of the database

First of all, the data coming from VISAGE and CONCERTO were verified and relocated. Then, analyses were realized in three steps. In a first step, a global statistical study is done on skid resistance properties. The aim is the determination of evolving laws depending on traffic or age. In a second step, the geometrical characteristics of the roads are added to the statistical analyses. In a third step, the skid resistance evolutions are compared to the accidents occurrence in view of detecting levels that can explain accidents. In parallel, a bibliographical study is done in view of comparing the evolution laws obtained in this study and the evolution laws obtained in the past.

3. EVOLUTION LAWS

3.1. Short bibliographical study

Skid resistance evolution is deeply influenced by the type of pavement surface, traffic and age. Several authors propose relationships between these parameters.

First, the variations of skid resistance can be modelled using linear regressions. For example, Gaspar [3] analysed the skid resistance on Hungarian primary roads between 1991 and 2000. He proposed some linear regressions between microtexture and traffic (resp. age). Nevertheless, only a small part of the results are available. For example, the following laws are provided for asphalt pavement with a traffic lying between 1 501 and 3 000 veh./day:

$$\text{Microtexture} = 0.24 - 0.005 \cdot \text{TRA}$$

$$\text{Microtexture} = 0.22 - 0.004 \cdot \text{AGE}$$

With TRA : mean daily traffic (number of vehicles per day)
AGE: age in year

Then, a more complex approach can be used as in TROWS European project [6]. The idea was to consider that polishing effect is mainly responsible of the skid resistance evolution. Therefore, polishing effect is due to the effect of traffic on texture. The effect of traffic depends on the number of vehicles that drive on the road, but also on the type of tyres and the geometry of the road considering the fact that sharp curves generate constraints on the vehicle (longitudinal and transversal accelerations). Eight itineraries were chosen and characterised in the project. The SFC, MPD, megatexture, IRI, traffic, geometrical characteristics (radius of curvature, longitudinal and transversal slope) and the dynamic constraints due to the infrastructure were measured. Then, a mark of aggressiveness due to the tyre and a mark of aggressiveness due to the infrastructure were allocated to each itinerary. Thus, a global law of variation of SFC using several linear regressions is proposed:

$$100 \cdot \Delta \text{SFC} = -1.28 \cdot \text{N1} - 3.08 \cdot \text{MPD} + 12.63 \cdot \text{SFC} + 1.96$$

with N1: note of aggressiveness due to the tyre
MPD: mean profile depth (in mm)
SFC: initial Sideway Force Coefficient

Moreover, statistical approaches can be applied as in [9]. This study is based on the analyses of 8 860 sections of 200 m long. Each section is characterised by a mean SFC value, the age of the pavement, average daily traffic and the type of road structure. Two families of pavement are taken into account: asphalt concretes and surface dressings. For each section, a NE value is calculated. This NE parameter is the “number of equivalent axles”. It allows transforming traffic values in an equivalent number of axles of 13 tonnes, which is the reference in France. NE depends on traffic, age of pavement surface and type of pavement structure:

$$NE = 365 * TRA * AGE * CAM$$

with TRA : average daily traffic,
 AGE : age of the surface in year,
 CAM : coefficient of aggressiveness depending on the structure of the road.

The following non-linear regressions are obtained (table 1). The multiple regression correlation coefficient, R^2 , is a measure of the proportion of variability explained by, or due to the regression (linear relationship) in a sample of paired data. It is a number between zero and one and a value close to zero suggests a poor model.

We can notice that the linear coefficients of regression (R^2) obtained are rather low. These weak values could be explained by the use of NE, which doesn't seem to be the best parameter to model the SFC decrease.

Table 1 - Evolution law depending on the number of equivalent axles

| Pavement surface | SFC | Regression coefficient (R^2) |
|------------------------------|----------------------------|----------------------------------|
| Semi-coarse asphalt concrete | $-2.15 * \ln(NE) + 90.27$ | 0.10 |
| Thin asphalt concrete | $-3.51 * \ln(NE) + 105.08$ | 0.20 |
| Very thin asphalt concrete | $-5.15 * \ln(NE) + 129.99$ | 0.28 |
| Porous asphalt | $-6.41 * \ln(NE) + 145.79$ | 0.26 |
| Surface dressing | $-3.46 * \ln(NE) + 104.69$ | 0.24 |

Lastly, other studies were realized on Great Britain [13] and New Zealand [10]. Several sites were characterised with SFC values or SRT values and global evolution of skid resistance were proposed.

