ACCELERATED PERFORMANCE TESTING OF CANADIAN ASPHALT MIXES USING THREE DIFFERENT WHEEL RUT TESTERS

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ABSTRACT

Asphalt pavement rutting is one of the most common and destructive pavement distresses observed on Canadian roads, particularly in the urban environment at intersections. A reliable, accelerated laboratory performance test to evaluate rutting resistance of asphalt mixes is considered necessary. There are three wheel rut testers that are commonly used for asphalt testing: Asphalt Pavement Analyzer; Hamburg Wheel Rut Tester; and the French Laboratory Rutting Tester. All three wheel testers are in use in Canada. Hot-mix asphalt rut resistance testing using the French Laboratory Rutting Tester is required by the Quebec Ministre des Transports on high volume roads. Other provinces currently do not routinely require rutting resistance testing, even for roads with very heavy traffic loading.

An accelerated performance testing study is being carried out using all three rut wheel testers and Canadian asphalt mixes. The objective of this study is to compare the performance of the asphalt mixes in the field with their ranking in three different rut wheel testers. Based on the results, comments will be forwarded on the effectiveness of the test equipment in predicting asphalt concrete rutting. This paper describes the equipment, procedures, criteria and a potential use of the rut testers. However, as the study has not been completed yet, it is too early to provide final conclusions.

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1. Introduction

There are five major asphalt pavement distresses that may result in loss of performance: fatigue cracking; rutting; thermal cracking; friction; and moisture susceptibility. Asphalt pavement rutting is one of the most common and destructive pavement distresses observed on Canadian roads (Photograph 1), particularly in the urban environment at intersections. Asphalt pavement rutting can be caused by insufficient pavement structural support allowing excessive stress to be transferred to the subgrade (structural rutting); however, the most common type of rutting is asphalt ‘stability’ rutting caused by the plastic movement of asphalt mix under heavy, often slow moving loading. The cost of asphalt pavement rutting repairs can be very high and disruptive on traffic operations. A reliable, accelerated laboratory performance test to evaluate rutting resistance of asphalt mixes is considered necessary. It would be beneficial for use in verifying mix designs, for pavement failure investigations and for new materials evaluation. Although the AASHTO 2002 guide includes the procedure for evaluation of asphalt mix resistance to permanent deformation, its full implementation will likely take years and the recommended equipment is not readily available and is considered to be expensive.

PHOTOGRAPH 1 Asphalt pavement rutting due to plastic movement of the asphalt mix under heavy loads.

There are three wheel ruts testers that are commonly used for asphalt testing: Asphalt Pavement Analyzer; Hamburg Wheel Rut Tester; and French Laboratory Rutting Tester. All three wheel testers are in use in Canada. Hot-mix asphalt rut resistance testing using the French Laboratory Rutting Tester is required by the Quebec Ministre des Transports on medium to high volume roads [1]. Other provinces currently do not routinely require rutting resistance testing, even for roads with very heavy traffic loading.

An accelerated performance testing study is being carried out using all three rut wheel testers and Canadian asphalt mixes. The study includes various mixes of known, proven field performance obtained from Quebec and Ontario. All mixes are being tested in each of the rut wheel testers.

2. Methods of Permanent Deformation Evaluation

The Superpave Mix Design and Analysis System developed in the early 1990's in the U.S. under the Strategic Highway Research Program (SHRP) initially intended (in Step 4) to provide a method to analyze the potential performance of the mix. However, Step 4 is not available yet. Conventional mix design methods, such as Marshall, are not able to rank the mixes in terms of the resistance to permanent deformation.

The tests that have the potential for predicting rutting resistance include: uniaxial static and repeated load tests; triaxial static and repeated load tests; SST frequency sweep test; and simulative tests [2]. The simulative tests primarily include wheel tracking tests. The Asphalt Pavement Analyzer (APA), Hamburg Wheel Rut Tester (HWRT) and French Laboratory Rutting Tester (FLRT) are considered to provide reasonable results and correlation with field performance. These rut testers have been used in Canada and the United States for: mix designs; pavement evaluation; assessment of new materials; quality control; and pavement failure investigation.

