

## A BRIEF REVIEW OF TYRE-PAVEMENT INTERACTION AND AN INSIGHT ON NEW REGULATION ON TYRE ROLLING RESISTANCE IN EUROPE

Graduate of Ecole Nationale Supérieure de Techniques Avancées – Paris 1978. Currently worldwide strategy manager for standards and regulations. Group Michelin.



**Christophe PENANT**  
Michelin  
France

### **Abstract**

This paper first gives a brief review of tyre-pavement interaction. The main tyre performances affected by pavement nature are external noise, rolling resistance, wet grip and tread wear. It then gives an insight of the future EU commercial vehicle tyres Rolling Resistance standards and regulations and their foreseeable influence on the CO<sub>2</sub> emissions and fuel consumption of road transportation.

**Keywords:** Tyre, Pavement, Noise, Grip, Rolling resistance, Wear, Regulation, CO<sub>2</sub>.

### **Résumé**

Ce papier donne d'abord une brève revue de l'interaction entre pneus et chaussées. Les principales performances des pneus influencées par la nature des chaussées sont le bruit extérieur au véhicule, la résistance au roulement, l'adhérence sur chaussée humide et la résistance à l'usure.

Il donne ensuite un aperçu sur les futures normes et règlements européens sur la résistance au roulement des pneus des véhicules industriels ainsi que leur influence prévisible sur les émissions de CO<sub>2</sub> et la consommation de carburant des transports routiers.

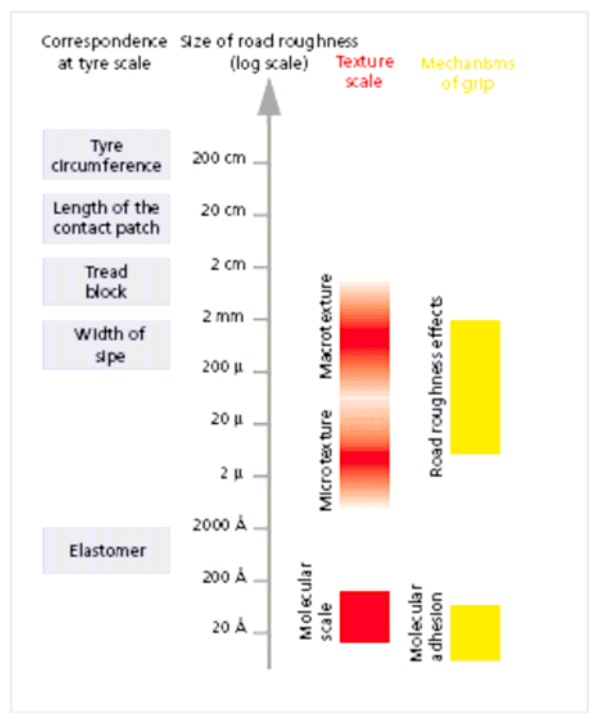
**Mots-clés:** Pneu, chaussée, bruit, résistance au roulement, usure, réglementation, CO<sub>2</sub>.

## 1. General Context and introduction

The only contacts between road vehicles and pavement are the tyres and specifically their contact areas with the pavement.

In consequence the phenomena which occur in these contact areas influence vehicle performance, in areas such as stability and road handling, traffic noise generation, fuel consumption and gaseous emissions, braking distances, maintenance costs...

The most important characteristics of pavements with respect to tyre-pavement interactions are their roughness, both on centimetric to millimetric scale, which we call macro-texture and on millimetric to micrometric scale, which we call micro-texture (Figure 1).



**Figure 1** – Scale of pavement influence. Source : Michelin.

The object of the first part of this paper is to give an insight on how pavement characteristics influence some of these performances, through their action on tyres. We shall successively consider the influence of the pavement on external noise, rolling resistance, wet grip and tread wear.

On the other hand, energy conservation and respect for the environment are two issues at the very heart of mobility today.

This is very evident when the following figures are considered:

In 1950 there were 50 million vehicles on earth.

In 1980 they were about 400 million.

In 2000 they were 800 million.

And by 2030 there will be 1.6 billion vehicles on earth.

This means that 800 million new vehicles will be on the world's roads in the next 20 or 30 years. This surge will of course be impelled by the emergence of mobility in huge countries such as China and India, but also by growth in developed nations.

The question raised by these numbers is how do we reconcile the legitimate yet enormous demand for mobility among people across our planet with the steady decline in energy and other natural resources and the ever-greater impact of cars on the environment?

