Québec's Experience with Smoothness Specifications on Concrete Pavements

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Abstract

Smoothness is one of the most important characteristics of pavement because it directly affects the traveling public. Furthermore, the initial smoothness reflects the quality of construction and is an essential condition for the pavement's future performance. The Québec Ministry of Transportation (MTQ) has been using smoothness specifications for all concrete pavement projects since the early 1990s. The Profile Ride Index (PRI) was replaced in 1998 by the International Roughness Index (IRI) so the same specifications would apply for concrete and asphalt pavements. IRI specifications stated that profile measurements be made with a truck-mounted inertial profiler after the work is finished. Today, some contractors are still using the profilograph for control purposes during construction and there has been an increase in diamond grinded surface area, up to 32% on some projects. A study was undertaken in 2000 to assess different kinds of roughness measuring equipment (profilograph, Disptick©, lightweight inertial profiler, rolling profiler and 2 types of truck-mounted inertial profiler) and determine those that would be best suited for construction control. This study concluded that the rolling profiler was the best equipment for this purpose. In 2003, MTQ experimented with modified specifications requiring that roughness measurements be made using a rolling profiler and forbidding any surface correction before the measurements were made. The main benefits of this method were that MTQ could check the 100-metre control lots soon after they were built instead of waiting until the end of the work and the contractors could also use the results for own quality control.

Introduction

Québec's Ministry of Transportation (MTQ) manages a 28,000 kilometre road network, including 1,200 kilometres in concrete. Even though concrete pavements represent only 4% of the whole network they bear 35% of the total traffic so each of these roads is heavily trafficked. Any pavement roughness will thus affect a lot of roadway users. Smoothness is perhaps the most important pavement

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characteristics for the travelling public and the smoother the pavement is immediately after construction the longer it will stay in an acceptable condition.

This paper presents the evolution of MTQ smoothness specifications for concrete pavements, from profilograph Profile Ride Index (PRI) to rolling profiler International Roughness Index (IRI) over a course of 10 years.

For researchers and practitioners, this paper provides a case study of different trials to determine the most appropriate device for construction smoothness control as well as the most representative index of the pavement surface condition.

History of MTQ Smoothness Specifications for Concrete Pavements

When the MTQ first began using concrete slabs for road construction, the surface of the slabs was checked by means of a 10-foot ruler, which was placed parallel to the axis of the paved surface at five-foot intervals. In the Standard Specifications, any irregularity exceeding 1/8 of an inch had to be corrected by adding or removing fresh concrete (Ministère de la Voirie, 1945). A similar specification is still in effect today.

The MTQ began including smoothness specifications in concrete road construction contracts in 1994. Construction projects for Highway 15 in Montréal and Highway 440 in Laval instituted the use of the profilograph to control smoothness (Dallaire, 1994). At the time in North America, the profilograph was considered the best device for measuring smoothness. Given that it had a reach of 7.5 m and that it did not matter whether there were changes in operators or changes in the direction, it was the ideal equipment for that purpose. Contractors could also use it as a control device because of its lightness. It allowed them to quickly find out the results and to adjust their paving method on the next section.

At that time, contractors' terms of payment included the application of penalties and bonuses depending on the value of the profile that was achieved. Contractors could also use diamond grinding to correct smoothness and thereby come within the range of acceptable values and even the bonus range. Making bonuses possible has been found to be an excellent incentive to promote high quality work by contractors. Furthermore, corrections were made as the work proceeded (i.e., while the road was still closed to traffic).

Meanwhile, in 1993 the MTQ introduced a procedure for controlling the smoothness of new asphalt surface layers on heavily trafficked pavements using an inertial profiler (Durand, 1997). The need to have reliable, high-tech equipment for road management and smoothness control became apparent in the early 1990s. Thus, in November 1994 the MTQ acquired a Road Surveyor T-6500 inertial profiler from K.J. Law. Earlier, in 1990, the MTQ had adopted the International Roughness Index (IRI) for its inventory and road repairs management needs. Obtaining IRI ratings equal to or lower than 1.2 m/km became the main requirement in the MTQ's smoothness specifications.

