MEASURING AND SPECIFYING SURFACE RIDE

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MEASURING AND SPECIFYING SURFACE RIDE

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SUMMARY

The implementation of ride-quality specifications is growing around the world and it has been proven to be effective in reducing the whole life cost of a pavement.

This paper illustrates the key issues which have to be faced in setting a specification such as what to measure, how to measure it and what are the target levels to be achieved or penalties to be applied.

In the paper it is shown that the allowed initial unevenness has to be defined as a function of local conditions (design, traffic, environment), allowed structural variability and terminal serviceability. The penalties, on the other hand, have to be assessed against the increased maintenance and rehabilitation costs which can be related to the increased initial unevenness.

An example of smoothness specification already in place is also described based, on a specific application on an Italian toll road.

INTRODUCTION

Smoothness (also called roughness or unevenness) is commonly recognized as the pavement characteristic which is mostly perceived by road users. Several studies have shown that the most common roughness indicator (the IRI, International Roughness Index [1], [2]) has a very good correlation with serviceability rating both on rural roads ([3], [4]) and in an urban environment ([5]). For this reason, smoothness is generally associated with "ride quality" of a travelled surface.

It should be kept in mind, however, that smoothness affects much more than just ride quality, as shown in Figure 1, developed by PIARC Committee C1 on surface characteristics [6]. One of the most important effects of surface unevenness is the increase in dynamic loads which results in an increase in the rate of pavement deterioration. The new modelling and design capabilities allow the quantification of the effect on pavement performance, of an increase in surface unevenness. This has led to the definition, in many parts of the world, of construction specifications based on the achievement of a given level of smoothness together with penalties for levels above the acceptable thresholds.

This paper will provide support for setting up ride quality specifications by means of the following:

- To identify WHY it is important to measure and specify ride quality;
- To identify WHAT can be measured and specified;
- To identify HOW this can be measured;
- To identify key issues for SPECIFICATIONS with examples from existing ones.

Even though most of the principles are valid for any type of pavement, this paper will focus mainly on asphalt concrete pavements.

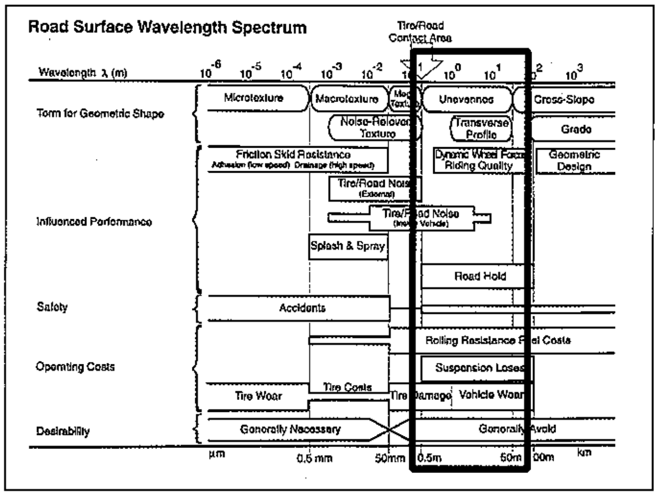

Figure 1 - Bar chart showing wavelengths related to particular pavement characteristics [6]

WHY should we measure and specify surface ride?

The control of smoothness at the construction stage is attracting interest in road authorities as it has been proven that:

- smoother pavements stay smoother longer;
- the rate of deterioration increases as unevenness increases;
- the whole life cost (construction + maintenance and rehabilitation) can be reduced by achieving good smoothness during construction.

The first issue has been proven both with mechanistic modelling [7] as well as by means of statistical analysis on in-service pavements [8].

In terms of deterioration, it is well established that the deterioration curves for unevenness are not linear (fig 2) and it has been shown [9] that the IRI variation over the analysis period is affected considerably by the initial IRI (see example of fig 3).

