THE MEASUREMENT OF ROAD SURFACE CHARACTERISTICS

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ABSTRACT

The continuing growth of road traffic, in both developed and developing countries, has further increased the emphasis on the need to provide sustainable infrastructure that has acceptable levels of safety and comfort.

It is therefore, widely recognised that in order to maintain the road surfaces to an acceptable standard there is a need to monitor the surface parameters at regular intervals. Thus, much research and development work is devoted to the design and construction of equipment capable of measuring the required parameters to an acceptable level of accuracy. The wide range of equipment developed for road monitoring purposes has in turn led to the need for harmonisation of the road assessments provided by the different equipment. This is particularly important, not only for correct and equitable maintenance investment decisions by government departments and by funding institutions such as the World Bank, but also to aid collaborative research between different countries.

The current work programme of the Technical Committee on Surface Characteristics (TC1) has endeavoured to continue with these developments and to further promote the adoption of appropriate and improved practices throughout the world. In particular the programme of work undertaken by Working Group A of TC1 has been concerned with both new and ongoing studies relating to the improvement and harmonisation of measurements of the road surface characteristics that influence skid resistance, profile, traffic rolling noise and surface distress.

This paper provides a summary of the work of the various subgroups within Working Group A, together with related items on the harmonisation and standardisation of measurement methods and an experiment to continue this work in the area of skid resistance measurement.

KEY WORDS

PAVEMENT / SURFACE / SKID RESISTANCE / PROFILE / NOISE / CRACKING

1. INTRODUCTION

The continuing growth of road traffic, in both developed and developing countries, has further increased the emphasis on the need to provide sustainable infrastructure that has acceptable levels of safety and comfort.

Previous programmes of work, carried out by the Technical Committee on Surface Characteristics (TC1), have recognised the significance of this growth in traffic for the design, construction and maintenance of durable and economic road surfacings. In addition the growing concerns about environmental pollution, and in particular traffic noise, has focused much attention on the need to understand and to control the adverse influence of surface characteristics in this area while still maintaining acceptable safety and comfort. Successive work programmes by TC1 have contributed to a better understanding of the surface parameters that are important for the achievement of road surfaces with reduced environmental effects, but that have good standards of safety and comfort.

Another consideration is the introduction, in many countries, of new forms of contract for the management of road networks. There is a requirement in these contracts for roads to have specified levels of condition at both the beginning and end of the contract period; a review of this subject is published in Routes Roads (PIARC, 2002a). Also, in a number of countries, bonuses or financial penalties may be imposed depending on whether or not the surface evenness requirements for new road construction are achieved. These requirements emphasise the need for accurate and consistent measures of surface condition.

It is recognised that to maintain road surfaces to an acceptable standard there is a need to monitor the surface parameters at regular intervals. Thus, much research and development work is devoted to the design and construction of equipment capable of measuring the required parameters to an acceptable level of accuracy. The wide range of equipment developed for road monitoring purposes has in turn led to the need for harmonisation of the road assessments provided by the different equipment. This is particularly important, not only for correct and equitable maintenance investment decisions by government departments and by funding institutions such as the World Bank, but also to aid collaborative research between different countries.

The current work programme of TC1 has endeavoured to continue with these developments and to promote the adoption of appropriate and improved practices throughout the world. In particular the programme of work undertaken by Working Group A of TC1 has been concerned with both new and ongoing studies relating to the improvement and harmonisation of measurements of the road surface characteristics that influence skid resistance, profile, the rolling noise of traffic and surface distress.

This paper will cover the main elements of the work of Working Group A, together with related items on the harmonisation and standardisation of measurement methods and an experiment to continue this work in the area of skid resistance measurement, HERMES (Harmonisation of European Routine and research Measuring Equipment for Skid resistance of roads and runways).

In the following sections the scope of the work programme, undertaken by Working Group A, is described together with its organisation and the summaries of the presentations to be made in the Additional Session.