3.2. Non-linear regressions

In a first step, the database was analysed by considering that all the sections of 20 m are equivalent (geometry is not taken into account). Some non-linear regressions are proposed to connect the age of the pavement surface in months and the SFC evolution for each type of pavement surface.

Table 2 - Evolution law depending on age

| Pavement surface | SFC | Regression coefficient (R^2) |
|------------------------------------|-----------------------------------|----------------------------------|
| Thin asphalt concrete | $-7.03 * \ln(\text{age}) + 90.26$ | 0.50 |
| Very thin asphalt concrete | $-2.59 * \ln(\text{age}) + 76.94$ | 0.43 |
| Semi-coarse asphalt concrete | $-4.48 * \ln(\text{age}) + 78.36$ | 0.24 |
| Asphalt concrete with high modulus | $-1.28 * \ln(\text{age}) + 58.66$ | 0.13 |
| Porous asphalt concrete | $-1.61 * \ln(\text{age}) + 68.78$ | 0.09 |

The regression coefficient are rather low for porous asphalt, asphalt with high modulus and semi-coarse asphalt concrete. Nevertheless, these types of pavement are the less numerous in the database. Thin asphalt and very thin asphalt represent more than the two thirds of the data. The regression coefficients obtained with them are better than the other but not very high.

Similar process was used to connect SFC values and the traffic. For each section, the total traffic (TT) is calculated by considering the age of the pavement and the daily traffic:

$$TT = 30 * AGE * TRA$$

with TRA : average daily traffic,
AGE : age of the surface in months.

The results are rather similar to the one obtained with age.

This fact can be explained by the seasonal variations of SFC values, which entail a scattering of the data. A seasonal correction of the data was tried but the results were unconvincing considering the fact that the seasonal variations depend on the type of pavement, the weather, pollution generated by traffic... Thus, the use of an average coefficient of correction was not enough precise for this kind of study. Moreover, using various coefficient of correction was rather difficult because a wide range of measurements on reference surfaces are needed to obtain representative values for the coefficients of correction. That's why this method wasn't used.

Thus, we can conclude that this kind of analyses cannot allow representing reality. Other parameters enter into account to explain SFC age evolution.

3.3. Influence of geometry on skid resistance evolution

In a second step of the study, the effect of geometry was explored. Indeed, SFC evolution is directly linked to the polishing effect on aggregates. Thus, the dynamic constraints applied by the vehicles on pavements are not the same in curves and in straight lines. So, the evolution of SFC is different. The database was divided into two parts: the first one corresponds to straight lines and the second one corresponds to curves.

Straight lines are defined as road section with a radius of curvature superior or equal to 600 m in absolute value. The SFC values were correlated to age (table 3). Whatever the type of surface pavement, the relationships present low regression coefficients, which tend to prove that the optimal parameters of the laws were not found. Similar results were obtained with traffic.

Table 3 - Evolution laws in straight lines depending on age

| Pavement surface | SFC | Regression coefficient (R ²) |
|------------------------------------|---------------------|--|
| All pavements | -0.91*LN(age)+61.21 | 0.02 |
| Semi-coarse asphalt concrete | -5.07*LN(age)+81.23 | 0.31 |
| Asphalt concrete with high modulus | -1.38*LN(age)+58.88 | 0.15 |
| Very thin asphalt concrete | -5.87*LN(age)+84.67 | 0.14 |
| Thin asphalt concrete | -0.42*LN(age)+57.33 | 0.02 |

For curves, the data were merged by considering classes of radius of curvature. Three categories are defined: 0 – 150 m, 150 – 300 m and 300 m – 600 m. The limits of the categories were chosen both to have a representative number of values and take into account European safety studies results [12].

The results showed that it was not possible to connect SFC values from the database and age or traffic (figure 3). This could be explained by the fact that the database is not large enough to hide seasonal effects [4] and the impact of the geometry on the measurements [7].