Governments, across Europe and the rest of the world, are actively discussing regulatory paths to reduce CO<sub>2</sub> emissions.

The object of the second part of this paper is to describe the future EU commercial vehicle tyres Rolling Resistance standards and regulations and their foreseeable influence on the CO<sub>2</sub> emissions and fuel consumption of road transportation.

## **2. First Part - Brief review of pavement characteristics influence on tyre performances**

Tyre pavement interactions are generally not concerned by pavement rugosity (wave length of about 1 to 30 m) but much more by local geometric characteristics which we call macro-roughness, or macro-texture, and micro-roughness, or micro-texture (Figure 1).

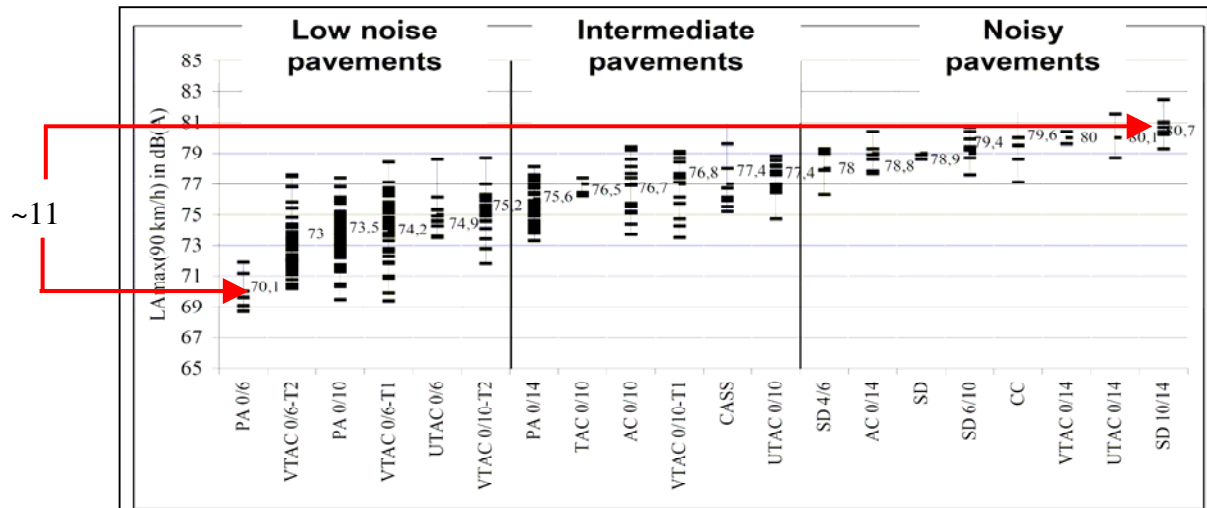
### **2.1 External tyre-pavement noise**

External tyre-pavement noise is the one emitted outside moving road vehicles. It contributes to road traffic noise and is the most important contributor among vehicle sources (engine, transmission, aerodynamics) from a speed of about 40 to 50 km/h for passenger cars and 60 to 70 km/h for commercial vehicles. It is measured according to ISO standard 13325 on tracks complying with ISO 10844 and is regulated in the European Union by Directive 2001/43 and at UN/ECE level through regulation R117. Present maximum authorized values are 76 dB(A) for "normal" and 78 dB(A) for M+S (Mud and Snow) on-the-road truck tyres and all truck tyres sold on the European market comply with these values. External tyre-pavement noise is generated through different mechanisms influenced by tyre tread pattern and pavement upper layer macro-roughness, which induce an excitation of tyre tread and structure.

Tyres also contribute to acoustic comfort of road vehicles, through what we call internal noise, but this performance is governed by OEMs specifications and not regulated.

Although tyre external noise is measured on a reference pavement surface (ISO 10844), in the real world it is much influenced by road pavement surface, as recalled in figure 2. According to the pavement upper layer surface, external tyre-pavement noise may vary in a range of more than 11 dB(A), which is very important.

On the tyre side, external noise could be reduced by only about 3 dB(A) if its tread was a slick one. Of course slick tyres would unacceptably perform on wet roads. This shows that an important synergy is to be sought between the development of more silent tyres and more silent pavements in populated areas.



