

ROAD POLISHING ASSESSMENT METHODOLOGY (TROWS) – PIARC XXIIND WORLD ROAD CONGRESS

M.GOTHIÉ
CETE de LYON, Bron, Rhône, France
michel.gothie@equipement.gouv.fr

M.T.DO
LCPC, Nantes, Loire Atlantique, France
Minh-tan.do@lcpc.fr

ABSTRACT

Both tyre wear and road polishing are complex phenomenon, which are obviously strongly related; the energy that polishes the road is the energy that wears the tyre. They both depend non-linearly on numerous parameters, like materials used, vehicle and road usage, environmental conditions (e.g., temperature) and many others.

Due to their many economic and ecological implications, including those concerning the road users safety, the possibility to predict them is of major importance to tyre manufacturers, fleet owners, road authorities and governments.

Based on these observations, in 2000 we started the three-year 5th framework EU project TROWS (Tyre and ROad Wear and Slip assessment). The results include tools to analyse tyre wear and road polishing. These will be combined in a suitable wear prediction environment. This paper focuses on the followed methods and results of TROWS for road polishing.

Using available databases a detailed analysis of the different types of road surfaces has been performed to evaluate the relationship between the type of road surface and the evolution of skid resistance. These general studies have given some input to support the selection of the best road surfaces to be used in special carousel tests, as well as to assess the representative ness of the road circuit for the passenger and truck driving tests made also in the TROWS project to study the tyre wear.

Three types of BFC alterations according to accumulated traffic, led to three particular surfaces to be used for the wear tests on the LCPC carousel in Nantes: a AC 0/14, a Very Thin AC 0/10 and a Very Thin AC 0/6.

The main objective of the experiments carried out on the Carousel test tracks was the assessment of tyre and road polishing under pure cornering manoeuvres.

Two tables were built with marks characterising the aggressiveness of the road surfaces on tyres and of the aggressiveness of tyres on the road surface. These marks were based on road engineer's expertise and calculated with the data collected on the Italian road circuit.

With the experiment carried out on the Italian public road circuit we obtained good correlations between the polishing parameters due to traffic and the evolution of the polishing state of the various surfaces of the circuit.

These various elements could be used in management models to make choice of techniques to use easier, and to determine the time when the works will prove necessary.

KEY WORDS

PAVEMENT / SKID RESISTANCE / MACROTEXTURE / MICROTEXTURE / FRICTION

1. INTRODUCTION

In 2000 a three-year 5th framework EU project named TROWS (Tyre and ROad Wear and Slip assessment) started. It is managed by TNO (The Netherlands) and groups 10 partners from 6 different countries. The main objective of TROWS project is to predict tyre and road surface wear from a better understanding of the wear process and the development of experimental and numerical tools. The TROWS research programme is mainly based on two experimentations organized in real conditions:

- tests made on the LCPC carousel in Nantes,

- tests made on a road and on a motorway circuit in Italy as representative as possible of traffic conditions encountered by the users (roads, motorways, easy layout, uneasy layout...).

The aim of these various experimentations is to gather the greatest number of facts to characterize the relative wearing sensibility of the road surface and of the tyres

From the carousel tests, we will study the influence of two big surface types upon the tyres wear in the same test conditions.

On the road circuit, Passenger Car (PC) and Heavy Goods Vehicle (HGV) equipped will make many kilometres with an accurate monitoring of the driving parameters and of the tyres wear. We plan to make 40 000 km with a HGV articulate lorry and then 20 000 km with a PC equipped with summer tyres, and 20 000 km with a PC equipped with winter tyres.

Conventional tests were made, and will be made on this circuit in order to assess the characteristics of the encountered surfaces before, during and after the wear tests. These conventional tests regularly made, mainly aim at defining the aggressiveness features of the road toward the tyres and at assessing the traffic aggressiveness in following the relative evolution of the most solicited parts of the circuit.