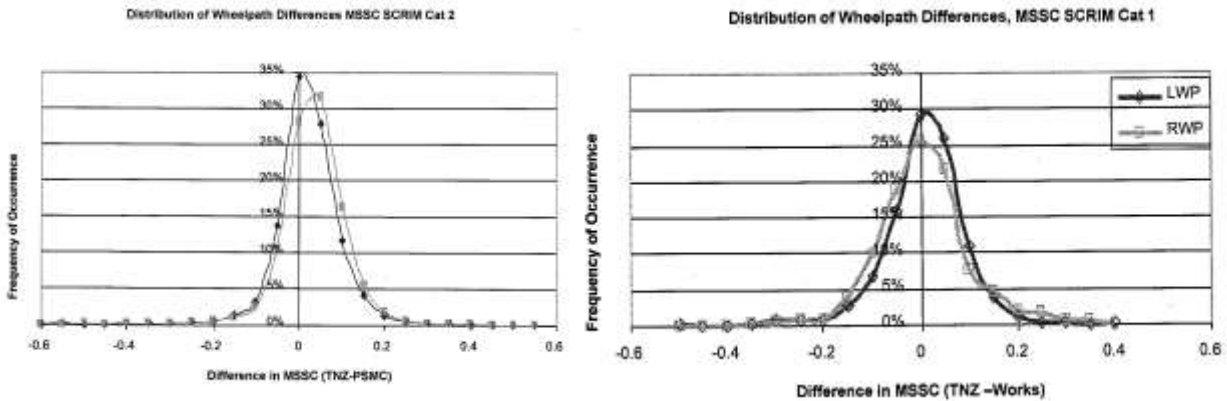


Figure 3 - Frequency of occurrence of the difference in SFC values between two surveys done by SCRIM in 2000 and 2001 in New Zealand [7]

Indeed, the SCRIM measures SFC on the right wheel path. If the curve is very sharp, the SCRIM will have troubles to follow exactly the wheel path because it is a heavy vehicle with large dimensions, which tends to minimize the dynamic effects by choosing a trajectory with the highest radius of curvature as possible. [7] studied the repeatability of SCRIM measurements by comparing two surveys done in New Zealand network (figure 3). He concluded that mean difference and the standard deviation of the difference in runs were 0.04 and 0.05 respectively.

Table 4 - Evolution laws in curves depending on age

| Radius of curvature (m) | SFC | Regression coefficient (R ²) |
|-------------------------|---------------------|--|
| > 600 m | -0.91*LN(age)+61.21 | 0.02 |
| 300 < R < 600 m | -0.35*LN(age)+58.15 | 0.00 |
| 150 < R < 300 m | -1.18*LN(age)+61.77 | 0.03 |
| R < 150 m | 0.21*LN(age)+55.23 | 0.02 |

4. SKID RESISTANCE AND ACCIDENTS

4.1. Definitions

Accidents are the results of infrastructure/vehicle/driver interactions. Safety experts can detect dangerous areas by considering the accidents rate τ_{acc} , which indicates the average number of accidents per year for 10^8 vehicles.km on an itinerary:

$$\tau_{acc} = \frac{n_{acc}}{n_{veh} \Delta t \cdot L} \times 10^8$$

with n_{acc} : number of accidents that occurred on the itinerary in the duration of the study,

n_{veh} : average daily traffic (in veh./day),

L : length of the itinerary (km),

Δt : duration of the study (in days).

This index gives a level of risk to have an accident on an itinerary but it isn't very usable to detect "black spots". In France, the detection of dangerous area is realized by counting the

number of injuries and the number of accidents that occurred in 5 years on a length of 850 meters. If the two values are greater than 10, this area is considered as very dangerous (level 3). If the two values are greater than 7, this area is considered as dangerous (level 2). If the values are greater than 4, this area can be dangerous (level 1). Below these values, the area is not detected as an area with series of accidents.

Among the parameters that enter into account in accidents analyses, skid resistance, traffic and geometry (especially radius of curvature) seem to be the most interesting to study. The results of two studies presenting some connections between accidents and these parameters are given in a first time. In a second time, some results of the analyses of our database are presented.

4.2. Bibliographical study

First of all, a French work was done on three types of roads in the 90's (1985 – 1994). Accidents that occurred on wet surfaces in Rhône-Alpes (French region) were studied. The roads had the following characteristics:

- primary roads with single lane (215 km) with a traffic of 10 000 veh./day,
- primary road with two lanes (35 km) with a traffic of 38 000 veh./day,
- difficult road with two lanes (13 km) with a traffic of 9 000 veh./day.