**Figure 2** – Influence of pavement surface on tyre external noise.

(Source: Yves MEUNIER - USIRF/ROUTIÈRE MORIN : LOW-NOISE PAVEMENTS : THE SOLUTIONS OFFERED BY THE FRENCH ROAD BUILDING INDUSTRY, Internoise 2001, The Hague, The Netherlands)

## 2.2 Tyre rolling resistance (RR)

Tyre RR is the resistive force induced by energy losses within tyre rubber mixes when stressed and strained. It has to be overcome by the vehicle engine to ensure vehicle movement.

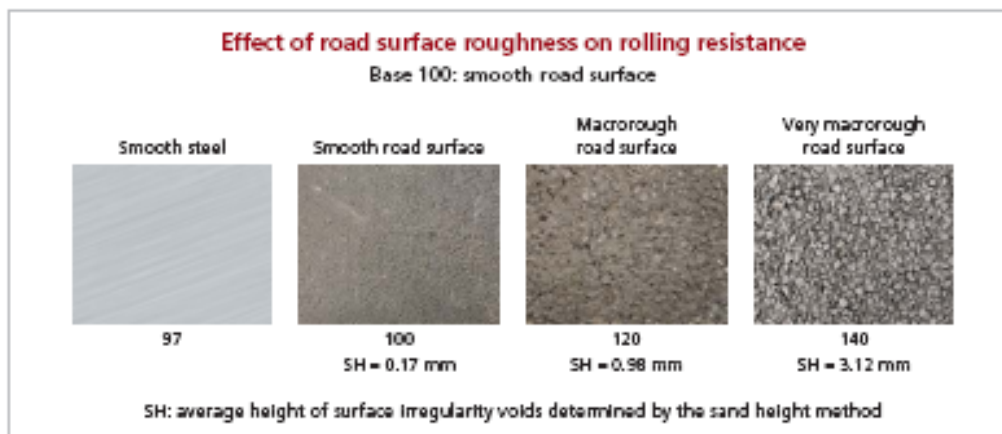
Thus it contributes to vehicle fuel economy and CO<sub>2</sub> and pollutant emissions. The corresponding energy is transformed into heat which raises tyre temperature and is dissipated mainly into the atmosphere.

Tyre RR is an important contributor to vehicles fuel consumption. It accounts for about 20% of total consumption for passenger cars and up to 30% for heavy commercial vehicles, when compared to the other resistive forces that have to be overcome by the vehicle. Tyre RR is usually quantified through RR Coefficient (RRC), which is the ratio between tyre RR and tyre load. It is a dimensionless coefficient, currently expressed in kg/t: kg force of RR per tonne of carried load (or 10<sup>-3</sup>).

For radial on-the-road truck tyres currently on the European market, the range of RRC is between about 4.0 and 7.5 kg/t for steer and trailer axle tyres and about 5.5 to 8.5 kg/t for traction tyres.

As a matter of comparison, for radial on-the-road Passenger Car tyres currently on the European market, the range of RRC is between about 7 and 14 kg/t, according to speed symbol, tyre category and range ...

Tyre RR is much influenced by pavement upper layer macro-texture, which induces increased stresses and strains in tyre tread. See figure 3.



**Figure 3** – Influence of road surface roughness on tyre RR. (Source : Michelin)

### 2.3 Tyre wet grip

Tyre wet grip is an important tyre safety feature. It has various components, such as wet braking on damp pavement, hydroplaning on thick water layer... It is regulated at UN/ECE level through regulation R117.

Two measurement methods are used, either wet vehicle braking on a reference surface or measurement of maximum friction on a reference surface, in comparison with SRTT (Standard Reference Tyres for Testing, standardized by ASTM). The resulting value is expressed in % of SRTT performance.

Current limits of R117 are 110% for "normal road" passenger car tyres, which means 10% better than SRTT wet grip performance, 100% for M+S tyres with a Speed Symbol higher than Q (160 km/h) and 90% for M+S tyres with a Speed Symbol equal or lower than Q.