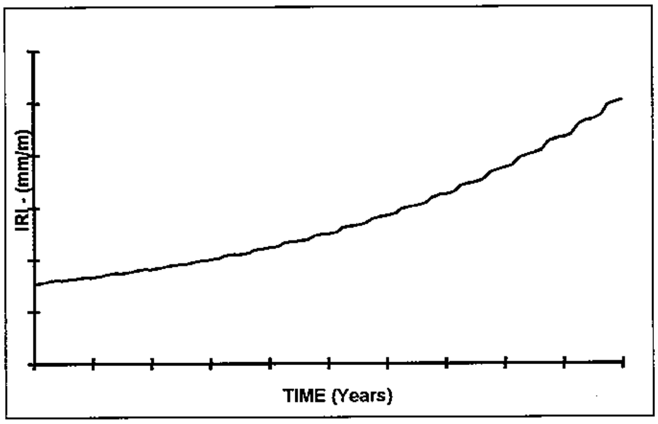

Figure 2 - Typical IRI deterioration curve for an asphalt concrete pavement

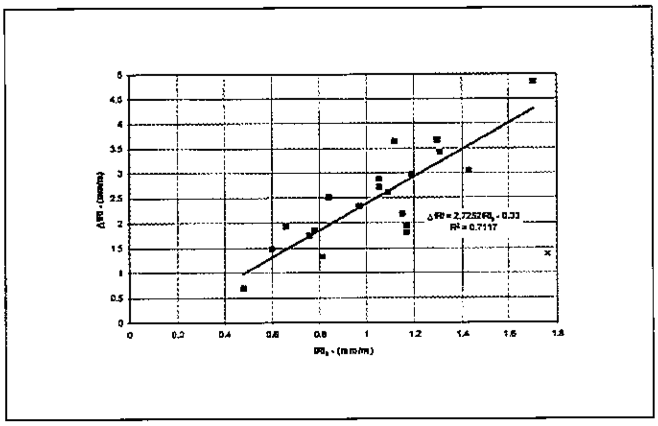

Figure 3 - Example of variation of IRI over the analysis period as a function of initial IRI for a given structure and traffic

It is quite clear, on the other hand, that achieving a better smoothness during construction results in an increase in construction costs. Accordingly, a balance has to be established for each project as a function of the specific local and design conditions. For this reason, NCHRP funded an extensive study covering all US states (NCHRP 1-31) which evaluated the whole life cost of pavements as a function of initial smoothness.

In Figure 4 a typical trend of whole life cost against initial smoothness is shown [8]. ("M & R Cost" means maintenance and rehabilitation cost.) As shown, there is a "point of optimum cost-effectiveness" and a range of smoothness values (eg IRI values) within which the overall cost is virtually constant. For higher IRI values, the maintenance cost rises rapidly while IRI values which are too low are impractical and require a considerable increase in construction and overall costs.

Smoothness specifications are aimed at defining the optimum as well as the range of accepted values without penalties, together with the penalty which has to be applied if the construction smoothness does not reach the target levels (as a function of the increased maintenance and rehabilitation costs). Finally, it also seeks to ascertain the maximum permissible unevenness beyond which the pavement cannot be properly maintained and requires reconstruction.

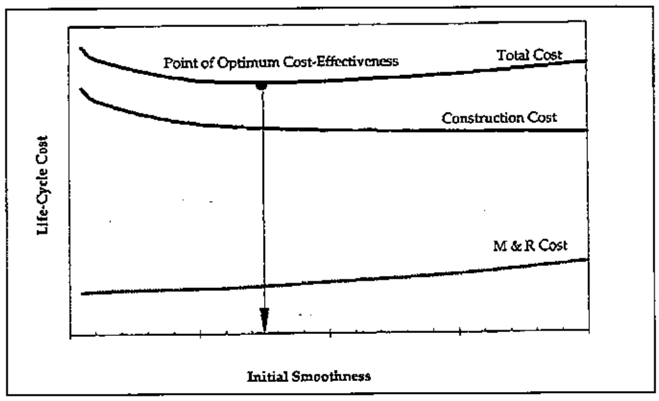

Figure 4 - Typical trend of whole life cost against initial smoothness [8]

WHAT should we measure and specify?

In setting up a specification, it is very important to define the indicators that have to be used and the limiting thresholds.