2.1 Hamburg Wheel Rut Tester (HWRT)

The HWRT (Photograph 2) is used for evaluation of rutting and moisture resistance of asphalt mixes [3 to 6]. In a conventional HWRT test, a slab of hot-mix asphalt is submerged in hot water (Photograph 3) and a steel wheel is rolled across its surface. Two samples can be tested simultaneously in one HWRT run. The wheels can be either steel (47 mm wide) or rubber (50 m wide). The load applied to the wheels is 710 ± 1 N. The customary temperature for the HWRT test is 50 ºC, which was developed in Europe for a climate close to a Superpave high temperature PG of 58. However, the testing specifications may differ, and some researchers recommend a testing mixes incorporating a PG 58 asphalt cement at a temperature of 58 ºC. The test path is 230 ± 10 mm long and the average speed of each wheel is approximately 1.1 km/h (53 ± 2 wheel passes per minute). Samples can be either 260 x 300 mm and 40, 80 or 120 mm thick slabs, or 2 or 3 cores or laboratory prepared Superpave briquettes of 150 mm diameter. The samples are compacted to 7 ± 1 percent air voids. The number of wheel passes being used in the United States (Texas DOT, Washington DOT and Colorado DOT, for instance) [7 and 8] is 20,000 although up to 100,000 passes can be applied. Susceptibility to rutting (and moisture susceptibility) is based on pass/fail criteria. Colorado DOT recommends maximum allowable rut depth (Photograph 4) of 4.0 mm at 10,000 wheel passes and 10 mm at 20,000 wheel passes while the Texas DOT specification requires that the rut depth be less than 12.0 mm at 20,000 passes (in a wet test using a steel wheel) [7]. The analysis of HWRT testing results can include postcompaction consolidation, creep slope, stripping inflection point and stripping slope. In Europe, EU prEN 12697-22 is used, although some countries have developed their own standards (UK ISO 5725, German Hamburg RST 4/90 and Czech TP 109/A1, for instance) . Some of the European standards specify the requirements for a dry test using the rubber wheel. An example is given in Table 1. Some researchers in Europe consider that the use of the steel wheel is too severe and may cause excessive damage to asphalt samples.

PHOTOGRAPH 2 Hamburg Wheel Rut Tester in operation.

PHOTOGRAPH 3 Asphalt samples submerged in water prepared for the HWRT wet test.

PHOTOGRAPH 4 Asphalt cylindrical samples after application of 20,000 wheel passes. (HWRT)

Table 1
Example of HWRT Maximum Allowable Rutting Using Rubber Wheel

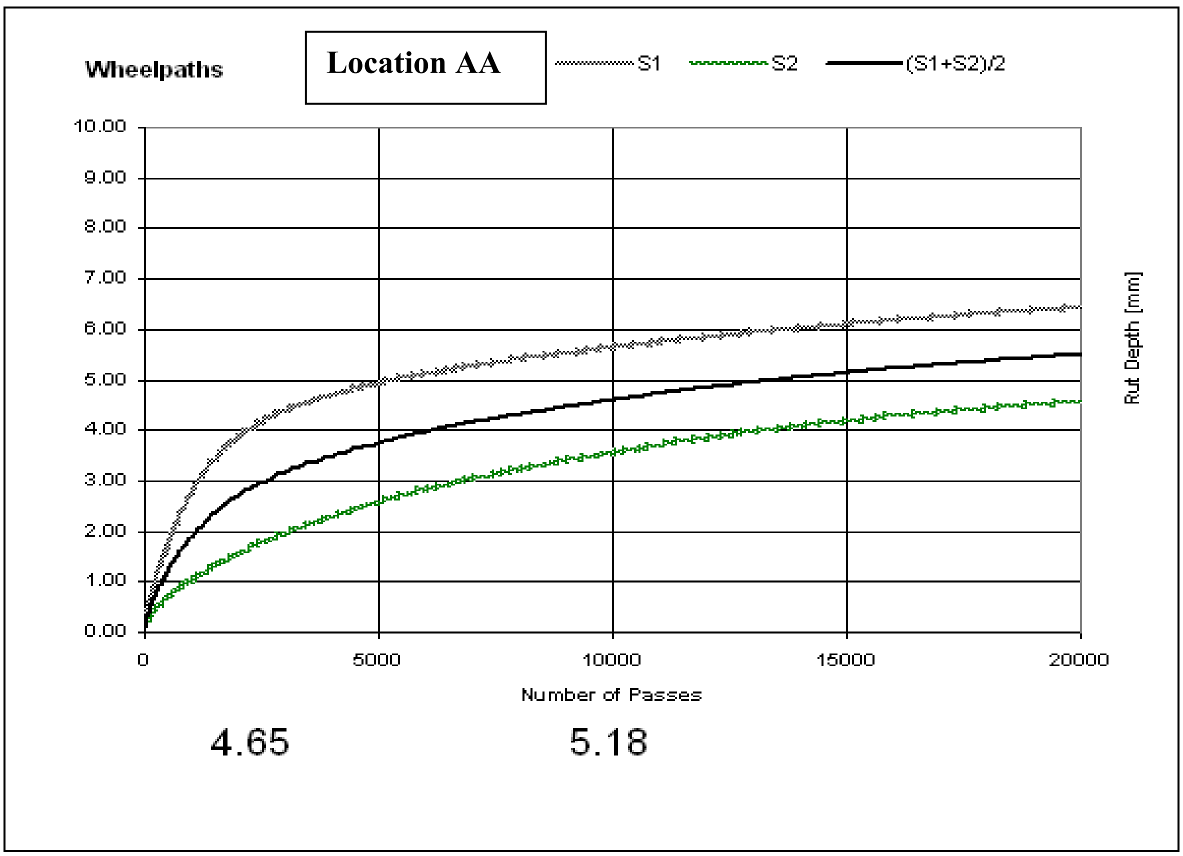
Class of Traffic Loading	Rut Depth after 10,000 passes, y_3 (mm)		Increase of rut depth between 10,000 and 15,000 passes, p_2 (mm)		Increase of rut depth between 10,000 and 20,000 passes p_3 (mm)	
	Wearing Course	Binder Course	Wearing Course	Binder Course	Wearing Course	Binder Course
Class I with extreme heavy, slow, and stopping traffic	1.60	1.50	0.20	0.15	0.30	0.22
Class II and III with slow and stopping traffic	2.00	1.60	0.25	0.20	0.40	0.32
Class II and III	2.40	1.80	0.36	0.28	0.55	0.45

