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# DEVELOPMENT OF A METHODOLOGY TO FOLLOWEVOLUTION OF TEXTURE UNDER REPETITIVE LOADING

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## ABSTRACT

*A formulation with available constituents that assures durability of macro-texture is necessary to improve the surface properties of an asphalt wearing courses such a skid resistance, drainability and rolling noise. The aim of this work is to develop a methodology to analyse the effect of binder on evolution of surface characteristics on samples in laboratory. We identify available laboratory techniques that would allow road laboratories to measure the impact of gradations and nature of bitumen on the friction properties of the pavement surface. In this work, we try to follow the evolution of macro-texture of a given mixture in laboratory, we develop a methodology, inspired from French design, involves a series of steps: choice of components, optimisation of proportions of ingredients and control of homogeneity by gamma bench test. We finally evaluate macro-texture by using modern electronic technology, specifically laser surface imaging that could be applied in the laboratory. We quantify surface characteristics by using two differing techniques: sand patch test and statistical analysis.*

*The wear test is designed to simulate the wear of extended trafficking using LPC rutting machine applying loads through wheel. The test temperature set to 20°C. Measurements of texture depth, both by the sand patch method and by non-contact laser method, were carried out on the surfacing of slabs inside a well-defined area before and after loading. The repeatability test will be done to check the accuracy of the methodology.*

## RÉSUMÉ

*Afin d'assurer la durabilité de la texture des revêtements routiers sous un trafic canalisé, il est nécessaire d'effectuer au préalable une étude de formulation avec des constituants de qualité et disponible localement afin de garantir les propriétés de surface comme l'adhérence, le drainage de l'eau et le bruit de roulement. Le but de ce travail est de développer une méthodologie d'étude au laboratoire afin d'analyser l'effet du liant sur l'évolution des caractéristiques de surface. Nous avons identifié deux techniques de laboratoire existantes pouvant répondre aux interrogations des laboratoires routiers sur l'effet de la granulométrie et la nature du bitume sur les propriétés de surface. Dans ce travail, on tente de suivre l'évolution de la macrotexture sur une enrobé de surface, on a ainsi développé une méthodologie en s'inspirant de la formulation française : choix des composants, optimisation des proportions des fractions granulaires et contrôle de l'homogénéité au gammadensimètre. Puis,*

*on effectue un relevé 3D à l'aide d'un capteur laser sans contact. On aborde la quantification des caractéristiques de surface en utilisant la hauteur au sable et l'analyse statistique des relevés 3D. Puis on décrit la nature et le niveau des charges répétées simulant le trafic à l'aide de l'ornièreur LPC. La température d'essai étant fixée à 20°C. On abordera ensuite une étude de comparaison des méthodes de calculs ainsi que la répétabilité de cette approche.*

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**Keywords:** Wearing courses, Texture, surface characteristics

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## 1. INTRODUCTION

Given the increasingly varied and demanding requirements of managers and users, there has been in France for more than a decade a substantial diversification of wearing-course asphalt mix techniques, both for new works and for maintenance. In effect, to improve comfort and safety, meet increasingly acute financial constraints, and increase the durability of wearing courses, thereby helping to reduce maintenance sequences, wearing courses are being made thinner and rougher, with better skidding resistance, and faster to apply. In France, the hot bituminous mixtures have been used in very thin layers (designated BBTM) for more than ten years. These surface courses provide a good answer to the user demands and improve the durability of the characteristics.

Over the years the importance of evolution of surface characteristics have been pro-eminent. In the late 1950's to 1960's of greatest importance seems to have been skid resistance: its measurement and its relation to road safety. Into the 1980's and till the present time environmental concerns and durability of surface coarse have become predominant. The problem is to estimate the performances of materials and construction technologies to meet surface requirements.

Field evaluations of surface friction performance take 7 years to accumulate an adequate number of vehicle passes. Are there laboratory techniques to accelerate the surface degradation and measure the friction characteristics?

Texture depth is a measure of the macro-texture surface determined by sand patch test. Generally speaking, all of the very thin wearing courses (designated BBTM in France) having a gap-graded 0/10 formulation have a texture depth greater than 1.0 mm, twice that of conventional thick mixes (designated BBSG in France). A very thin asphalt concrete have a texture depth at commissioning between 1.0 to 1.5. The wearing courses have a texture depth between 0.9 to 1.2 after 2 to 3 years traffic [3].

The mix design is based on empirical approach and it's difficult to predict the macro-texture of bituminous mix. The well know accumulated experience on field don't give good indications. The plant used to produce the mix and the compactor used in situ have a great influence on roughness. The materials used on field are different from the laboratory. In these conditions, the prediction of macro-texture in laboratory is difficult.