The SFC values were measured with SCRIM and merged by classes (SFC < 0.40, 0.40 < SFC < 0.50, 0.50 < SFC < 0.60, 0.60 < SFC < 0.70 etc...). The values of radius of curvature measured on the mountain road were merged in classes (50 < R < 150 m, 150 < R < 250 m, 250 < R < 350 m). The accidents data were correlated to SFC and radius values. The study showed that (figure 4):

- accidents rate decreases when SFC values increases,
- a value of SFC around 0.5 seems to be a safety limit,
- accidents rate is sensitive to the radius of curvature,
- a value of 150 m seems to be a safety limits

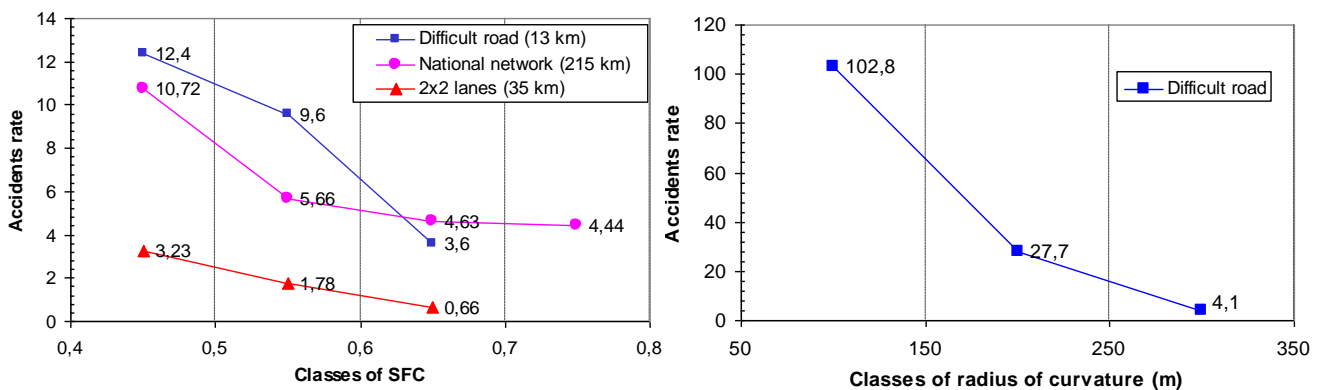


Figure 4 - Accidents rate for 10^8 vehicles.km/year depending on the classes of SFC on some French roads (4a) and depending on the radius of curvature on difficult road (4b) between 1985 and 1994 [4]

Another study focussed on accidents that occurred on New Zealand highways between 1998 and 2002. It led to similar conclusions than the French work by giving a safety limit value of SFC around 0.50. Nevertheless, the effect of radius of curvature is not obvious in this work. This fact can be explained by the typology of road. Indeed, highways generally present few areas with weak radius of curvature. Thus, the number of accidents and their location on sharp curves were low, which can explain the results presented on figure 5b.

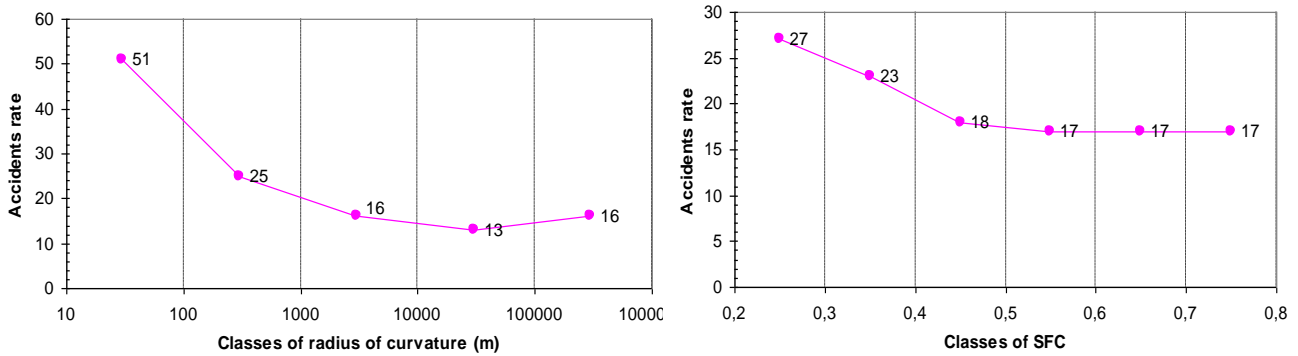


Figure 5- Accidents rate for 10^8 vehicles.km/year depending on the classes of SFC (5a) and the radius of curvature (5b) on New Zealand highways [10]

Lastly, this New Zealand study crossed data and concluded on the fact that accident rate is more dependant on radius and traffic than on skid resistance level.