2. TEST CONDUCTED ON THE LCPC CAROUSEL IN NANTES

The LCPC fatigue test track was developed for research on the mechanical behaviour of road structures subjected to heavy traffic. Loads are applied on the pavement by means of a four-arm carousel (Figure 1).



Figure 1 - LCPC Carousel and fatigue test track.

On each arm, various loading conditions can be configured. For both experiments, each carousel arm was equipped with tandem. Truck front wheels were used. The required vertical loads varied from 30 to 37.5 kN and yaw angles varied from -0.4° to $+0.7^\circ$. Three types of road surface were investigated (the number provides the maximum aggregate size in millimetre):

- 14 mm dense asphalt concrete (DA14);
- 10 mm very thin asphalt concrete (VTA10);
- 6 mm very thin asphalt concrete (VTA6).

Selection of the mixes is supported by the fact that they are representative of actual surfaces under traffic in France and that variations of their skid resistance according to traffic are significantly different. Wearing courses were laid on 19 m-radius circle of 3 m wide. Existing support representative of usual pavement structures was employed.

2.1. Test performing

2.1.1. Test duration and wear state definition

It was decided to run 200 000 rotations for each experiment. Pavements were then subjected to 800 000 passages. Measurements were carried out at different wear states in order to establish evolution curves for tyre and road characteristics. Wear states are expressed as the number of rotations; the initial state is expressed as 0-rotation stage. Eight wear states were defined: $0 - 10^4 - 3 \cdot 10^4 - 5 \cdot 10^4 - 10^5 - 1.8 \cdot 10^5 - 1.9 \cdot 10^5 - 2 \cdot 10^5$. Tolerance of ± 2000 rotations was given to the number of rotations at which the Carousel arms are stopped for measurements.

2.1.2. Acceleration of wear process

In order to speed up the polishing of road surfaces, it was decided to spread abrasive materials on the pavement during the last 20 000 rotations. The abrasive materials are the same as those employed in the British Polishing Test (BPT) to assess the polishing resistance of aggregates. They are composed of fine sand and fine emery. In BPT tests, sand is first introduced together with water during 3 hours, and then replaced by emery during 3 further hours. For TROWS program, it was decided to keep the same chronological order and to introduce each abrasive during 10 000 rotations. Existing equipment was mounted on one Carousel arm. By this way, abrasive was spread continuously on the tracks during the rotations. Spreading was carried out without water.

2.2. Assessment of tyre and road characteristics

At each wear state, the Carousel arms were stopped and measurements were carried out on tyres and road surfaces. The whole measurements lasted after 1 ½ to 2 days after which rotations were restarted until the next wear states.

2.2.1. Assessment of tyre characteristics

Evolution of each tyre was assessed by groove depth measurement, which was done by means of displacement gauge at four cardinal areas of each tyre. At each area, four groove depths were measured.

2.2.2. Assessment of road characteristics

Evolution of road surfaces was assessed by friction and texture measurements. Two types of measurement were carried out:

- Dynamic measurements along the test track central line;

- Static measurements at 6 predefined areas uniformly marked along the test track. Measurement areas for the first experiment, where the wearing course was laid on the whole test track, were located on one half of the track.

Dynamic texture measurements were performed by means of Protex M 2 device manually pushed equipped with laser sensor (Figure 2), giving ISO mean profile depth (MPD) (ISO 13473-1 standard). Averaged 1 m-values were registered from which the mean was calculated to give the MPD of the test surface.