Pavement skid resistance changes with time, we observe an effect of traffic and climatic conditions on durability of asphalt wearing courses. The evolution of surface characteristics of wearing courses depends of several factors that it isn't been well investigated like:

Mineralogical nature of aggregates;

- Nature of bitumen;
- Grading curve;
- Level of compaction and possible evolution with traffic;
- Thickness of wearing courses;
- Progression of heavy traffic.

The problem is complex. However, good surface characteristics of asphalt wearing courses and durability of used materials are requirements of managers and users. We must find a methodology in the setting of the laboratory to evaluate the durability of surface characteristics of bituminous mixes. The objective of our research is to identify available laboratory techniques that would allow road laboratories to measure the impact of gradations and nature of bitumen on the friction properties of the pavement surface.

In this work, we propose to find a methodology and the good parameter to follow evolution of macro-texture under repetitive loading in laboratory only. It is necessary that this methodology is sufficiently simple to achieve and to interpret and provide an appreciable indicator change of formulation.

To determine this methodology completely, We pose the problem as follows : we have a given texture imposed by the laboratory conditions. How is the evolution under repetitive loading? Which is the most applicable parameter that will permit us following the evolution of texture?

We try to develop a methodology, inspired from French design, involves a series of steps: choice of components, optimisation of proportions of ingredients and control of homogeneity by gamma bench test. We finally evaluate macro-texture by using modern electronic technology, specifically laser surface imaging that could be applied in the laboratory. We quantify surface characteristics by using two differing techniques: sand patch test and statistical analysis.

The wear test is designed to simulate the wear of extended trafficking using LPC rutting machine applying loads through wheel. The test temperature set to 20°C. Measurements of texture depth, both by the sand patch method and by non-contact laser method, were carried out on the surfacing of slabs inside a well-defined area before and after loading.

## 2. MIX DESIGN

The texture of bituminous mixes depends of arrangement of granular skeleton. The aim of our investigation is to look on intrinsic property (2D or 3D description). For a given level of loading, the evolution of macro-texture will depend of the constituent as the curve grading, nature of bitumen and of the compaction in place.

We have applied our methodology to very thin bituminous mixes with a well-defined grading curve following specification NF P 98-137. This material is made of crushed diorite aggregates from La Noubleau with 5,7 pph (*related to the weight of aggregate*) content of 50/70 pen. grade pure binder. The main characteristics of these materials are reported in the following table:

Material	(%) Passing							Binder type	Binder content (pph)	Void content (%)
	0.08	0.31	1	2	4	6.3	10			
Sieve in mm		5								
BBTM 0/10	8.3	13.2	20.1	28.6	31.3	41.3	95	50/70	5.7	12.5

The plate compactor is a laboratory machine. It's used to prepare homogenous slabs of bituminous mixes. This machine LPC is utilisable to simulate the compaction in situ and find on the sample the same mechanical characteristics as in place. We have adopted a high level of compaction with a large steel-wheel to obtain a good surface shape. The dimensions of slabs used in this work: length equal 500 mm and width equal 180 mm.

The very thin mix is pre-compacting, compacting and surfacing with a thickness of 25 mm. The support is constituted of a high modulus bituminous concrete (EME) (figure2).

We check the homogeneity of a series of slabs by gamma ray bench by measurement of their density by absorption of gamma rays following AFNOR specification NF P 98-138.

Sample	% voids	
	Average	Standard deviation
F203	12.2	2.9
F204	11.5	3.0
F207	12.7	3.2
F208	12.8	2.8

The traffic simulator like pavement-rutting tester LPC is designated to simulate the turning action of heavy traffic and record any changes in the geometrical characteristics of the surfacing. The tests were carried out at ambient temperature (20°C). The carriages simulate the action of a vehicle axle with a pressure of 0.6 MPa. The elliptic pressure applied on slabs is obtained with the following dimensions; 12 cm in longitudinal direction and 8 cm in transversal one.

### 3. EXPERIMENTATION

#### a) Sand patch test

Texture depth determined by sand patch method is the mostly know measure of macro-texture of surface. This method is used in France since 1962 and is operational in most countries to characterise the macro-texture. This test is used on field to give us the state of the macro-texture in real pavement condition with a unit value between 1 and 3 mm, normal on pavements in service.

This method of measure is generally easy to put but it doesn't permit to analyse in a fine enough manner the evolution of a macro-texture and notably movements of aggregates in surface.

The experiment is conducted on four samples made in laboratory in the same conditions show a decrease of texture depth until 5000 cycles and do not varies while increasing the number of cycles.