Construction on the westbound portion of Highway 40 at Vaudreuil marked the first time that a contractor had to meet smoothness requirements using an inertial profiler (Cormier et al., 2001). This contract, which contained a performance guarantee, included profilograph specifications for smoothness, but performance specifications over the ten-year guarantee period used IRI specifications.

In 1998, the regional office of Montréal decided to use smoothness specifications adapted from the specifications of asphalt pavements in spite of the fact that the MTQ's standard for concrete pavements was the Profile Ride Index (PRI) measured by a profilograph. The contractual specifications of the time did not prevent the correction of surfaces before the measurement of smoothness.

After a few experimental contracts including IRI smoothness specifications measured by an inertial profiler, the MTQ officially adopted this procedure in 2000, and it was added to the Standard Specifications in 2003.

Table 1 shows how the main criteria for smoothness specifications evolved between 1994 and 2003. The requirements with regard to bonuses and penalties were made more stringent between 1994 and 1998, and the minimum value for the penalty range was lowered from 180 mm/km to 160 mm/km, a value recommended by the American Concrete Pavement Association (ACPA, 1990). A turning point came in 1998, when IRI specifications for asphalt pavements were adopted on some projects for concrete pavements. The target IRI value is 1.2 m/km, and the limit where a corrective work is required is 1.8 m/km. The maximum penalty was increased to 85% of the unit cost of concrete. In the years that followed, the length of control lots for measurement was set at 100 m, and pre-established per-lot values for penalties were added to the smoothness specifications.

Table 1 – Comparison of Smoothness Specifications; 1994 to 2003

Description	PRI 1994 A-440 Laval	PRI 1998 A-440 Laval	IRI 1998 A-40 Montréal	IRI 1999 A-40 Montréal	IRI 2003 Std. Spec MTQ
Sub-lots	-	-	100 m lane	100 m lane	-
Lots	500 m lane, 200 m min	500 m lane	500 m lane	1000 m lane	100 m lane
Blanking band	5 mm	5 mm	-	-	-
Corrections needed	Scallop>10 mm over 7.5 m	Scallop>10 mm over 7.6 m	IRI sub-lot > 1.7 m/km	IRI sub-lot > 1.7 m/km	IRI lot > 1.7 m/km
Upper limits	PRI>240 mm/km = correction	PRI>240 mm/km = correction	4 sub-lots/5 ≤ 1.2 m/km 5 sub-lots/5 ≤ 1.4 m/km	7 sub-lots/10 ≤ 1.2 m/km 10 sub-lots/10 ≤ 1.4 m/km	Lots ≤ 1.2 m/km
Penalties	180<PRI<240 mm/km	160<PRI<240 mm/km	1.2<IRI.< 1.8 m/km	1.2<IRI< 1.8 m/km	1.2<IRI<1.8 m/km
Range without bonus or penalty	110<PRI<180 mm/km	110<PRI<160 mm/km	1.1<IRI.< 1.2m/km	1.1<IRI< 1.2m/km	-
Bonus range	PRI<110 mm/km	PRI<110 mm/km	0.8<IRI.< 1.0 m/km	0.8<IRI< 1.0 m/km	IRI<1.2 m/km
Maximum penalty	94% of unit cost	90% of unit cost	85% of unit cost	85% of unit cost	2,000 $CAN/lot
Maximum bonus	105% of unit cost	103% of unit cost	105% of unit cost	105% of unit cost	200 $CAN/lot

Problems Encountered in Changing the Index and Measuring Equipment

In the mid-1990s, the industry and the MTQ began to address fundamental concerns regarding the type of measurement equipment to use in assessing smoothness and the consequences of replacing one index by another.

The main objective for smoothness specifications is that the roadway users obtain the best level of service possible. This level of service should not depend on the material used; therefore the requirements should be the same for both types of pavement.

A U.S. study (Ksaibati et al., 1994) showed that 30 states used profilographs to measure compliance with smoothness specifications on concrete pavements, while only two states used inertial profilers. Ontario's Ministry of Transportation also uses the profilograph. In general, IRI is used only at the network level as an index for pavement management systems.