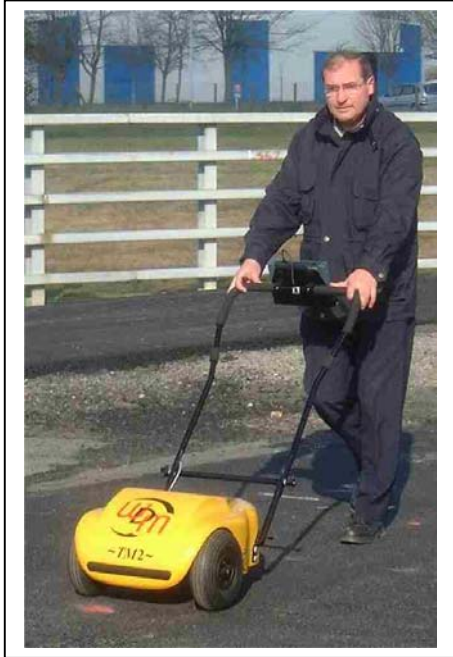


Figure 2 – Protex TM 2 device



Figure 3 – Griptester device

Static texture measurements included sand patch measurements, giving mean texture depth (MTD), and profile measurements, giving information about sharpness of surface asperities and macrotexture and microtexture of the test surface.

Static friction measurements were performed by means of British Pendulum. Dynamic friction measurements were performed by means of Griptester a manually pushed device. (Figure 3).

2.3. Results

2.3.1. Evolution of tyre characteristics

Survey of groove depth evolution of the tyres was done only between 0 and 180 000 rotations. Linear decrease of groove depth with the number of rotations was observed. Results show that tyre wear is more severe on the inner side than on the outer side and central bands wear more than external bands.

2.3.2. Evolution of surface characteristics

2.3.2.1. Visual examination

Surface binder film was rapidly suppressed under the rotation action. The surfaces seemed then to be covered by a very thin film from 10 000 rotations. It is not sure whether the film is composed of rubber or a mix between rubber and other materials. The surface was smooth by touch and hydrophobic (water drops had characteristic shape of oil drops).

Compaction of the surfaces was observed during the first wear states. After 30 000 rotations, all surfaces presented some rutting (1 to 2 mm). Aggregates of DA14 wearing course were laid flat by the tyres. For the second experiment, it was observed some pulling out of aggregates on the two wearing courses VTA10 and VTA6. Visually, surface evolutions were rapid up to 30 000 rotations then stabilized after.

2.3.2.2. Friction evolution

Friction evolution is presented in term of PTV evolution (Figure 4); dynamic friction measurement showed the same tendency.

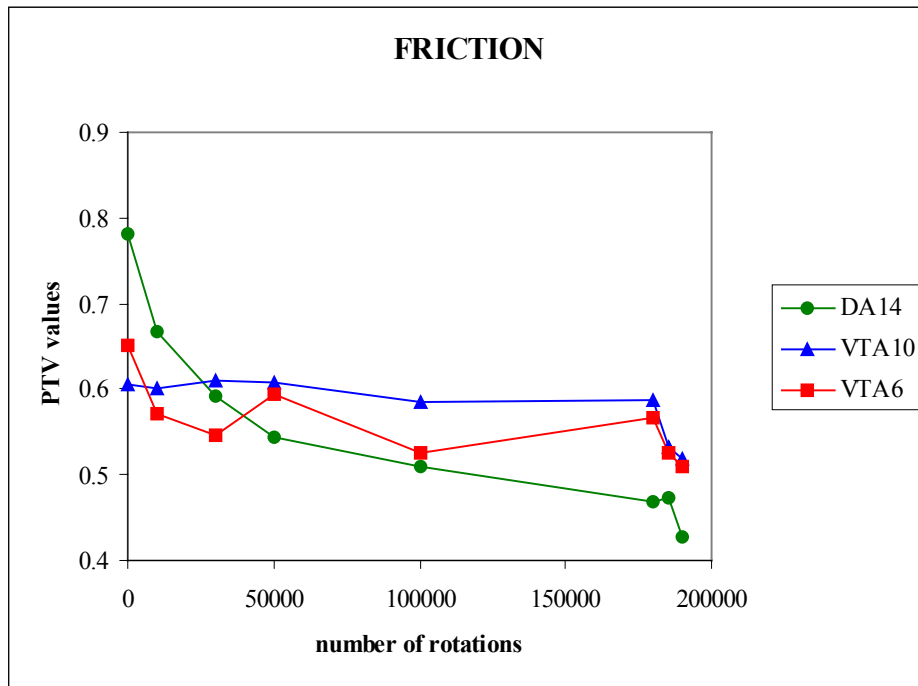


Figure 4 - Evolution of British Pendulum friction values with the number of rotations