Class of Traffic Loading	Number of Heavy Trucks per Day
I	> 3500
II	1501 - 3500
III	501 - 1500
IV	101 - 500
V	15 - 100
VI	< 15

Example

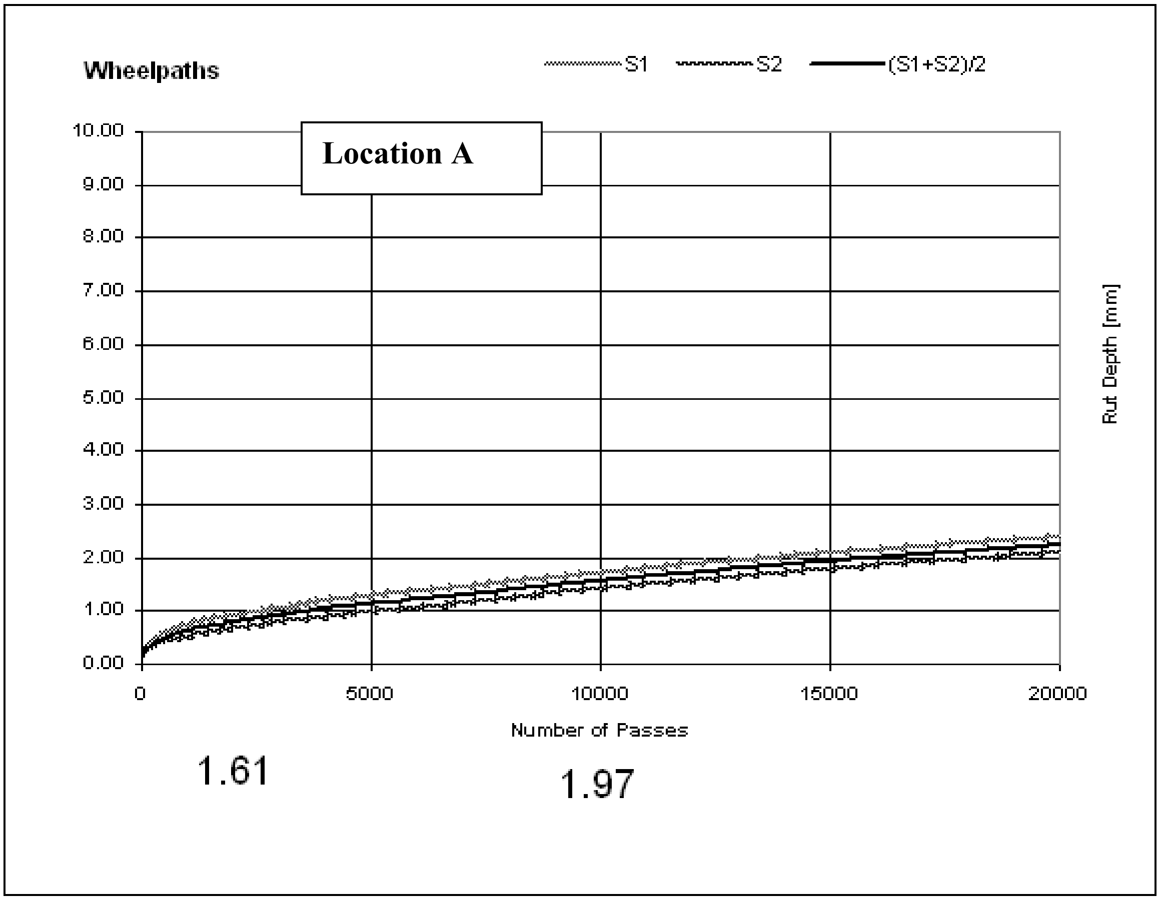
Two sets of six cores were obtained from two asphalt pavements experiencing very heavy traffic loading. The same mix type (HL 1 frictional surface course mix) was used in both pavements; however, different mix designs were used on these projects. The hot-mix asphalt (HMA) at Location AA exhibited very little rutting (about 2 to 3 mm) while the HMA at Location A exhibited severe rutting (25 to 40 mm). The cores were tested in the HWRT for resistance to rutting using a dry test (the samples were conditioned in air) and the rubber wheel. The HWRT plots for both tests are shown in Figure 1. The cores from the Location A exhibited little rutting (1.97 mm at 20,000 passes) and the cores from the Location AA exhibited serious rutting (5.18 mm at 20,000 passes). The results of the rut resistance testing in the HWRT correlate well with the filed observations.