4.3. Some results

First, accidents analyses were realised on wet surfaces to evaluate the impact of skid resistance. The SFC values are grouped in classes of 0.10 SFC units. The roads considered in the database present accidents rate for 10^8 vehicles.km/year lying between 0.5 and more than 100 with various traffic (10 000 veh./day – 60 000 veh./day) and various geometrical characteristics.

The curves giving the variation of accidents as a function of SFC present a classic shape with a decrease of accidents when SFC values increase. One of the results obtained is given in figure 6a. The accidents rates are rather similar to the values obtained in [4] for the same type of roads and confirm these previous results. However, we can notice that the set of data used in this study is wider and the levels of traffic considered here are 2 or 3 times higher than the other study.

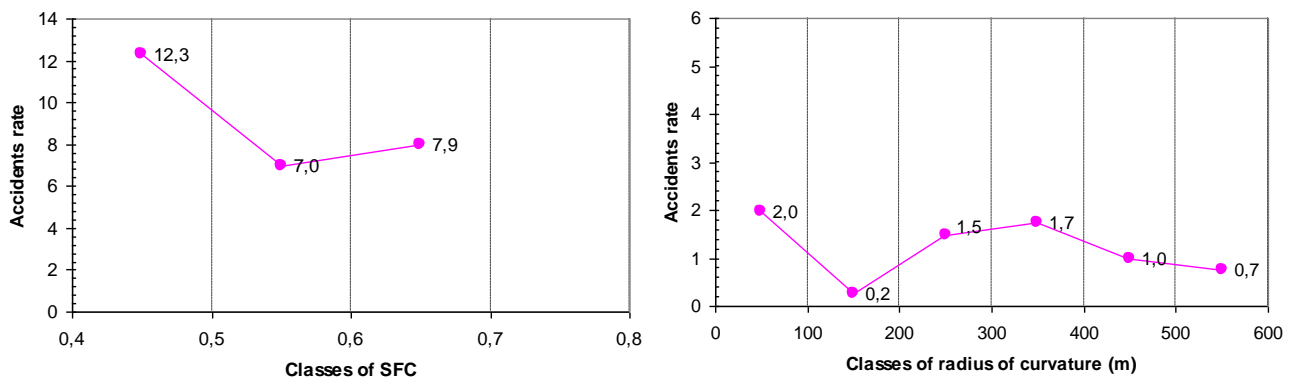


Figure 6 - Accidents rate for 10^8 veh.km/year depending on the classes of SFC (6a) and radius of curvature (6b) on French rural road with an average daily traffic of 37 000 veh.

However, some curves present a different shape, when the evolution of accidents rate depending on radius is considered. On some highways with a high traffic rate of accidents increase with radius of curvature. This can be explained by the fact that drivers take risks in large curves (around 500 m) and have an unsuited speed because they don't feel the danger. Safety experts read policeman reports concerning a part of these accidents and conclude that the behaviour of the driver was responsible for them. Finally, radius of curvature is not the main factor that can explain accidents considering the high level of traffic of these roads.

Moreover, accidents rate is weak for curves with radius ranging from 100 to 200 m. This result is due to the fact that this type of curves is few represented in the database. Only 2% of accidents analysed in the study occurred there.