General tendency shows a decrease of PTV with wear. Skid resistance seems to be less affected by traffic on very thin asphalt surface than on dense asphalt surface. Actually, friction loss between 0-cycle state and 180 000-cycle state is about 40 % for DA14, and only 12% for VTA6 and almost negligible for VTA10. On very thin asphalt surfaces, PTV values stabilized at 0.6. On dense asphalt surface, PTV was very high at the initial state, but decreased rapidly to values lower than 0.5 at the end of the experiment. Adding of abrasive speeded up the decrease of PTV values (Figure 4). Smoothing of surface asperities due to abrasive particles was probably the main cause of skid resistance loss. Dense asphalt surface was mostly affected by fine abrasive, whereas both abrasive types affected very thin asphalt surface. Additional friction loss due to abrasives was about 10% for all surfaces.

2.3.2.3. Texture evolution

Mean depth

Evolution of MTD is shown in the figure 5. A similar tendency was observed for MPD. The decrease of MTD on the graphs corroborates the compaction effect. After 50 000 rotations, MTD of the very thin asphalt stabilized, whereas MTD of the dense asphalt increased. This secondary roughening effect could be due to the fact that the tyres moved aggregates in the dense asphalt and re-arranged in the wear track. It would be more difficult to move

aggregates in the very thin asphalt, since less sand is included in the mix giving a more rigid skeleton.

Figure 5 - Evolution of mean texture depth with the number of rotations

2.3.3. Influence of road surface microtexture on tyre wear

Surface analysis at the microtexture scale showed higher sharpness for very thin asphalt surface VTA10 compared with VTA6 and dense asphalt DA14 surfaces. Tyre wear should be then more pronounced on VTA10 surface. Comparison between the first and second experiment was then carried out for tyres subject to the same normal load and yaw angles, that means, C1 was compared to C2 and so on. Since wear was not uniform on tyre tread width, separate comparisons were done for the different measurement spots.

2.3. Conclusions

The main objective of the experiments carried out on the Carousel test tracks is the assessment of tyre and road wear under pure cornering manoeuvres. Different loading configurations (normal load, yaw angle) were tested on three road surfaces. The main conclusions from the experiments are the following:

- Traffic induced first compaction of the surfaces and lie flat the surface aggregates. These effects decrease the surface mean depth. Rutting was then formed in the wear track, mainly at the end of the experiments, and re-arrangement of surface aggregates could be observed, mainly on the dense asphalt.
- Thin film is formed rapidly after the departure of binder and covered the road surface. The film is hydrophobic. Its composition is not defined; it might be a mix between rubber and other materials such as road material debris and dust.

- Surface skid resistance decreased with the number of passages. Friction loss is more important on dense asphalt wearing course (40%) compared with very thin asphalt wearing course (10% or less).
- Surface macrotexture decreased with traffic. Texture depth reduction can be related to the compaction effect exerted by the tyres.
- Surface microtexture decreased with traffic. It is not clear whether the evolution was due to smoothing of asperity angularity or to the fact that the thin film progressively covered the road surface.
- Microtexture of very thin asphalt wearing courses is well maintained under traffic. It could explain the fact that tyre wear is more severe on this type of surface than on dense asphalt surfaces.

3. TESTS CONDUCTED ON THE ITALIEN CIRCUIT

3.1. Measurements done on the circuit

On this road circuit of 120 km long a lot of measurements have been done during the three years of the TROWS project. Macrotexture and megatexture measurements with the mlpc device named RUGO. Sideway force coefficient (SFC) measurements with the SCRIM device of the CETE of Lyon (Figure 6). Transverse and longitudinal accelerations with the Xantia device of the CETE of Lyon (Figure 7). Roughness indices, geometric characteristics measured with the ARAN device from VIAGROUP Company. Traffic information has been collected on all the sections of the circuit and four different passages have been done with the SCRIM device. Two tables have been built to quantify on one hand the aggressiveness of the road on the tyres and on the other hand the aggressiveness of the tyres on the road surfaces.