2. SCOPE OF PROGRAMME OF WORKING GROUP A

Working Group A was concerned with the measurement of surface characteristics that relate to the friction, texture, noise, evenness and distress of trafficked pavements. Previous PIARC programmes of work in this area have included studies, and a number of international experiments, designed to provide information leading to the harmonisation of the assessments of the friction, texture and evenness surface parameters that are measured by existing road monitoring systems. At the last World Congress, in Kuala

Lumpur in 1999, an investigation to harmonise rolling noise measurements was proposed, and the development of more consistent methods of assessing surface distress, using automated systems, was also suggested. For the current programme the Working Group decided to review the outcome of previous studies and experiments, in terms of their practicality and implementation; to assess new and ongoing developments and to examine the use of surface measurements by road managers and decision makers. The main thrust of the work programme was to provide up-to-date information that would lead to improvement and harmonisation of the road surface assessments made by road monitoring systems. The working group recognised that, with the pace of technical developments, most of the surface parameters could be, in time, measured by automated systems operating at traffic speeds where this was appropriate to the needs of the network. Although for some networks, such as in developing countries, such expensive and complex system could not be justified. However, even here simple video-based image collection systems could be economically worthwhile. They also recognised that the large quantities of data collected by the more complex equipment needed to be processed so as to provide meaningful and concise surface condition indices that could be readily understood by road managers and highway departments of governments. This latter work has been taken forward by two of the other Working Groups in Committee C1, namely B and C.

In the following section the way in which the work programme was carried out is described and the main activities are summarised.

3. ORGANISATION OF WORK PROGRAMME

To carry out the agreed work programme, five subgroups were formed from the main Working Group to collect and evaluate the latest information on specific topics as shown in Table 1.

Table 1 - Topic and leader of each subgroup

Subgroup	Leader	TOPIC
A1	B de Wit (NL)	Friction and Texture
A2	L Sjogren (SE)	Profilometer measurements
A3	U Sandberg (SE)	Rolling Noise
A4	A Gulyas (HU) and M Grondin (CA-Q)	Surface deterioration
A5	B Ferne (GB)	Requirements for measurements

Each subgroup comprised a team drawn from the main working group, who supported the leader in carrying out the agreed programme of activities. The main activities for each subgroup are summarised in Table 2.

Table 2 - Topic activities addressed by each subgroup

Topic	Main Activities
Friction and Texture	Summary of recent studies. Review of ongoing investigations, State-of-the-art Report on the use of friction and texture measurements to assess skid resistance.
Profilometer measurements	Analysis of reference measurements of the EVEN experiment. Review of the Final Report on the EVEN project. Examination of the need for reference profiles for calibration purposes.
Rolling Noise	State-of-the-art Report addressing measuring methods, status of standardisation, comparison of methods, ongoing developments and need for comparative experiment.
Surface Deterioration	Review of practical measuring systems covering surveys, comparison of existing systems and their application.
Requirements for measurements	Review of use of surface condition parameters; requirement for other measurements and the feasibility of making such measurements.

In carrying out the activities listed in Table 2 each subgroup also maintained a close liaison with a wide range of external bodies and in particular the Standardisation bodies (ISO, CEN, ASTM etc) covering the surface parameters being addressed. From the formulation of the activity programme in May 2000 the work has been carried forward by each subgroup through a series of meetings up to May 2003 following which the final submissions for the Durban World Congress were made. In addition the subgroups contributed to an international seminar in Havana, Cuba in April 2002 organised by the Technical Committee on surface characteristics (C1) which was reported in the April 2003 edition of Routes Roads (Swanlund and Alonso, 2003).