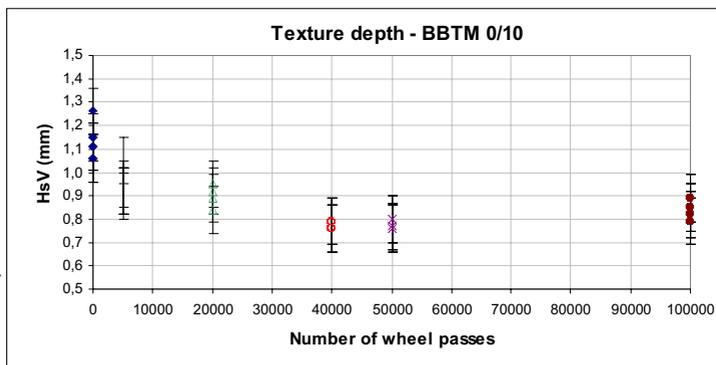
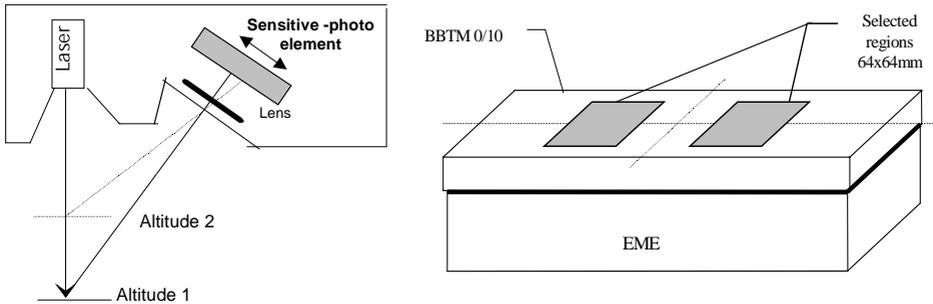


Figure 1 – Evolution of texture under repetitive loading

### b) Non-contact laser

The material used in this work is a profilometer using laser sensor without contact in the material. The test is carried out on the samples on a square of 64 mm of side at initial state and after wheel passes. This region of measure is inside the print of the tire. The laser measures 256 points by 256 points (every 0.25mm) within the selected area.



**Figure 2** – Tridim laser capture and position of area window and bituminous sample

In order to separate roughness and shape of the sample, we applied a preliminary operation on topographic data by calculate the minimum zone. The minimum zone plane has very simple mathematical expression and is recommended in standards [7] and is widely used to assess flatness and form errors of surfaces. We used an algorithm of a linear least squares mean plane to determine the minimum of the sum of the squares of asperity departures  $Z(x_i, y_i)$  from a given plane  $Z = ax + by + c$  is minimum. The coefficients  $a$ ,  $b$  and  $c$  are determined by solving the sum of the squares of the asperity departures from this plane and is given by

$$\psi = \sum [Z(x_i, y_j) - ax_i - by_j - c]^2$$

### c) Statistical characterisation

Analyse des résultats par les critères statistiques

The statistical characterisation of surface topography has been widely used both in academia and industry. Since statistics is the best tool for processing random data, it is seen as a natural and meaningful method of analysis for surfaces especially in terms of the increased reliability of the analysis. In this work, we are mainly concerned with one aspect of characterisation i.e. statistical distribution.

Topographic height, slope or curvature are frequently modelled by the probability density function denoted by  $p(k)$  ( $k$  is an integer) for discrete distributions. Generally the probability density function is described from four aspects, i.e. central tendency, dispersion, asymmetry and peakedness. As for topography characterisation, the central tendency is often neglected while attention is concentrated on dispersion, asymmetry and peakedness.

$Ra$  : Mean deviation (absolute) of asperity  $Z(i)$  .

$Rq$  : Standard deviation of asperity  $Z(i)$  .

$S_k$  : coefficient without dimension indicate asymmetry of distribution  $Z(i)$  “Skewness”

$E_k$  : coefficient without dimension indicate peakedness of distribution  $Z(i)$  “Kurtosis”.