Figure 6 – SCRIM device



Figure 7 – Xantia device

3.2. Evolution law of road surfaces polishing

The SFC evolution of the road circuit various surfaces is mainly caused by traffic, therefore we put into relation the average SFC deltas worked out previously with the marks worked out in order to characterize the tyres aggressiveness (therefore traffic) on the road surfaces.

The linear correlation obtained shows the rather good relationship between the traffic aggressiveness and the polishing level of the road surfaces. This relation is also interesting because it brings to the fore an aggressiveness threshold of traffic under which

the SFC level tends to increase. This observation had been made very often on few used roads, on which the combination of rain, and temperature variations tended to clean the relationship (1) is that for the first time, anyway in France, this phenomenon could be quantified.

Figure 8 – Marks on road aggressiveness

Mark on tyres	aggressiveness
Total strains (longitudinal + transversal) in g	Mark = to the total strains (0 to 8)
Traffic	Mark
T<3000 v/d	1
3000<T<9000 v/d	5
9000<T<15000 v/d	9
15000 v/d<T	12
Maximum mark	20

Figure 9 – Marks on tyre aggressiveness

If we consider that the SFC evolution corresponds to the surface polishing, we can write this correlation (1) as a general rule for all surfaces:

$$\text{Polishing} = -1.64 \cdot (\text{tyre aggressiveness mark}) + 10.42 \quad (R^2 = 0.76) \quad (1)$$

In order to refine the obtained relation and take into account two other important parameters in the evolution of skidding resistance under traffic, we worked out a multi criterion correlation between the SFC deltas, the tyre aggressiveness marks, and the road dressing parameters as microtexture (characterized by SFC) and macrotexture (characterized by the estimation of texture depth, ETD). The correlation level still improved in using these two explanatory factors. The corresponding rule is:

$$\text{Polishing} = -1.28 \cdot (\text{tyre aggressiveness mark}) - 3.08 \cdot (\text{macrotexture}) + 12.63 \cdot (\text{SFC}) + 1.96 \quad (R^2 = 0.78) \quad (2)$$

With : The macrotexture expressed in mm (ETD, Estimated Texture Depth),
 SFC expressed in hundredth,
 The aggressiveness mark value between 0 and 20.

3.3. Conclusions

The experiment carried out in full-size on the Italian road circuit allowed to cross the polishing parameters due to traffic and the evolution of the polishing state of the circuit various surfaces. The levels of the obtained correlation coefficients allow noting the good relationship between the investigated parameters. The evolution of the road surfaces level of polishing can be explained and even foreseen if we know the nature of the road dressings used and the constraints due to traffic.

These constraints can be assessed by the traffic level and by an assessment of the longitudinal and transverse constraints it conveys. This latter assessment can be made either by using the building parameters of the road, or by measures made by an instrumented vehicle

The type of the road dressing plays also a part in that polishing evolution, and it is noted that the negative macrotexture surfaces (Porous Asphalt Concrete, VTAC) although keeping an higher macrotexture in time, are more rapidly polished than positive macrotexture surfaces. These noting reinforce the use of 0/6 formulations in negative macrotexture surfaces (increase of microtexture, better polishing resistance, and keeping of a sufficient macrotexture level

These various elements could be used in management models, on the one hand for making easier the choice of techniques to use, and on the other hand determining the time when the works will prove necessary.

REFERENCES

DO, M-T; KERZREHO, J-P; BALAY, J-M; BROSSEAUD, Y; GOTHIE, M. (2002) Truck Tyre Carousel Test Final Report for TROWS project and LCPC Committee C.

DRURE, J-P ; GORAND, J-L ; DELCOURT, C. ; GOTHIE, M. (2003) Assessment of relative aggressiveness of tyres and road for TROWS project and LCPC Committee C.