Figure 1
Rutting of Cores from Locations AA and A



rut depth y_3 after 10 000 passes		p_2 10 000 to 15 000, mm		p_3 10 000 to 20 000, mm	
4.59	TP 109 **1.60**	**0.55**	TP 109 **0.20**	**0.90**	TP 109 **0.30**

p_2 = increase of rut depth from 10,000 to 15,000 passes
p_3 - increase of rut depth from 10,000 to 20,000 passes



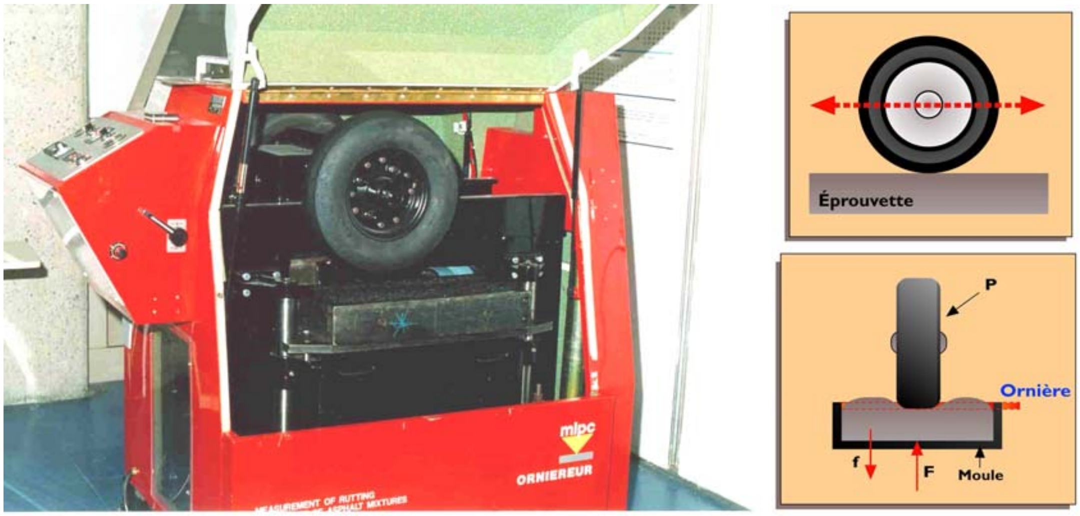
rut depth y_3 after 10 000 passes		p_2 10 000 to 15 000, mm		p_3 10 000 to 20 000, mm	
1.56	TP 109	**0.37**	TP 109	**0.67**	TP 109
	1.60		**0.20**		**0.30**

p_2 = increase of rut depth from 10,000 to 15,000 passes

p_3 - increase of rut depth from 10,000 to 20,000 passes

2.2 French Laboratory Rutting Tester (FLRT)

Since the early 1990s, the French Laboratory Rutting Tester (FLRT) (Photograph 5) has been used in Quebec to evaluate asphalt mixes in terms of rutting resistance. The FLRT is an integral part of the LC method created by the Ministère des Transports du Québec [1]. The principle is simple and accurately represents the most severe traffic and temperature conditions found in Québec. The hot-mix asphalt slab samples are prepared in the slab compactor (Photograph 6) following the specified compaction procedure in accordance with the NF P 98-250-2 standard [9]. The slab compactor includes a pneumatic tire mounted on a hydraulic jack. The mix is compacted at given temperatures by the passage of the tire over a mold that is 500 mm long, 180 mm wide and 50 mm high for the surface course and 100 mm high for the base course. The mix slabs are compacted at the mixing and compaction temperatures specified for the type of asphalt cement used in the mix. The slab is then transferred to the FLRT for rut testing. The testing is carried out in accordance with the NF P 98-253-1 standard [10].