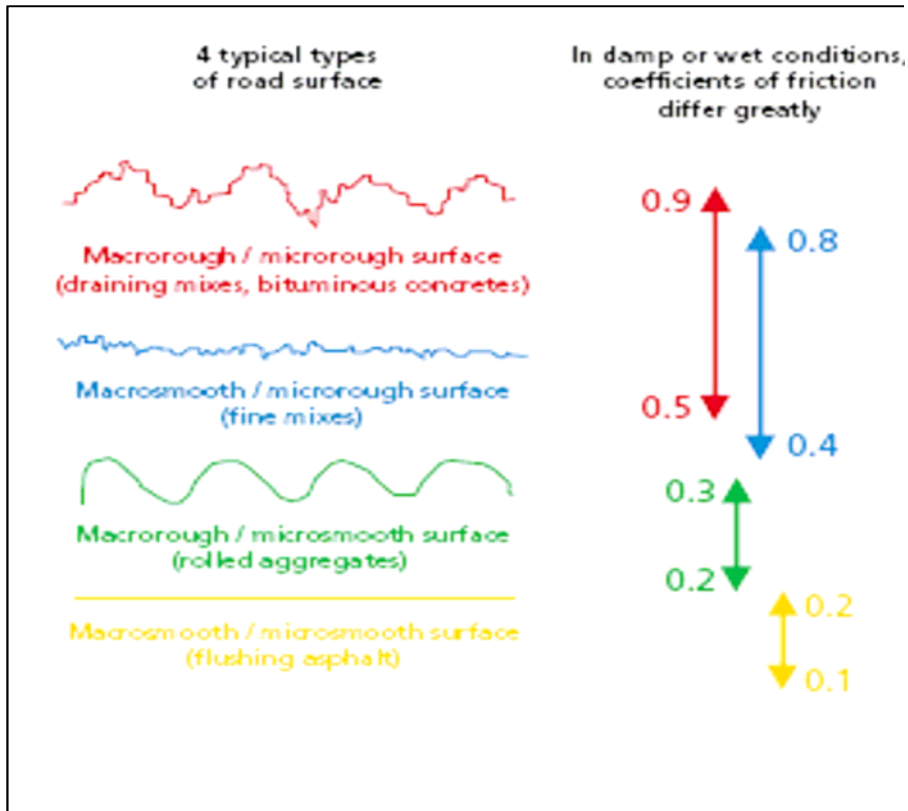
Wet grip performance for Light Truck and Truck and Bus tyres is not yet regulated but the process is in progress at UN/ECE level.

Tyre wet grip is much influenced by pavement upper layer texture. Micro-roughness drives wet grip at low vehicle speeds by the cyclic deformation imposed to the tread rubber, and macro-roughness drives the evolution of wet grip at higher vehicle speeds by the drainage capability of the road. Figure 4 shows the resulting effect of road surface nature on its coefficient of friction in damp or wet conditions.

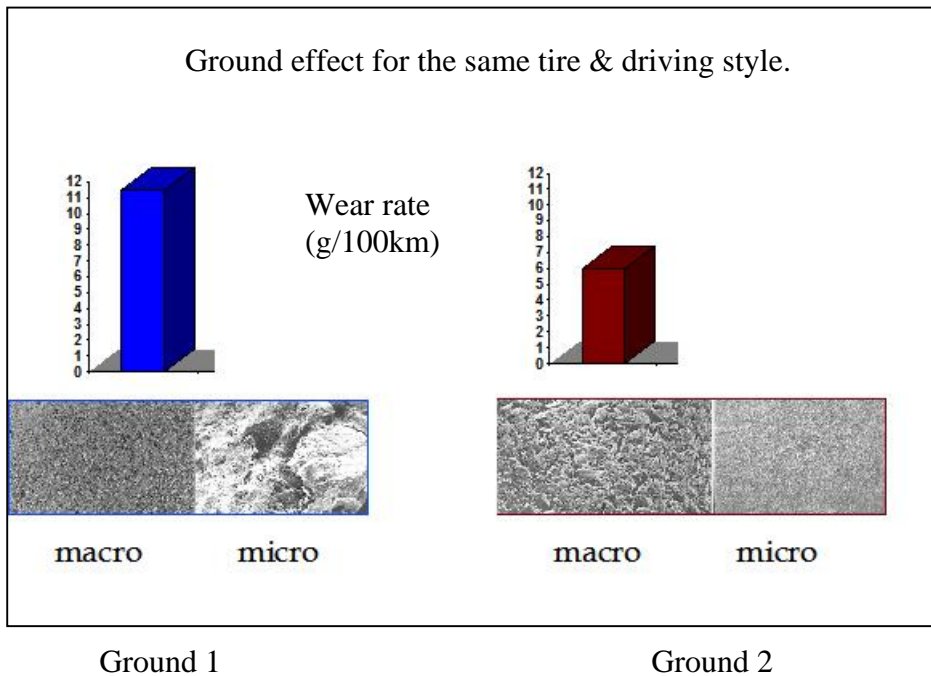
### 2.4 Tyre tread wear

Tyre tread wear is the most considered tyre feature for heavy commercial vehicle tyre buyers, for economic reasons. It is influenced by pavement surface roughness through a modification of the rubber/ground interface characteristics (friction, abrasion).