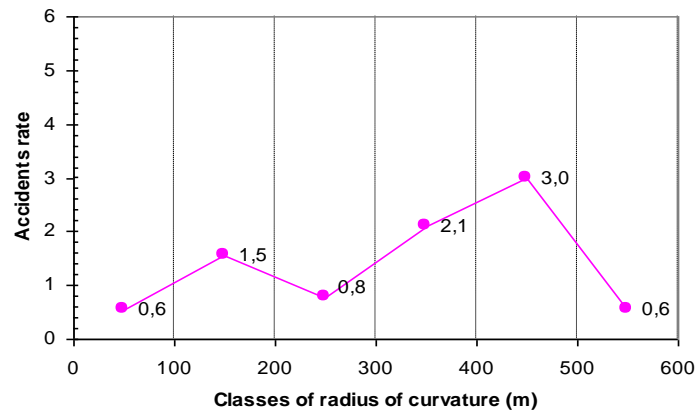


Figure 7 - Accidents rate for 10^8 veh.km/year depending on the classes of the radius of curvature on French urban highways with an average daily traffic of 59 000 vehicles

5. CONCLUDING REMARKS

First, this study showed that the determination of evolution laws is very complex. Proposing direct relationship between SFC and parameters like traffic or age lead to approximate results. The laws that fit to experimental data concern mainly data obtained on very thin asphalt concrete. This is due to the fact that this kind of pavement is the most represented in France. Thus, the set of data is very important to adjust the coefficient of the laws.

Then, the comparison between accident location and skid resistance or radius of curvature allows strengthening the existence of a link between accidents and infrastructure characteristics. Moreover, the curves giving accident rate versus SFC present an inflexion around 0.5, which seems to be a threshold value for road safety. On the contrary, special results when considering accident rate and radius of curvature, don't allow conclusions. On primary roads, accident rate decreases when radius of curvature increases, whereas on some highways the situation is different. This point should be studied thoroughly in the next months.

To conclude, the next steps of the work will be the increase of the set of values by adding data concerning thin asphalt concrete or surface dressing, the use of more complex statistical laws like "survival laws" and the correlation between accidents data and longitudinal/transversal profile. Indeed, this first part showed that a "multi-parameters" approach is needed to improve the reliability of the evolution laws.

REFERENCES

1. Davies, R. Cenek, P. and Henderson, R. (2005). The effect of skid resistance and texture on crash risk. International Surface Friction Conference, Christchurch, New Zealand, 1st – 4th May.
2. Galindo B. (2001). Identifying potentially dangerous driving situations. 2nd International Colloquium one Vehicle Tyre Road Interaction. Friction potential and safety: prediction off handling behaviour, Florence, Italy, February 23rd.

3. Gaspar, L. (2002). Highway pavement performance models. IXth Int. Conf. of Asphalt Pavements. Copenhagen, Denmark, 17-22 august.
4. Gothié, M. (2000). Apport à la sécurité routière des caractéristiques de surface des chaussées. Bulletin de Liaison des Ponts et Chaussées, vol.224, pp.5-12.
5. Gothié, M. (2002). Skid resistance evolution of different wearing course techniques according to traffic. IXth Int. Conf. of Asphalt Pavements. Copenhagen, Denmark, 17-22 August.
6. Gothié, M. et Do, Minh Tan (2003). Méthode d'évaluation du polissage superficiel des routes (TROWS). XXII^{ème} Congrès Mondial de la Route. Durban, Afrique du Sud, 19-25 octobre.
7. Haydon, M. (2005). The management of skid resistance on a state highway network. International Surface Friction Conference, Christchurch, New Zealand, 1st – 4th May.
8. ISO 13473-1 (2002). Characterization of pavement texture by use of a surface profile – Part 1: determination of mean profile depth.
9. Lorino, T. Lepert, P. et Riouall, A. (2006). Application à la campagne IQRN des méthodes statistiques d'analyse de l'évolution des chaussées. Bulletin de Liaison des Ponts et Chaussées. vol.261-262, pp.25-41.
10. Rainsford, S. and Parkman, C. (2005). Predicting texture deficiency in pavement management. International Surface Friction Conference, Christchurch, New Zealand, 1st – 4th May.
11. Roe, P. Webster, D. and West, G. (1991). The relationship between the surface texture of roads and accidents. Transport Research Laboratory, Research report 296.
12. [VERTEC EC-Contract G3RD-2002-00805](#) (2006). [Vehicle road, tyre and electronic control system interaction – prediction and validation of handling behaviour](#). 3rd International Colloquium on Vehicle Tyre Road Interaction, Tyre Technology Conference, Stuttgart, Germany, 8 mars, 200 pages.
13. Viner, H. Sinhal, R. and Parry, A. (2005). Linking road traffic accidents with skid resistance – recent UK developments. International Surface Friction Conference, Christchurch, New Zealand, 1st – 4th May.