PHOTOGRAPH 5 French Laboratory Rutting Tester.

PHOTOGRAPH 6 Slab compactor used for sample preparation.

In the FLRT, the repetitive load is applied by a pneumatic tire (400 mm diameter and 80 mm wide) passing on the surface of the slab at a frequency of 1 Hz. Two slabs can be tested simultaneously in one run of the FLRT. The tester is considered to simulate the same loading conditions for asphalt mixes as subjected in the field on a hot summer day under a heavy traffic load. The pressure of the tires is set at 600 ± 30 kPa, the applied load is 5000 ± 50 N and the typical testing temperature is 60° C. The rut depth (Photograph 7) and the number of cycles are monitored and must be recorded at 100, 300, 1000, 3000 and

10000 cycles, and 30000 cycles for the base course. MTQ specifications require that for the mixes to be used on heavy trafficked pavements the rut depth in the FRT should not exceed 10 mm or 20 percent of the depth after 3000 cycles for the surface course (50 mm thick sample) and 10 mm or 10% after 30000 cycles for the base course (100 mm thick sample).

PHOTOGRAPH 7 Asphalt samples tested in the FLRT.

Example

In a previous study (1), the same mix type was used to prepare samples with three selected PG 64-28 asphalt cements as well as PG 58-28 and PG 64-34 at two different asphalt cement content levels, 4.8 and 5.6 percent. Then, ten sets of test samples were tested in the FLRT for resistance to permanent deformation. The test results are summarized in Table 2 and Figure 2.

Table 2
Rut Depth Summary (% of sample thickness)

Asphalt Cement Content (%)	PG 64-28 A		PG 64-28 B		PG 64-28 C		PG 58-28		PG 64-34	
	4.8	5.6	4.8	5.6	4.8	5.6	4.8	5.6	4.8	5.6
100 cycles	0.7	1.4	1.3	1.4	1.3	1.7	1.3	2.3	1.0	0.6
300 cycles	1.9	2.8	2.3	2.6	2.3	3.3	2.4	4.4	1.4	2.2
1,000 cycles	3.4	4.8	3.4	4.8	4.3	7.6	4.9	9.4	2.1	4.2
3,000 cycles	5.0	9.8	5.1	9.4	6.8	15.1	8.5	23.3	3.5	10.0
10,000 cycles	5.6	17.2	7.1	17.5	11.0	30.4	15.6	42.5	4.9	30.5

PG 64-28 A Binder modified with oxidized components
PG 64-28 B Binder modified with SBS polymers + modifier
PG 64-28 C Neat binder

The mixes with the PG 64-28 asphalt cement exhibited better rutting resistance than the mix with the PG 58-28 asphalt cement. With the exception of the neat binder, the mixes with PG 64-28 asphalt cement exhibited similar performance to that of the mix with the PG 64-34 asphalt cement. Mixes with a lower binder content (4.8 percent) exhibited better resistance to rutting than mixes with a higher binder content (5.6 percent) regardless of the type of asphalt cement. With the exception of the mix incorporating 5.6 percent of the PG 58-28 asphalt cement, all mixes met the MTQ 4201 Standard requirements (<20% ruts at 3000 cycles).

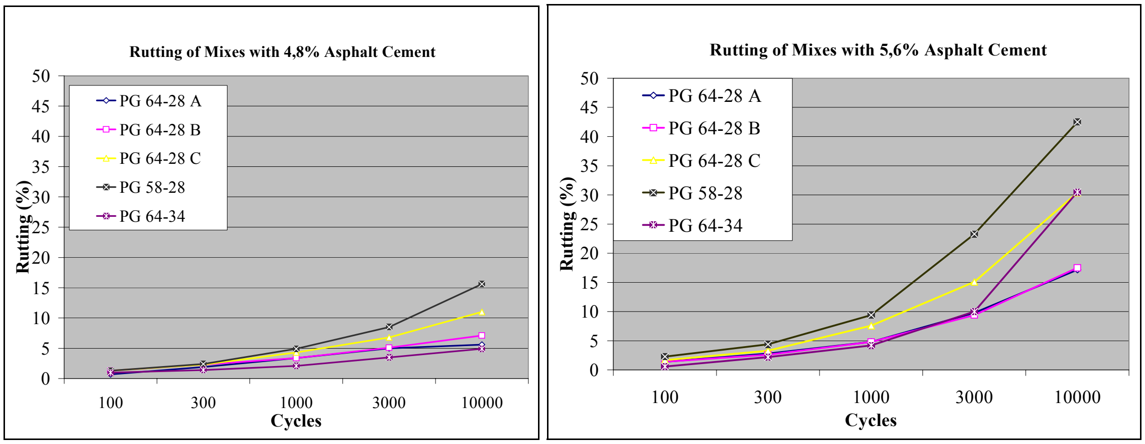


FIGURE 2 Comparison of rutting of asphalt mixes with 4.8 and 5.6 percent asphalt cement content.