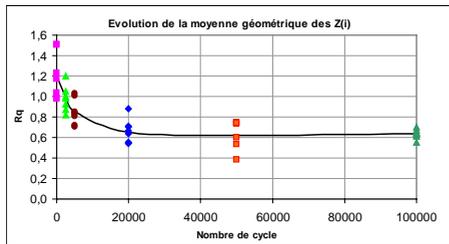


Figure 3 : Evolution of standard deviation

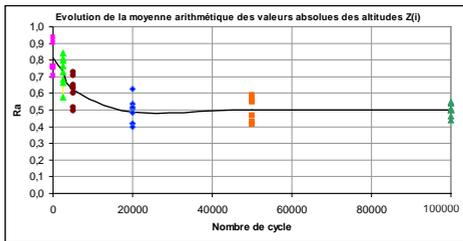


Figure 4 : Evolution of mean deviation

The curves in figure 3 and 4 represent the average evolution of selected square area i.e. 8 area corresponding to an average evolution of four samples. The important evolution of between 0 and 20000 cycles of loading seems a clear indication of the change in macrotecture corresponding to an important movement of aggregates on surface. This parameters  $Rq$  and  $Ra$  don't change while increasing the number of cycles until 100000 cycles.

Others parameters like skewness  $S_k$  and Kurtosis  $E_k$  are applied on selected surface. A value of zero for the skewness indicates a symmetric distribution and a non-zero value of the skewness indicates an asymmetric distribution, which has a long tail in the maximum value side for a positive value and a long tail in the minimum value side for a negative value.

A distribution with the shape of sharp peaks has a Kurtosis value larger than 3, whilst a shape of smoother peaks has a kurtosis value smaller than 3. The curve in figure 5 shows the change of texture towards a symmetric distribution and smoother shape.

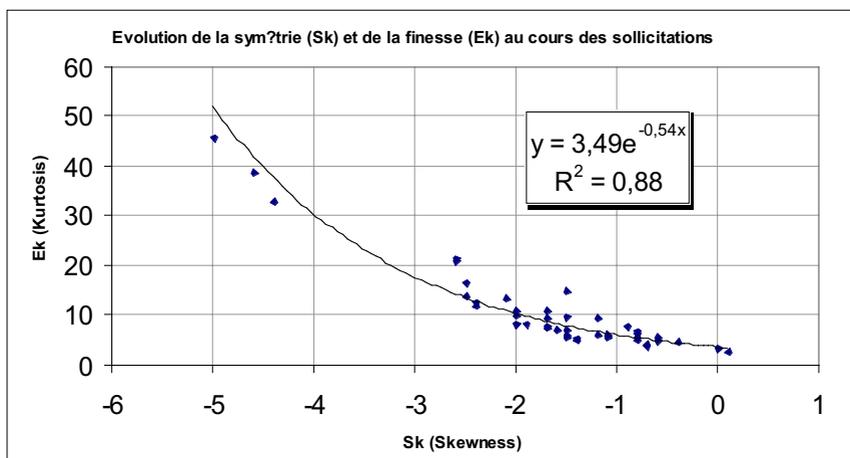
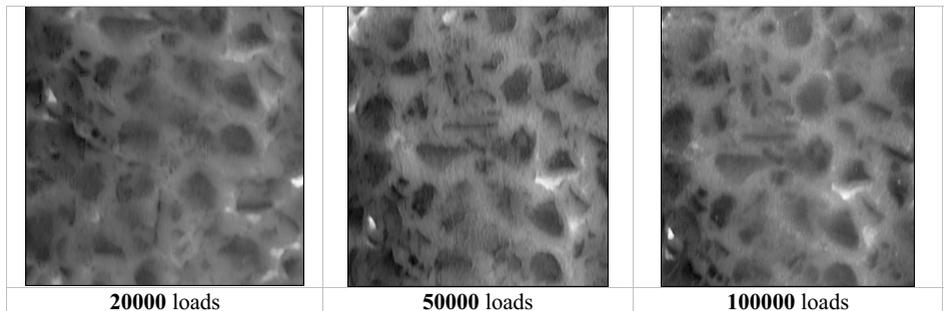
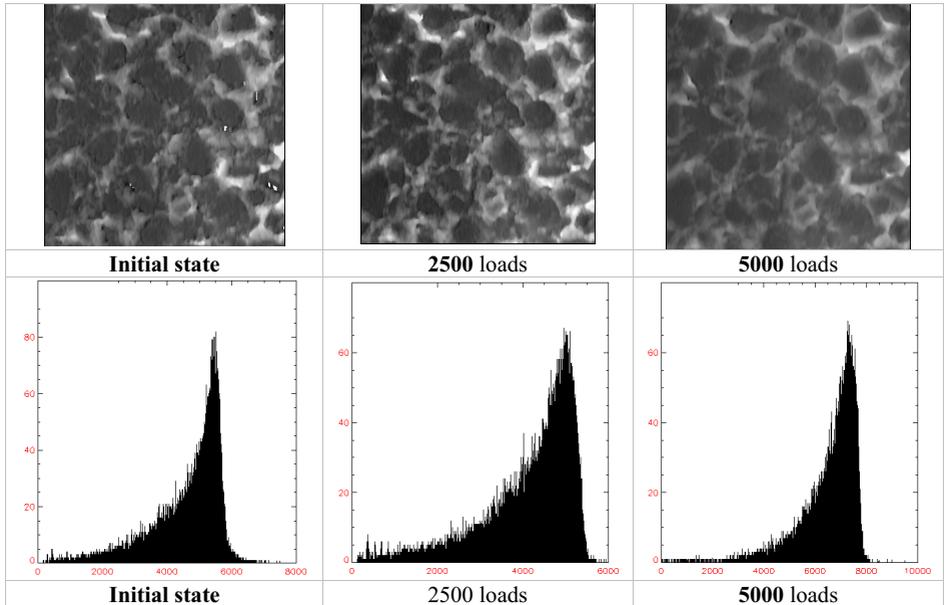
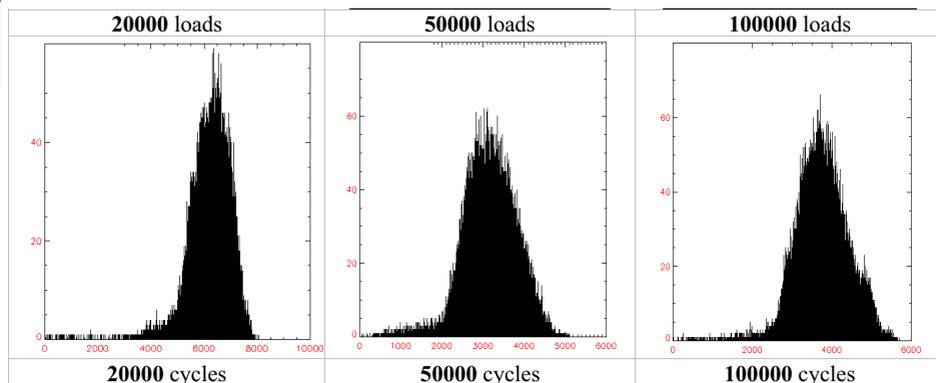