The profilograph appeared at that time to be better adapted to the work than the truck-mounted inertial profiler or rather it was used more widely than other measurement devices and indices. Nevertheless, profilograph use posed a number of problems:

- The MTQ profilograph was not computerized, which was not practical for applying smoothness specification requirements.
- Before having the contractors carry out control tests, the MTQ must first establish a calibration procedure or some form of certification.
- The inertial profiler could theoretically provide the results of the PRI index, but no clear correlation had yet been established between results obtained by the computer processing of data from the profiler and results obtained from a real profilograph.

But contractors have always insisted on using the profilograph to measure smoothness on concrete pavements because it allows them a closer quality control. It allows them also to adjust production quality on a day to day basis and to locate and quantify the extent of surface distortions (must grind). On the other hand, truck-mounted inertial profiler results are available only when a phase of work is completed or when the entire contract is finished and the road has been put into service.

For the MTQ, the problem in measuring smoothness with a truck-mounted inertial profiler on concrete pavements can be summed up as follows:

- First, since they do not have smoothness data during the course of a contract, MTQ engineers are unable to determine how much concrete surface correction will be required. On several occasions during the contract, profilers were requested to carry out tests in order to obtain preliminary results.
- Smoothness testing after the work is finished, could, despite corrections made during the project by the contractors, lead to additional corrections being needed. The closing of some sections of the road could happen again after the road had been opened to traffic. Roadway users were further inconvenienced, after the work had been completed. In addition, correcting the surface by grinding often created the need to reseal the joints in these areas. This work was often postponed to the following year because of cold weather.
- The penalties that are imposed for smoothness defects are more severe for concrete pavements than asphalt pavements. Cost corrections are established according to the unit price by ton for asphalt and by cubic metres for cement concrete. But, given the respective costs and the

fact that concrete pavements are thicker than asphalt pavements, these cost adjustments penalize concrete pavement contractors much more.

Before the year 2000, both the MTQ and the contractors carried out a study to find a correlation between the PRI and IRI indices. For example, using a blanking band of 0 (0.254 mm) and 143 comparative statistical data from PRI and IRI, the contractors found a linear correlation coefficient of 0.695, which is clearly insufficient for using a device for contracts. Even though the correlation between the two indices is difficult to determine, the contractors still use rules of thumb for certain PRI values. For example, an IRI value of 1.2 m/km corresponds to a profilograph index range of 441 mm/km to 485 mm/km, according to a contractor (Demix, 2002). Diamond grinding was carried out when there was a distortion of at least 10 mm over 7.6 m and when the PRI was higher than 570 mm/km (IRI of 1.6 or more).

The Search for a Solution to the Index/Measurement Equipment Problem

Since the introduction of smoothness measurement by means of a truck-mounted inertial profiler in 1998, contractors have continued using a profilograph for own quality control. Contractors are still requested to make corrections by grinding when required (as noted above) despite the problem in correlating the two indices. As a result of this situation, smoothness evaluation by a truck-mounted inertial profiler shows in some cases that the lots were still defective and thus in need of an additional correction. It appears that the standard watchwords for concrete pavements projects ”Get in, get out and stay out” were not followed very much in these cases.

The MTQ decided to keep the same index for measuring smoothness, no matter what the type of pavement, despite the insistence of concrete pavement contractors to go back to using the PRI.

The ideal solution for resolving this problem would be to find a device that could be used to measure IRI smoothness specifications during construction and at the same time could be used by the contractors for own quality control. Such a device would have to possess the following characteristics: be computerized and able to detect depressions or bumps; be light and small enough to go onto the concrete slabs in the days immediately following the placing of the concrete; be easy to operate and run at the same speed as a profilograph; meet the bias and repeatability requirements of a Class 1 device in accordance with the ASTM E950 standard; not being affected by surface texture; be affordable; and be readily available for rental or purchase.

In 1995, the MTQ went looking for a device that was faster than the Dipstick for calibration purposes. It obtained a rolling profiler Profilite 300 from CSC Profilair (see Figure 1). It was seen immediately to possess many of the characteristics necessary for measuring smoothness of concrete pavements.

In 1998, the regional office of Montreal and the contractors asked for the go-ahead to test this device within the reconstruction project on Highway 40 in east Montréal. Before it was used on-site, a preliminary evaluation was made to become familiar with its operation and to validate it according to the ASTM E950 standard. The evaluation concluded that the device was easy to use and user-friendly despite its limited battery life and its operating speed. Its profiles met the bias and repeatability requirements that complied with the standard when they were filtered and compared with the reference device (Dipstick). However, the IRI data presented some discrepancy when compared to the IRI obtained by other devices used by the MTQ. The software used with the Profilite 300 can simulate a profilograph in locating areas where the profile needs to be corrected (St-Laurent, 1998).