2.3 Asphalt Pavement Analyzer (APA)

The APA was developed in 1996. It is used mainly for hot-mix asphalt rut resistance testing in Canada and a number of States with U.S. Although, APA is mainly used for resistance to rutting testing, it can also be used for evaluating moisture susceptibility fatigue endurance of asphalt mixes. The APA rutting procedure for rutting testing is covered by the AASHTO TP-63-03 standard [11]. A technical paper on the use of the APA for mix design and evaluation, including three practical examples of APA testing, was presented at the 2001 TAC Conference in Halifax [12]. Therefore, this paper only briefly touching on the basics of the APA testing (Figure 3).

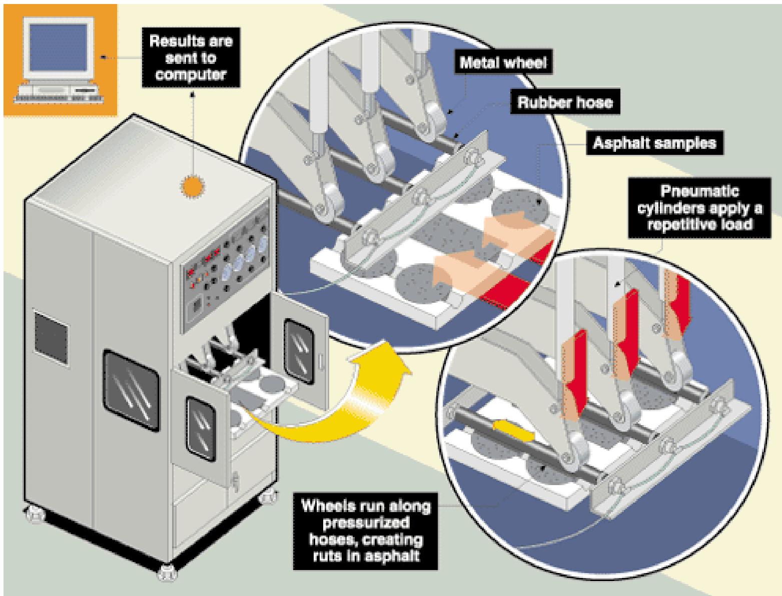


FIGURE 3 Testing of asphalt cylindrical and beam samples in the APA.

In the rutting resistance test, beam or cylindrical samples (Photograph 8) are placed in a test chamber. The amount of permanent deformation (rut depth) under repetitive wheel loads is monitored by a computer and displayed on the screen. The road conditions are simulated in the APA by a concave steel wheel rolling on a pressurized rubber hose for 8,000 cycles. The rubber hose is pressurized to 700 ± 35 kPa (100 ± 5 psi). A load of 445 ± 22 N (100 ± 5 lbs) is typically applied to the wheel. The hose remains in contact with the sample and under the load applied, by the steel wheel creates a rut (Photograph 9) in the sample. The following sample types can be used in the APA: laboratory prepared beam samples; laboratory prepared cylindrical samples (in the Superpave Gyratory Compactor); and field cores.

Some States use a maximum deformation of 5.0 mm in the APA as the pass-fail criterion for mixes designed to be used on interstate highways.

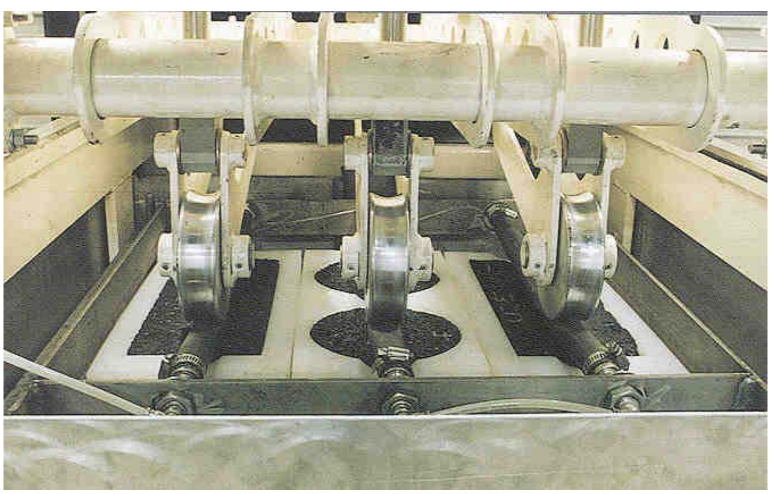


FIGURE 8 Testing of cylindrical and beam hot-mix asphalt samples in the APA.