4. SUMMARIES OF THE WORK OF THE SUBGROUPS

4.1. Why measure surface condition?

Road surface condition has wide ranging effects on traffic, the infrastructure and the environment. The effects include traffic safety, travelling comfort, road user costs, vehicle pollution, tyre noise and pavement wear. Such road user costs are generated, for example, by vehicle and tyre wear, fuel consumption and journey time. For commercial vehicle operators damage to vulnerable freight by road-induced vibrations may also be a significant economic issue. Climatic conditions, such as heavy rainfall, ice and snow can adversely affect traffic safety and journey time.

Though many of these effects also apply to paved roads in developing countries, there exists a very extensive network of more basic roads where the main requirement is to keep them in a passable condition for traffic. These roads still need objective and consistent assessment of condition in order to make the most effective use of limited budgets; assessment techniques here need to be both robust and maintainable using locally available and appropriate technical resources.

Not surprisingly therefore, much effort has been made, world-wide, to identify and quantify the surface characteristics that can develop into having an adverse effect on traffic, the infrastructure and the environment. The growth in the volume of the traffic, together with increasing traffic speeds, has further exacerbated the demands being made on road surfacings and on the need to maintain them to an acceptable standard within available budgets.

Constraints on highway budgets has also focussed the attention of road owners on the need to invest wisely, in order to provide sustainable infrastructure of a good standard at an economic cost. Thus, satisfying road user requirements, whilst maintaining the infrastructure in a sustainable way, may require the road manager to identify the need for maintenance sufficiently early to allow the most economic surface maintenance to be carried out with minimum disruption to traffic and nuisance to the public.

To achieve this desirable objective it is essential that the condition of the road surface be monitored at regular intervals to allow trends in surface deterioration to be identified in good time for the planning of cost effective maintenance. The provision of this condition information requires reliable and robust measuring techniques that are capable of providing consistent quantitative information on the important surface characteristics. This topic is presented in more detail in a paper to the PIARC Durban Congress (Ferne, 2003). In addition, because of potential traffic congestion problems, it can often be beneficial if these measuring techniques are capable of being operated at traffic speed and preferably at variable speeds. This latter requirement helps to reduce monitoring costs and minimises disruption to traffic.

Much research and development has been carried out to provide road managers and highway administrations with reliable data on which to base investment decisions. They are a core part of the road management systems now being used to achieve these ends, such as the HDM-4 system, shown in diagrammatic form in Figure 1. PIARC have also made a substantial contribution, through its harmonisation experiments, in providing information that permits co-operation between regions and countries in carrying out surface condition surveys and in sharing research results.

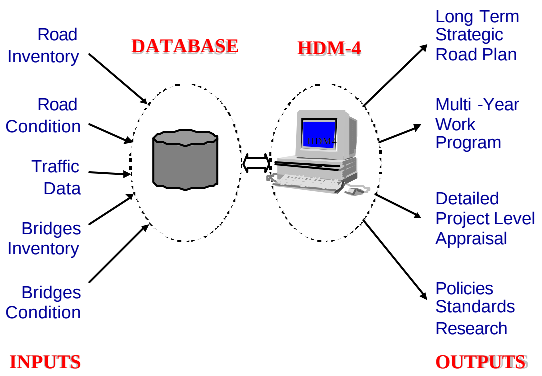

Figure 1 – Components of road management system based on HDM-4

4.2. Harmonisation and standardisation of test methods for the assessment of surface characteristics

At the 18th Road World Congress (Brussels, 1987) the PIARC committee, C1, on surface characteristics, pointed out the difficulties in comparing the specifications and practices of PIARC member countries in the field of surface characteristics in pavements. These difficulties were attributed to the wide range of test methods to assess these characteristics that were in use throughout the world. PIARC recognised that these difficulties adversely affected the exchange of information and technologies that they wished to promote to improve road engineering practices worldwide. So it was recommended to decision-makers that harmonisation of these test methods should be improved. As a result, PIARC agreed to provide a stimulus for this work by including the design and organisation of international experiments to compare the main test methods used worldwide, in the working programme of Committee C1 for the 1988 – 1991 period.