The road abrasion is highly dependent upon the micro-roughness (but is roughly independent of macro-roughness) of the ground materials. A difference in magnitude of 2 to 3 may be seen for the same use, depending upon the ground characteristics (Figure 5).



**Figure 4** – Influence of road surface roughness on tyre wet grip. Source : Michelin.



**Figure 5** – Influence of road surface roughness on tyre wear resistance. Source : Michelin. Despite a smoother macro-roughness the ground 1 give a higher wear rate because of a higher micro-roughness.

## 2.5 Conclusion of part 1

This brief review shows that important tyre properties are influenced by pavement roughness and should be well known by pavement engineers and road authorities to reach a better optimization of road transportation.

### 3. Second Part - Future EU commercial vehicle tyres Rolling Resistance standards and regulations

As parts of road vehicles and contributing to their fuel consumption and CO<sub>2</sub> and polluting emissions, tyres will get regulated regarding their Rolling Resistance values. The process is currently started in the EU, USA and in Japan. The introduction of a tyre RR grading system for Passenger Car tyres was already signed into law by the President of the USA as part of the Energy Bill (December 2008). In this second part of the paper we shall describe the European regulation process and its foreseeable influence on the CO<sub>2</sub> emissions and fuel consumption of road transportation

#### 3.1 Legislative context

The European Commission issued on October 19<sup>th</sup>, 2006 the communication document COM(2006)545 final : "Action Plan for Energy Efficiency: Realising the Potential". This important orientation document deals with all kind of energy efficiency concerns at EU level, including those related to transportation and, of course, road transportation. And within this topic, the European Commission dealt with tyre efficiency and proposed to issue a mandate for a recognized European Norm and international standard to measure tyre rolling resistance (2008), and also to propose a labelling scheme for tyres (2008). Although it is not explicitly stated, and although the European Commission usually introduces regulation relative first to passenger cars and later to commercial vehicles, this scheme should also be applied to commercial vehicle tyres.

In COM(2007) 19 final " Results of the review of the Community Strategy to reduce CO<sub>2</sub> emissions from passenger cars and light-commercial vehicles", Brussels February 7<sup>th</sup>, 2007, the Commission announced it will set maximum tyre rolling resistance limits in the EU for tyres fitted on passenger cars and light commercial vehicles (2007-mid 2008). The EC also published, on August 24<sup>th</sup> 2007 its "Public consultation on outline proposals for a Regulation of the European Parliament and of the Council on Advanced Safety Features and Tyres". In the Annex 2 (Table 1) of this document, maximum values for the rolling resistance coefficient for each tyre type, measured in accordance with ISO 28580, were proposed. Some provisions were also proposed for some specific Off Road tyres.

**Table 1** – Maximum Values of the Rolling Resistance (ISO 28580).

Tyre category	Max value (kg/tonne)
C1 (Passenger Cars)	13.5
C2 (Light Trucks)	12.0
C3 (Trucks and Buses)	8.0

In addition, the EC proposed that tyres in categories C1 and C2 are to be graded according to the bands given in Table 2. The process of consultation is over and its results will be used by the EC to define the regulation. From these results, the EC already announced it accepts that banding will need to be refined, possibly using a seven band system.

**Table 2 – EC Tyre Categories by Rolling Resistance.**

Tyre Category	Maximum rolling resistance coefficient per band (kg/tonne)			
	Band A	Band B	Band C	Band D
C1	9.0	10.5	12.0	13.5
C2	7.5	9.0	10.5	12.0

### **3.2 Regulation building requirements**

To introduce such regulation a strong and internationally standardised measurement method is first needed. A method designed to facilitate international exchanges and regulation setting was set by European Tyre and Rim Technical Organisation and proposed to ISO in January 2006. This method was based upon ISO 18164, its testing conditions were restricted and the addition of a machine calibration process was proposed. This new standard proposal was accepted by the participating countries to ISO/TC31/WG6, dedicated to tyre Rolling Resistance (RR), in June 2006 and will be designated as ISO 28580. The Committee Draft was built and then approved by the participating countries in May 2007. This first official document can be used for regulatory purposes. It contains 9 chapters describing the whole measurement procedure.