PHOTOGRAPH 9 Laboratory prepared beam samples tested in the APA. The sample on the right hand side has a better resistance to permanent deformation (rutting) than the one on the left hand side.

3. Comparative Study

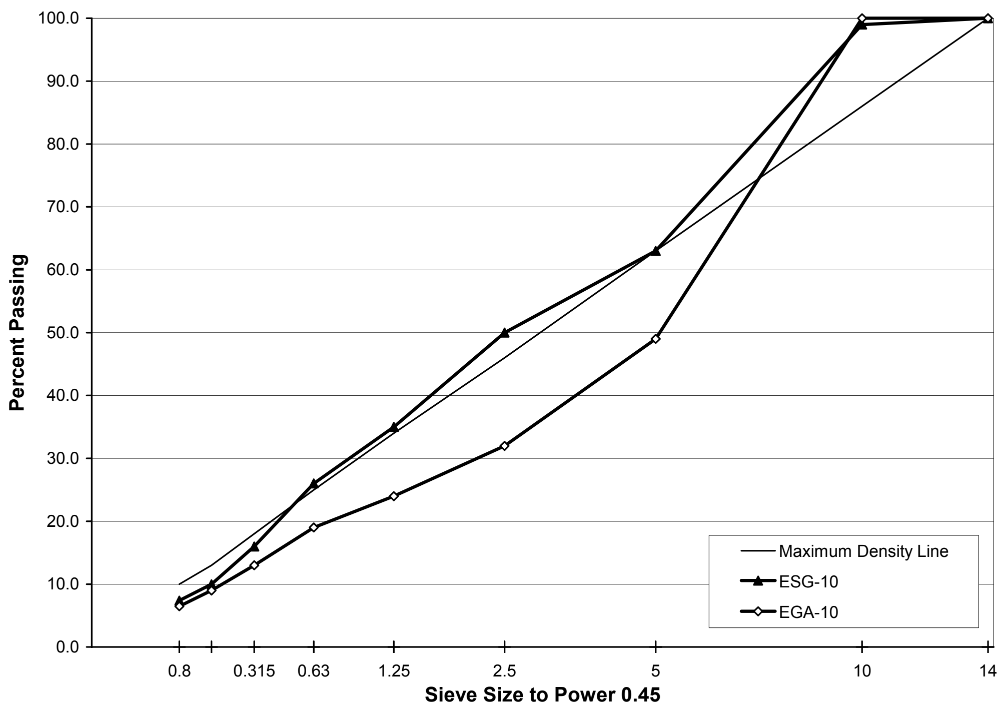
An accelerated performance testing study is being carried out using all three rut wheel testers on Canadian asphalt mixes. The objective of this study is to compare the performance of the asphalt mixes in the field with their ranking in three different rut wheel testers. Based on the results, comments will be forwarded on the effectiveness of the test equipment in predicting asphalt concrete rutting or at least ranking the mixes in terms of their resistance to rutting.

The agencies involved in the study include a government agency from Quebec using the FLRT, a contractor using the APA and a consulting firm using the HWRT. The asphalt mix samples used in the study are: laboratory prepared samples of two asphalt mixes of known good (EGA-10) and medium (ESG-10) performance used in Quebec for heavy traffic loaded pavements; and asphalt cores from Ontario from locations of observed good and poor performance in terms of rutting.

The gradations of both Quebec mixes are shown in Figure 4. The EGA-10 mix is a grained asphalt mix with high mastic content (6.5 percent of PG 58-28 asphalt cement) and 1.3 percent asbestos fiber. This mix type has a rough surface texture which enhances traffic safety in poor weather conditions. The EGA-10 mix has good resistance to fatigue cracking and can be used on pavement that exhibit higher deflections. This mix is anticipated to have good resistance to rutting.

The ESG-10 mix is a dense graded mix with 5.4 percent of PG 58-34 asphalt cement. The ESG-10 mix is used on national, regional and municipal roads. Typically the gradation curve of this mix is below the maximum density line (MDL) and MTQ tries to avoid mixes whose gradation curves are very close to the MDL. The ESG-10 mix used in this study had the gradation modified on purpose (close to MDL) so that its anticipated to have only medium resistance to rutting.