The first PIARC international experiment to compare friction and texture measurements was conducted in 1992 in Belgium and Spain. The final report, published by PIARC in 1995, has yielded a large amount of very useful information and resulted in the proposal for a common scale for tyre-road friction values, namely the International Friction Index (IFI). The experiment also allowed the validation of a method to calculate a macro-texture index (MPD, Mean Profile Depth) from a texture profile. This experiment was complemented by various national studies and by new international experiments, such as the Joint Winter Runway Friction Measurement Programme (JWRFMP) conducted by NASA and Transport Canada since 1997. Canada, USA and many European countries are participating in this project.

Figure 2 - Example of test carried out under Joint Winter Runway Friction Measurement Programme

The JWRFMP aims to harmonise the methods for the assessment of skid resistance of airport runways in winter conditions and to establish a correlation with aircraft braking performance. One result from this project is the definition of an International Runway Friction Index (IRFI) for the friction values on runways.

In Europe, FEHRL (Forum of European Highway Research Laboratories) launched, in 2000, the new HERMES (Harmonisation of European Routine and research Measuring Equipment for Skid resistance of roads and runways) project. The aim of the project is to demonstrate the relevance, reliability and feasibility of a procedure for periodically calibrating friction-measuring devices according to a common scale.

A second PIARC experiment was conducted in 1998 to compare measurements of transverse and longitudinal unevenness made using profilometric methods. This project was conducted in Europe, in Japan and the USA and was co-ordinated by the PIARC Committee C1. The results of the European component of the project were published in 2000 and 2001 in five FEHRL reports. The final report of the complete project (EVEN) was delivered in 2002 (PIARC, 2002b).

American standardisation bodies, concerned with friction and evenness measurements, have made extensive use of the results from the PIARC international experiments in the development of their specifications. In Europe, the European Committee for Standardisation (CEN) has been mandated to draft European standards on test methods for pavement surface characteristics. Because of the variety of test methods available for the dynamic measurements of surface characteristics the CEN Committee has focussed on static methods. However, the future standard for longitudinal evenness assessment is directly based on the results of the European component of PIARC international evenness experiment. An update on all these matters is presented in a paper to the PIARC Durban Congress (Boulet, 2003).

4.3. State-of-the-art friction and texture measurements to assess skid resistance

An adequate level of friction between the road surface and vehicle tyres is necessary to make controlled vehicle movements such as steering, acceleration and braking. Insufficient friction can result in reduced vehicle control and may lead to accidents. To establish what constitutes an adequate level of friction, studies have been made into the relation between friction and traffic safety. However, as road and car technologies change with time, and the friction studies were made decades ago, some countries have decided to review their friction levels in the light of modern traffic safety requirements.

To ensure that adequate levels of friction are maintained over time, road authorities carry out regular surveys of their road networks using equipment specially designed for this purpose. As the need for measuring friction emerged over a period of time, different equipment was developed in different countries to make the measurements. These differences also led to different interpretations of what was considered an adequate friction for traffic safety.

In the last ten years much effort has been applied to the harmonisation of friction assessments made by different equipment. Recent developments to improve comparability of equipment include the definition of an international friction index (IFI) and the ongoing European Study (HERMES) as reported in Routes Roads (Bennis and De Wit, 2003) and at the PIARC Durban World Congress (De Wit and Bennis, 2003). These varied studies, including some carried out in New Zealand and illustrated in Figure 3, have shown that a measurement of macro-texture needs to be considered to improve comparability of equipment.