Figure 1 – Profilite 300 of CSC Profilair

This device was calibrated more thoroughly a year later (St-Laurent, 1999). Its accuracy was found to be excellent because the grinding zones measured by the profilograph and simulated by the Profilite corresponded. However, its average speed of 1.5 km/h is low and it cannot cover more than the width of one wheelpath at a time. The lack of experience using this device, combined with the pressure on the worksite in 1998 during the first test to determine the grinding zones in synchronous time with the grinding, led to difficulties in interpreting the measurements for correlating the IRI to the profilograph. It was therefore decided to put this solution on hold for a number of years, during which time we would try to find a better solution to the problem.

In 2000, the MTQ conducted a new study to find a way of correlating the two indices and find a common basis for comparison, for purposes of establishing specifications for concrete pavements similar to the ones used for asphalt pavements (Grondin, 2000). Following is a summary of the information obtained through that study:

- Profilographs, although still used extensively, were developed several years ago when the related technology was just being developed. The requirements were accordingly less stringent at the time. Today, there are serious doubts concerning their reliability for measuring the smoothness of new pavement.
- It is possible but not desirable to correlate IRI with PRI because doing so requires a lot more on-site effort (number of passes and control testing of the device), and the correlation is extremely various with a range of R^2 going from 0.7 to 0.95.
- The profilograph simulations calculated on the basis of profiles obtained by the profilers are considered to be good as far as the PRI and grinding zones are concerned.

- Everything indicates that the specifications should be established based on the pavement profile, and not on the device being used.
- The trend in evaluating smoothness specifications on new pavements is towards using a lightweight profiler, which led to the MTQ's interest in doing its own testing.

The MTQ then suggested carrying out a preliminary study made up of three steps, the first of which was to evaluate the profile measurement devices used for concrete pavements. These devices were as follows: inertial profilers (lightweight and truck-mounted), profilograph, rolling profiler and Dipstick. The next step was to determine how useful the devices were in verifying a new concrete pavement, and the last step was to propose smoothness specifications.

The equipment was evaluated during the reconstruction of the northbound section of Highway 13 in Laval in the summer of 2000. Both test runs were each 500 m long. The pavement was made of jointed plain concrete slabs. The joints of the first section (LW1) were sealed with a preformed material, whereas only the initial saw cuts (3 mm) were made in the joints of the second section (LW2). The surface was transversely tined according to a pre-established random sequence (figure 2).

Sections of pavement textured with transverse tining were chosen because this technique would probably become the standard for finishing the surface. They were also chosen in order to assess the effect of the tining and the joints on laser profile measurement.

Figure 2 – Test section on Hwy 13 (Laval) and a view of the transverse tining

Table 2 provides the main details on the types of device used and the number of tests. The Dipstick was used to measure the reference profiles of the right and left wheelpaths of each test lane. The standard required a minimum of ten passes, which was done by the inertial profilers (lightweight and truck-mounted). The Profilite 300 had already been evaluated in 1999 and therefore only a few passes have been done for this study.

Table 2: Number of Test Passes Made by the Devices

Device	Number of Passes				Owner and Operator
	Track LW1		Track LW2		
	Left	Right	Left	Right	
Dipstick	1	1	1	1	MTQ
CSC Profilair Profilite 300	4	2	2	2	MTQ
K. J. Law T-6500 Inertial Profiler (truck-mounted)	15	15	13	13	MTQ
Rainhart profilograph	5	5	5	5	Demix Construction inc.
K. J. Law T-6400 Profiler (lightweight)	12	12	12	12	Advance Testing (ATC) inc.
ICC Inertial Profiler (truck-mounted)	10	10	---	---	CRCAC

Figure 3 shows the lightweight T-6400 inertial profiler being tested and the Rainhart profilograph, which some contractors use for quality control.