Figure 5 : Evolution of discrete distribution  $Z(i)$  with repeated loads

For a given number of loading, we represent on figure 6 a true 3D description with corresponding histogram. Brightness zones represent valley and cavities and darkness zones represent peaks. Each altitude corresponding to a level of grey. The altitude distribution is represented by a histogram for a fixed number of wheels pass. The zero point on histogram corresponds to the least elevated material point of texture and the extent of histogram informs us on altitudes of the material points situated on aggregates (expressed in  $\mu\text{m}$ ).

Initially, The altitude distribution is asymmetric with a smooth variation of peak distribution. When we increase the number of wheels pass until 2000 cycles, the distribution of altitude  $Z(i)$  change towards Gaussian distribution and then a smooth region occur with increasing loads.





**Figure 6** – A true 3D dimensional representation with corresponding histogram of 256x256points

Other specific criterion can be calculated to characterise the roughness surface like developed surface area ratio estimated with real area generated on the geometrical area defined by scanned region (64x64mm). In the following table, we have reported the average values of 8 scanned regions corresponding to the four samples.

The developed surface is approximately 280% seems a level of roughness obtained initially from LPC compactor and others laboratory conditions. The standard deviation of 45 % of the developed surface translated the variability bound to the laboratory conditions. When we increasing the wheel passes on sample, the developed surface ratio decrease

Number of cycle	0	2500	5000	20000	50000	100000
Developed surface ratio (%)	280	219	192	159	163	155
Standard deviation	45	12	14	8	14	8

An increase of developed surface ratio on sample over 50000 cycles seems that a new or old valley occurs. We can show the formation of new valley on figure 6. The parameters  $Rq$  and  $Ra$  defined above don't reproduce local modifications over 50000 cycles. Also, the different histogram in figure 6 doesn't express clearly the occurring of the new valley.

## CONCLUSIONS

The main contribution of this work is to test methods of assessment existing of pavement texture and to show as well as these methods of global analysis only give a preview of the global changes of a measure change. We have shown that these methods like sand patch test and statistical distribution following specification NF P 216 –2 give an indication at early age only with a good approximation. But, these methods tested here don't give an indication of the local phenomena occurring beyond 20000 cycles.

These first results obtained by the two different techniques permit us to think about the possibility to use more sophisticated technical analysis like fractal, Fourier transform or wavelets. This in spite of the fact that their use is going to depend on conditions in laboratory.

## ACKNOWLEDGEMENT

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(Footnotes)

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