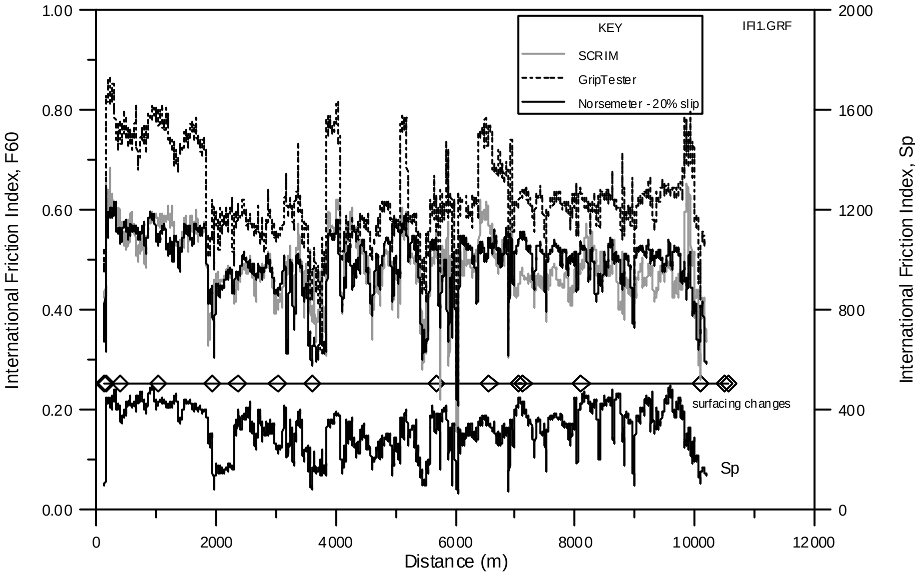

Figure 3 - Comparison of IFI values (New Zealand)

Traditionally macro-texture has been measured with a static method known as the 'sand-patch' test. But over the past ten years laser based devices have been developed to make this measurement either statically or at traffic speed.

4.4. The HERMES Project

HERMES is an acronym for "Harmonisation of European Routine and research Measurement Equipment for Skid resistance of roads and runways". HERMES is a project of co-operative pre-normative research to harmonise skid resistance measurement methods at the European level. It is run under the auspices of FEHRL (Forum of European national Highway Research Laboratories). The project started in January 2001 and is due to finish in December 2003. It will be reported at the PIARC Durban Congress (Descornet, 2003).

The primary aim of the project is to demonstrate the reliability, acceptability and feasibility of a draft standard, under study in CEN group TC 227/WG5, that defines a common scale for a tyre/road friction index; this index is the so-called European Friction Index (EFI). The draft standard specifies the procedure for calibrating measuring devices based on this index scale.

Figure 4 - Preparing for one of the HERMES calibration measurement runs

As part of the project the present definition of EFI will be examined, in the light of recent research and calibration exercise results, with a view to improving its precision. In addition the feasibility of specifying reference surfaces and reference friction measuring devices will be investigated with a view to the next generation of standards. Some of the participating devices are shown in Figure 4.

4.5. Road profiling reference measurement systems; an overview of possible reference profiling devices

Surface evenness is an important characteristic that can influence the functional performance of roads such as comfort, driver fatigue, vehicle operating costs and in extreme cases the trafficability of a road. Poor surface evenness can accelerate road deterioration by generating vehicle dynamic loading. Thus, the measurement of surface evenness provides important information that assists the road manager in identifying the need for surface maintenance.