Figure 3 – T-6400 lightweight profiler and Rainhart profilograph

The study (Delisle, 2001) led to several interesting conclusions. First, the use of the profilograph presents many disadvantages. It does not give the road profile and thus does not provide the IRI: this means that it cannot be assigned a class under the ASTM E-950 standard. It does not detect all wavelengths affecting the IRI or the ride comfort of roadway users. It is a Level 3 device according to the World Bank because of its low resolution and poor sampling. Also, it requires three to five passes to obtain a good PRI estimate.

Secondly, the IRI is the index recommended for use in conjunction with smoothness specifications because it is sensitive to the wavelengths that affect the ride comfort of users and because it is defined as a mathematical transform of the longitudinal profile, which makes the measurement independent of the device and stable over time.

Also, the author of the report do not recommend the use of the lightweight T-6400 for purposes of smoothness specifications or contractors' own quality control because even though it detects the location for grinding and provides a road profile, it is not classed for repeatability and has a Class 2 designation for bias. Its poor performance in repeatability has been attributed to the difficulty drivers have in keeping the vehicle in the wheelpaths, near or on the marked lines. On the other hand, the literature available at the time of the study indicated that the LISA lightweight profiler was better in accuracy and repeatability than the one that was tested.

Lastly, the rolling profiler Profilite 300 again gave very good results. It is thus the device recommended for purposes of contractors own quality control and smoothness specifications because it provides a road profile, detects the locations for grinding, and is easy to use. It is classed at 1 for bias and 2 for repeatability according to the ASTM E-950 standard and it has a variation coefficient usually lower than 5%, which demonstrates good repeatability for IRI measurement. Note that the truck-mounted profilers were classed similarly to the rolling profiler.

After the report on this study was produced, the MTQ officially adopted the IRI for its concrete pavement smoothness specifications. The penalties and bonuses were doubled to incite concrete contractors towards better smoothness, given that concrete pavements normally last much longer than asphalt pavements.

Even though the study recommended a rolling profiler as the best compromise for use in conjunction with smoothness specifications for concrete pavements, the truck-mounted inertial profiler continued to be used for construction projects. MTQ project engineers had several questions about the relevance of using a rolling profiler. Can reliable and reasonably-priced models be found on the market? Does it give contractors results for own quality control similar to the results obtained upon completion of the project by the truck-mounted inertial profiler? Should it undergo a pre-qualification procedure before the start of the construction season?

Problem of Excessive Grinding to Correct Smoothness

As indicated above, MTQ project engineers did not feel there was an immediate need to modify the type of device used to measure smoothness. They were satisfied with the use of the truck-mounted inertial profiler on projects until grinded areas became excessive.

Table 3 compiles information on percentage of grinded areas for projects from 1998 to 2002. The average percentage before 1998 was often below 10%, which was an acceptable figure. Both projects in 1998 were carried out by the same contractor in the same conditions, excepted for the smoothness specifications which required the profilograph in one case and the truck-mounted inertial profiler in the other case. According to the contractor, the higher grinding percentage was largely due to the use of the IRI. In the following years, we saw that the average grinding rate stood near 15%, with the highest at 32%.

Table 3 – Grinding Percentages for Various MTQ Projects

Project	Grinding % (approximation)	Index
Hwy 440 Laval 1998	8	PRI
Hwy 40 Montréal 1998	16	IRI
Hwy 40 Montréal 1999	20	IRI
Hwy 13 North Laval 2000	14	IRI
Hwy 13 South Laval 2001	18	IRI
Hwy 20 East Boucherville 2001	32	IRI
Hwy 20 East Boucherville 2002	16	IRI
Hwy 15 North Boisbriand 2002	15	IRI

The grinding percentage for the Highway 20 project in 2001 led the MTQ project engineers to question the relevance of grinding so great a surface area to achieve the required smoothness. In addition, the longitudinal grinding of the surface could create heterogeneous skid resistance because the original texture is transverse tining.

The contractor involved gave several reasons to explain the excessive grinding (Demix, 2002):

- The PRI and the IRI were poorly correlated.
- Using an inertial profiler to measure smoothness on transverse tining and joints has a noticeable effect and overestimates the IRI value.
- Starting the work on half the roadway makes paving operations more difficult.
- There was no open grade drainage layer, which would have improved the profile before concrete was placed.
- It is difficult to obtain a stable work platform for the tracks of the slipform paver when moving along the open grade edge drains.
- In 2001, the project had heavy traffic constraints.