FIGURE 4 SGA-10 AND ESG-10 MIX GRADATIONS



The testing procedures and the performance criteria are different for each of the testers. Where possible, certain aspects of the testing have been standardized in this study to facilitate comparison of results. After careful literature review, it was agreed for instance to carry out the resistance to permanent deformation testing in all three wheel rut testers at the same temperature of 58 ºC and that the rubber wheel will be used in the HWRT test. In order to eliminate the impact of potential stripping in the HWRT test, the dry test was carried out. The results of the resistance to permanent testing of the EGA-10 and ESG-10 mixes in all three wheel rut testers are given in Table 3. Photograph 10 shows a sample of the EGA-10 mix tested in the FLRT and Photograph 11 shows samples of the EGA-10 and ESG-10 mixes tested in the HWRT.

Table 3
Summary of EGA-10 and ESG-10 Mixes Rut Resistance Testing

Mix Type	Rut Tester	Test Results (mm)			Average (mm)
EGA-10	HWRT	-	-	-	1.79
	FRT	-	-	-	4.8
	APA	5.011	4.913	4.148	4.691
ESG-10	HWRT	-	-	-	2.12
	FRT	-	-	-	-
	APA	5.719	4.634	4.279	4.877

PHOTOGRAPH 10 A sample of the EGA-10 mix tested in the FLRT.

PHOTOGRPAH 11 Samples of EGA-10 and ESG-10 mixes tested in the HWRT. The EGA-10 sample exhibited better resistance to rutting.

The results of the testing completed to date are promising. However, more mix types and field samples are still to be tested, it is too early to draw final conclusions or provide comments on the effectiveness of the test equipment in predicting asphalt concrete rutting or ranking the mixes in terms of their resistance to rutting.

4. Summary

- A reliable, accelerated laboratory performance test to evaluate rutting resistance of asphalt mixes is considered necessary.

- There are three wheel ruts testers that are commonly used for asphalt testing: Asphalt Pavement Analyzer; Hamburg Wheel Rut Tester; and French Laboratory Rutting Tester. All three wheel testers are in use in Canada.

- The testing procedures and performance criteria are different for each of the testers. An accelerated performance testing study is being carried out using all three rut wheel testers and Canadian asphalt mixes to compare the performance of the asphalt mixes in the field with their ranking in the wheel testers. Although the results of the testing completed to date are promising, it is too early to provide comments on the effectiveness of the test equipment in predicting asphalt concrete rutting or ranking the mixes in terms of their resistance to rutting.

5. References

1. Gaetan Leclerc and Michel Paradis “Evaluation du PG-28 en Vue de Selectionner ses Usages au Quebec” Proceedings of Canadian Technical Asphalt Association Calgary 2000.

2. Ray Brown, Prithvi Kandhal and Jingna Zhang “Performance Testing for Hot Mix Asphalt, Executive Summary” NCAT Report No. 2001-05A, November 2001.

3. Aneel Gogula, Mustaque Hossain, John Boyer and Stefan Romanoschi “Effect of PG Binder and Source on Performance of Superpave Mixtures under Hamburg Wheel Tester” Proceedings of the 2003 Mid-Continent Transportation Research Symposium, Ames, Iowa August 2003.

4. Kevin Stuart and Walaa Mogawer “Modified Asphalt Binders in Mixtures, Topical Report: Permanent Deformation Using a Mixture With Diabase Aggregate” National Cooperative Highway Research Program NCHRP-RD-02-042.

5. Jack Youtcheff, Kevin Stuart and Walaa Mogawer “Understanding the Performance of Modified Asphalt binders in Mixtures: Evaluation of Moisture Sensitivity” Proceedings of Canadian Technical Asphalt Association Halifax 2003.

6. FHWA T-FHRC “Hamburg Wheel Tracking Device” U.S. Department of Transportation, Federal Highway Administration publication.

7. TDOT “Manual of Testing Procedures” Texas Department of Transportation.

8. WSDOT “Pavement Design Guide” Washington State, Department of Transportation, State Materials Laboratory.

9. Norme Francaise NF P 98-250-2 “Preparation des mélanges hydrocarbons”.

10. Norme Francaise NF P 98-253-1 "Deformation permanente des melanges hydrocarbons”.

11. AASHTO TP-63-03 “Standard Test Method for Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)” American Association of State Highway and Transportation Officials.

12. Ludomir Uzarowski and John Emery “Use of the Asphalt Pavement Analyzer for Asphalt Mix Design and Evaluation” Transportation Association of Canada Annual Conference in Halifax 2001.