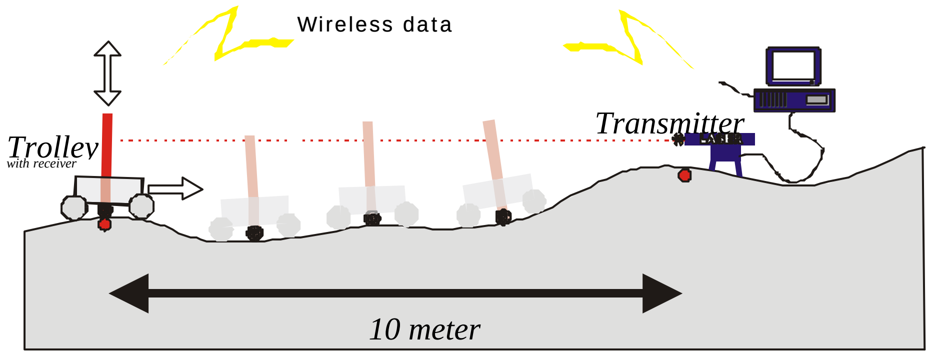

Figure 5 - Example of a system for measuring reference profiles

The change from response type evenness measurement, to systems that measure the road surface profile at traffic speed, has increased the need to develop practical and meaningful methods of validating evenness survey measurements. Measures need to be developed that can be used to make objective statements on the performance of road profiling systems. In some countries profiling systems are now being used for monitoring and evaluating contractor compliance with smoothness specifications on pavement construction projects. These specifications often involve bonuses or penalties for the contractor and therefore may have a significant financial impact on project participants. Consequently the verification/validation of the precision and accuracy of profiling devices has become ever more critical. An example of a system for measuring reference profiles is shown in Figure 5. This subject is discussed further in a paper presented at the PIARC Durban Congress (Sjogren, 2003).

4.6. Measurement of noise characteristics of pavements

The road surface characteristics that influence traffic noise emission include:

- Macrotexture
- Megatexture
- Porosity
- Friction
- Adhesion and
- Mechanical impedance

Macro and megatexture have a dramatic influence on tyre noise emission. However, noise emission does not increase uniformly with increasing texture. Texture, dominated by its spectrum wavelengths in the range 10-100 mm, increases low-frequency noise, whereas texture dominated by wavelengths in the range 1-10 mm decreases high-frequency noise. Therefore, depending on the composition of the road surface texture, noise can be influenced in complicated and not apparently consistent ways.

The porosity of a pavement surface influences tyre noise emission by providing effective drainage of the air entrapped in cavities in the tyre/road interface and thus reducing the air displacement mechanisms, one of which is popularly call “air pumping”. Furthermore, porosity may eliminate the amplification of sound generated by the leading and trailing edges of the tyre/road interface. Finally, tyre noises, as well as the power unit noise from the vehicle, are partly absorbed by the porous surface when the sound propagates over the surface from the tyre to the exterior environment. The closer the propagation path and the source are to the porous surface, the greater is the influence of the porosity
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Friction affects the tangential movements in the tyre/road interface. Adhesion (molecular attraction between two surfaces) affects the “stick-snap” that occurs when a tyre rubber block separates radially from the road surface roughness with which it is in contact. If adhesion is high such separation will be delayed until the separation forces exceed a certain limit, and the tyre rubber will vibrate when released from the surface; this mechanism can be quite important.

Pavement stiffness affects the mechanisms of impact (damping etc) between the tyre tread and the surface texture. All these aspects are discussed further in a paper to the PIARC Durban Congress (Sandberg, 2003) or more fully in other documents (Sandberg and Esjmont, 2002 and Descornet et al, 2000).

4.7. Automatic detection of cracks.

Road surface distress is generally considered to include various types of surface cracking, loss of surface material and deterioration along the edges of roads. Traditionally these aspects have played an important role in informing road managers of road maintenance requirements. The collection of these condition data is usually made by visual inspection of surface defects carried out by inspectors walking along the road. However, the inexorable increase in traffic growth and speed has made this type of inspection more hazardous as well as being slow, expensive and subject to considerable variability between inspection teams.

Thus, the original intention of the Working Group was to report the state-of-the-art of real time automatic equipment for the measurement of surface distress. However, at present, automatic systems have been applied successfully only to surface cracking. As a consequence only automatic detection of cracking is reported to the PIARC Durban Congress (Grondin and Gulyas, 2003).

Two questionnaire surveys have been carried out to gather information from system manufacturers and from road agencies as users. The surveys have identified the best known working systems for automatic crack detection, mainly based on advanced image processing methods. Practical use of such systems, especially for network level assessment is still rare although valuable experience of their use has been obtained from some states of USA, Canada, Australia, a few European countries and Japan.

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