In our opinion, the limited capacity of some slipform pavers for thicknesses approaching 300 mm could also explain the smoothness problems.

Experimental Smoothness Specifications for Projects in 2003 and 2004

Because of the excessive surface grinding done in previous years, MTQ authorities requested that a solution be developed for solving the problem. Engineers involved in the construction of concrete pavements agreed that contractors were using grinding systematically and over too large an area. Contractors were taking advantage of the smoothness specifications to meet the minimum requirements and thereby avoid penalties. Grinding has the disadvantage of eliminating locally the transverse tining texture. It was thus suggested that the current requirements be revised in order to optimize the grinding areas in the sections where smoothness has to be improved.

Experimental smoothness specifications were developed on the basis of the previous specifications. Some were modified or added, as follows:

- The rolling profiler is to be used as the measurement device. Each wheelpath is measured individually and the IRI value to be used for control purpose is the average of both wheelpaths values.
- Smoothness is to be measured along the construction, within four working days after the contractor's request. A minimum length of 500 metres must be paved before such a request may be made.
- No grinding is allowed before smoothness is measured. This is to ensure that grinding will be done in the required areas only.
- Control lots for which IRI values are higher than 1.2 m/km and lower than 1.8 m/km will be penalized and the contractor will not be allowed to correct them, excepted in areas with bumps or depressions exceeding 5 mm in height over a length of 3.0 m. The contractor will only use grinding for the correction of lots where values exceed 1.7 m/km from the start.
- A penalty of 5.40\$CAN/m^2 will be applied to the areas which will have been grinded. This provides an incentive to do as little grinding as possible.

Experimental specifications were applied in 2003 to a 9 km reconstruction project on Highway 40 in Montréal. This pavement is made up of three lanes in continuously reinforced concrete and shoulders in jointed plain concrete. The surface was textured by means of transverse tining.

The main comments received from people involved in this experimental project were as follows:

- Contractor: He was satisfied with being able to receive the results quickly and contemplated the possibility of buying a rolling profiler the next year.
- Control laboratory: The smoothness tests using a rolling profiler were long and required them to walk several hundreds of metres. The surface of the concrete had not always been cleaned before the testing and the contractor has waited to long at the beginning of the project to request smoothness measurements.
- MTQ project manager: Overall, he was very satisfied with the method. Results were provided quickly. There was some uncertainty regarding the calculation of bumps and depressions on the basis of data profile. It had been necessary to make on-site verifications using a 3 m straightedge. The cost of the testing was estimated at 0.35\$CAN/m^2, not including rental of the equipment. The main advantage was that the results of the smoothness measurements were quickly obtained and that the need for additional work after the opening of the road was very limited.

One of the concerns regarding the interdiction of grinding between 1.2 m/km and 1.8 m/km was that there would be a systematic increase in the average IRI (Table 4). This was not the case because the final average values were near the target value of 1.2 m/km (1.18, 1.24 and 1.30 respectively for the right, centre and left lanes after correction). Also, the grinding percentage obtained for the three lanes was 4.5%, which was well below the rates obtained in recent years.

Another variation from the Standard Specifications (Table 1: CCDG, 2003) was proposed for the Highway 15 Southbound in Boisbriand in the same year. Because it was assumed that the smoothness of the concrete pavement would remain relatively constant over time, the IRI target value was raised from 1.2 to 1.4 for that project. As shown in Table 4, the average IRI is the same as in the experimental contract but the grinding percentage is much higher.

Table 4 – Average IRI Values for Various Projects between 1998 and 2004

Project	Average Final IRI (m/km)	Remarks
Hwy 40 Montréal 1998	1.2	
Hwy 40 Montréal 1999	1.1	
Hwy 13 North Laval 2000	1.0	(1,1 before grinding)
Hwy 13 South Laval 2001	1.1	(1,3 before grinding)
Hwy 20 East Boucherville 2001	1.1	(1,7 before grinding)
Hwy 20 East Boucherville 2002	1.2	
Hwy 40 East St-Laurent 2003	1.24	Measured by the rolling profiler, 4.5% grinding
Hwy 15 South Boisbriand 2003	1.24	Measured by inertial profiler with Std spec., 1.4 as a target value, ±17% grinding
Hwy 40 West St-Laurent (1) 2004	1.17	Measured by inertial profiler 2.8% grinding
Hwy 40 West St-Laurent (2) 2004	1.23	Measured by a rolling profiler, 2.8% grinding