There are a number of indicators available worldwide to characterize longitudinal unevenness including, for example:

- DLC (dynamic load coefficient)
- ISO 8066 classification (for vibrations)
- slope variance
- power spectral density
- CAPL index
- IRI

The most widely used index around the world is the IRI, which can be considered as representative of the comfort of a "standard" user travelling in a "standard car" over the travelled surface and is, therefore, a very good indicator of ride quality.

The IRI cannot be measured directly over the surfaces but it has to be computed based on the standard procedure defined by the World Bank [1] knowing the longitudinal profile of the pavement surface.

If the IRI index is used for setting specifications; it is essential that the base over which the IRI is to be calculated is defined because the IRI is strongly dependent on the base length calculation [10]. The original international experiment for the development of the IRI index [11] was set over sections 320 m long and the IRI scale provided by the World Bank [1] can be considered as a reference for target values only if that length is adopted.

As a matter of fact, all the most common indicators of unevenness can be calculated once the longitudinal profile is given. The longitudinal profile is therefore widely adopted as the direct measure of unevenness.

HOW should we measure the longitudinal profile?

There are many devices available worldwide to measure the longitudinal profile of a pavement surface. In selecting the best device for profiling, key variables that make a difference between different devices are:

- precision
- speed of testing (ranging from the 150 m/h of a Dipstick to the 110 km/h of a laser profiler)
- cost
- practical applicability (depending on the location and on the length of the section to be tested)

A very interesting overview of profiling is given in [12] while more detailed information on the use of profilers can be found in the website of the "road profilers users group" (www.networkplus.net/rpug).

Since there is a wide range of types of profiler, the analysis of each single type would be beyond the scope of this paper, it is worthwhile mentioning the new devices which are gaining increasing interest in the specific field of construction control which are the "lightweight profilers" (fig 5).

Figure 5 - Example of a lightweight profiler

These devices have the advantage of being cheaper than standard beam profilers mounted on vans since they can move easily around construction sites. In 2001, a specific training course was set up by NHI (in the US) aimed at defining the key issues in using lightweight profilers for construction control [13].

RIDE QUALITY SPECIFICATIONS

In establishing ride quality specifications, it is important to remember that unevenness progression in time is related not only to initial smoothness but also to structural factors such as:

- mean structural properties (layers thickness and structural characteristics);
- variability in structural properties
- as well as to environmental and traffic conditions.

A specification should therefore be set up for any given type of project but, as a general guideline, it should be considered that it should tackle, at least, the following issues:

- what should be measured
- how it should be measured
- what are the targets to be achieved
- penalties (incentives and disincentives)

Several smoothness specification for construction and rehabilitation works currently exist eg in US, Canada and Italy. An AASHTO specification is currently under development. As indicated above, the specifications must be site dependent and any existing specification can be considered only as an example.

As far as the US specifications are concerned, a very wide review of the systems in place in different transport departments is included in the final report of NCHRP Project 1-31 [8]. In Italy, a specification applies to sections of some toll roads. These are described in some detail to provide an example of how a smoothness specification can be established.

Initially, it should be recalled that the performance of the pavement is due to a combination of structural and surface properties. Accordingly, the specifications usually cover a wide range of issues such as:

- "fatigue resistance";
- bearing capacity and evaluation of structural properties;
- skid resistance and macrotexture;
- unevenness (ride quality) in the track and on the joints; and
- acoustic and drainage properties (for porous surface courses).

In this paper, details are provided for unevenness only but it should be recognized that they are strongly related to the specifications given for structural properties.

The two indicators used for controlling unevenness are the IRI calculated over a base length of 20 m and the CPL (planar coefficient) calculated over different wavelengths (2.5, 10 and 40 m). For each of these indexes the following parameters are given:

- measuring specifications;
- target values; and
- penalties

as in the example given below.

IRI over a 20 m base

Measuring specifications

- the profile has to be measured in at least one lane (first or second from the right edge);
- the profile has to be measured between the 15th and the 180th day after the section has been opened to traffic;
- the profile has be measured with a laser profiler;
- the measuring step is set in 0.10 m;
- the profile has to be measured over at least 50% of the paved section length;
- the location of the sections to be tested (each of which cannot be shorter than 500 m) is selected by the engineer as being amongst those that look worst;
- the IRI value to be compared with the target is the average of the 20m section values within a "homogeneous section"; and
- a "homogeneous section" has to include at least 4 values and the measurements has to be "normally distributed".