The only missing chapter is dedicated to measurement machine alignment procedure. The aim of this part of the standard is to ensure that, for any complying measurement machine in the world, a high level of reproducibility of the measurement result is obtained for the same tyre. Several methods can be used for this alignment procedure, among which the use of a reference tyre or of a reference machine. The best suited method will be determined through an international cooperation involving 24 machines installed in Europe, USA and Japan, and nearly 800 individual measurements on Passenger Car, Light Truck or Truck and Bus tyres. The standard should be completed as a Draft International Standard in March 2008. It should be approved by the countries in 2008. The final version, called International Standard, should be approved and made available mid 2009.

To introduce such regulation an Impact Assessment is usually performed by the European Commission services, in order to assess the opportunity, feasibility and interest of the envisioned regulation.

### **3.3 Foreseeable influence on the CO<sub>2</sub> emissions of road transportation**

The European Tyre Industry, within the framework of European Project Cars 21 established that reducing Commercial vehicle tyres RR, in the way expected by the regulation should reduce annual CO<sub>2</sub> emission by about 10 Mt by 2020. This corresponds to a reduction of fuel consumption due to Low Rolling Resistance tyres of about 3%.

### **3.4 Foreseeable timeframe**

According to presently available elements, the foreseeable time frame is as shown in Figure 6.

### **3.5 Likely changes to the tyres that will result from the proposed standards**

To make these progresses on Rolling Resistance, the tyre design and rubber mixes will evolve in order to reach less stress and strains of less hysteretic compounds. Of course tyre wet grip



and tyre external noise performances, as well as all the other tyre performances, will be kept at very high levels to comply with market needs and regulations.

	2S 2007	1S 2008	2S 2008	1S 2009	2S 2009	1S 2010	2S 2010	1S 2011	2S 2011	2012
Impact assessment										
Drafting first document in an integrated approach with the other regulated tyre performances										
Public consultation										
Approval by all components of EC										
Vote by European Parliament										
Decision by EU Council of Ministers										
"Lead time" given to Tyre Industry to comply										
Progressive enforcement for PC and LT tyres										
Progressive enforcement for TB tyres								<b>2015 ??</b>		

**Figure 6** – Foreseen schedule of the future EU commercial vehicle tyres Rolling Resistance standards

**3.6 Tyre pressure monitoring**

Tyre inflation pressure has an important influence on the way tyre rubber mixes are stressed and strained when the loaded tyre rolls. In consequence, it has an influence on tyre RR. If under-inflated, a tyre is over deflected and has a higher RR. Within the communication paper to the Council and European Parliament published on Feb 2nd, 2007 "Results of the review of the Community Strategy to reduce CO<sub>2</sub> emissions from passenger cars and light-commercial vehicles", the European Commission announces the compulsory fitting of accurate tyre pressure monitoring systems. But nothing has been yet stated for heavy goods vehicles. From Michelin experience, the fitting of TPMS on passenger cars should help improve vehicle safety, by reducing the rate of important under inflation, but not significantly reduce CO<sub>2</sub> emissions, due to the evolution of users' behaviour which will wait for an underinflation signal instead of periodically checking.

**3.7 Conclusion of part 2**

All the necessary elements are currently being introduced to make possible the introduction of a European regulation on tyre Rolling Resistance, including commercial vehicle tyres. This regulation will help users to make better informed tyre choices and contribute to a reduction of road transportation CO<sub>2</sub> emissions.

#### 4. References

- Michelin (2001), “The Tyre – Grip”.
- Yves MEUNIER - USIRF/ROUTIÈRE MORIN : LOW-NOISE PAVEMENTS : THE SOLUTIONS OFFERED BY THE FRENCH ROAD BUILDING INDUSTRY, Internoise 2001, The Hague, The Netherlands.
- Michelin (2003), “The Tyre – Rolling Resistance and Fuel Savings”.
- EC Communication document: COM(2006)545 final “Action Plan for Energy Efficiency: Realising the Potential”, Brussels October 19<sup>th</sup>, 2006.
- EC Communication document: COM(2007) 19 final “Results of the Review of the Community Strategy to reduce CO<sub>2</sub> Emissions From Passenger Cars and Light-Commercial Vehicles”, Brussels February 7<sup>th</sup>, 2007.
- EC public consultation on outline proposals for a Regulation of the European Parliament and of the Council on Advanced Safety Features and Tyres. Brussels August 24<sup>th</sup>, 2007.