Due to the success obtained in 2003 for the new specifications using a rolling profiler, the experiment was repeated in 2004 for the two MTQ projects. There were no major changes made to the 2003 specifications when they were applied to the 2004 projects. However, because the device used in 2003 was found to be defective before the projects began, the MTQ had to find another supplier. We looked for one that would have reliable devices in sufficient quantities in the event that a private engineering firm or contractor wished to buy one. This was seen to be all the more necessary because it is difficult for the contractors to use their right of appeal if there is only one device available in the area.

Several months passed before the new device was functional and properly calibrated. Smoothness results were needed quickly during the work and it was necessary to use a truck-mounted inertial profiler (International Cybernetics Corporation – ICC profiler) in several lots. This device was used almost entirely for the St-Laurent Highway 40 West project (1), while the rolling profiler (ICC's Surpro 2000) was used for the St-Laurent Highway 40 West project (2).

The results for the projects in 2004 are given in Table 4. The grinding rates were negligible (2.8%) and the IRI averages were similar as before. The experimental smoothness specifications can now undeniably be said to have been a success. Unfortunately, the comparison of the results from the passes made by two devices (Surpro 2000 and ICC inertial profiler) over the same ten 100-metre sections in the St-Laurent Highway 40 West project (1) was made and we found out an IRI difference of up to 0.3 m/km between both devices.

Following these observations, two series of calibrations were performed with the devices, the first at the work site itself in mid-September and the second in October on Highway 13 in the city of Laval. In the first case, the purpose of the tests was to evaluate the average IRI bias obtained on four 100 m segments using the Surpro 2000 compared to the average bias obtained using the two types of truck-mounted inertial profilers in Québec (ICC, owned by CRCAC and K. J. Law, owned by the MTQ). The average bias obtained for the CRCAC device was ±0.0 m/km for the four segments, while the average bias for the MTQ device was 0.0 m/km for two segments and -0.1 m/km for the other two segments.

In the second case, the main objective was to determine whether the devices complied with the ASTM E950 standard when tests were conducted on a concrete pavement with transverse tining. The results (Leroux, 2005) for the comparison between the Dipstick and the Surpro 2000 rolling profiler are given in Table 5, with the Dipstick used as a reference device.

Table 5 – Results for the Calibration of the Surpro 2000 in October 2004

Elements Evaluated	ASTM Standard	Results	Remarks
Number of passes required	>10	3	Bias and repeatability were calculated for a number of required passes less than the specification. Since the 3 passes are repeatable, bias is probably well estimated
Reference value • Average • Number of points	 - >1057	 -0.13 1000	The number of points is significant
Average elevation of all passes • Average	 -	 -0.09	
BIAS (mm) • Bias • Bias – absolute value	 - <1.25	 0.04 0.95	The Surpro 2000 is Class 1 according to the standard
REPEATABILITY	<0.38	0.34	The Surpro 2000 is Class 1 according to the standard

The rolling profiler Surpro 2000, tested on a concrete pavement with transverse tining, was classed 1 for both bias and repeatability. MTQ thus established that this device is reliable.

Conclusion

After several trials over a period of 10 years, the PRI index measured by the profilograph was replaced in the smoothness specifications by the IRI index measured by a profiler. The regular truck-mounted profiler used by MTQ at the end of the work is not of great help to the contractor's quality control. So either the contractor should be able to perform his quality control with an affordable profiler that would correlate very well with the final quality assurance testing by the MTQ or MTQ should use a lighter profiler that can be used along the work so the contractor could get the results quickly and adjust his operations as necessary.

Different light profilers were tried to shorten the delay for smoothness evaluation and the rolling profiler was found to be the most appropriate regarding lightness, cost, compliance to ASTM E950 and availability. This profiler is also not affected by the surface texture.

The rolling profiler will be tested again in 2005 to confirm it's suitability for construction smoothness control and if the outcome is positive, the device will be included permanently in MTQ Standard Specifications.

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