Example of target values

- for full section paving: IRI(over 20 m) <1.8 mm/m
- for partial section paving: IRI(over 20 m) < 2 mm/m

Example of penalties

- for IRI(over 20 m) < 3.5 mm/m - reduction of 15% in the payment for the surface course
- for IRI(over 20 m) ≥ 3.5 mm/m - milling and reconstruction of the surface course

CPL planar coefficient

- measured for wavelengths of:

< 2.5 m (CP2.5)

2.5 m to 10 m (CP10)

10 m to 40 m (CP40) only as a reference

- it is based on the profile measured over which the IRI20 is calculated;
- the calculation base length is 100 m;
- each value is compared with the target value

Example of penalties

- for CP2.5 < 160 and CP10 < 320 - reduction of 15% in the payment for the surface course;
- for any of the two values above these: milling and reconstruction of the surface course.

	Full section	Partial section
$CP_{2.5}$	< 80	< 120
CP_{10}	< 160	< 240
CP_{40}	< 320	< 480

Example of target values

Note that these are only examples valid for specific traffic conditions and allowable structural variability.

The allowable initial unevenness for different traffic conditions and permissible variability can change considerably, as shown in Figure 6 which is an application of the Roughtime mechanistic-empirical model [9]. It is clear that the maximum allowable initial IRI (IRI0) to restrict the IRI at the end of the analysis period (which, in the example, is set to 20 years) within an allowed threshold is considerably different in the three situations. For lower traffic values, IRI0 can be increased but this should be reduced if a wider variability in structural properties is allowed. In addition, the IRI threshold at the end of the analysis period (in the example, IRI20) should be established based on the required terminal serviceability, which is generally different from country to country and for different road types (or design speeds). If the design final serviceability is given in terms of PSR or PSI, the corresponding IRI can be defined based on literature correlation such as the ones given in [3], [4] or [5] (the latter refers only to urban streets).

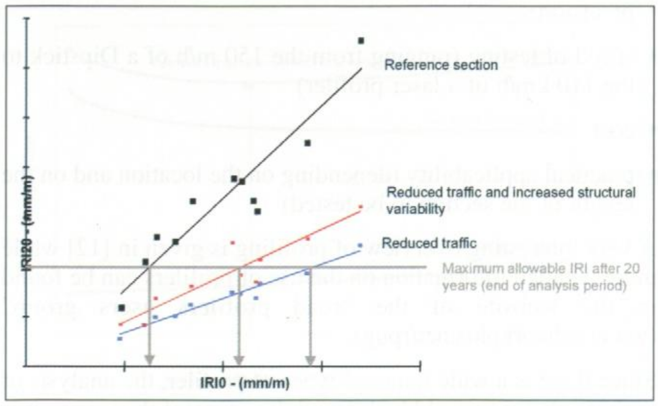

Figure 6 - Example of different IRI20 against IRI0 curves when changing traffic and allowable variability (developed with the Roughtime model [9]).

CONCLUSIONS

Ride quality is one of the key factors affecting user perception and pavement performance over time.

Several studies have shown that improving initial smoothness reduces pavement deterioration, in time increasing the pavement performance over the analysis period. It should be noted, however, that given the increase in cost related to constructing a smoother pavement, the optimum level of required smoothness should be established based on the analysis of the whole life costs (construction costs + maintenance and rehabilitation costs).

In setting specifications, it should be noted that several indexes and devices are available for characterizing ride quality. Specifications should set the requirements for testing and for calculating the indexes to be compared with the target values (as the base length if IRI is used). The selection of the appropriate device is dependent on the type of application (location and section length) but for specific application on construction sites, lightweight profilers can be extremely useful.

Finally, the definition of target values for initial smoothness and penalties should be related to the specific design, to the local environmental and traffic conditions as well as to the permissible variation in the structural properties.

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