Ontario

Ministry of Transportation
Materials Engineering and Research Office Report

Ontario Friction Testing Equipment and Test Site Selection Methodology Review

DRAFT

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Introduction

Over 90% of collisions are caused by driver error, often when driver's road safety expectations are not met. The Ontario Ministry of Transportation (MTO) strives to provide an acceptable level of friction to Ontario motorists. This is one of the reasons why, year after year, Ontario is classified as having the safest roads in North America.

Over many decades, MTO has developed material and construction specifications to control the quality, safety and durability of Ontario's road infrastructure. As new materials, technologies and processes were proven through experimental application in Ontario and elsewhere, and as MTO gained experience, these innovations / adjustments were incorporated in our specifications. In this manner, friction standards and policies have evolved as well.

To ensure that the driving public encounters adequate pavement friction, MTO has restricted the types of surface courses and aggregates suitable for high-speed, high volume highways. To ensure that high initial friction is achieved and that friction does not reduce dramatically during the life of the pavement, MTO instituted a policy to pre-approve aggregate sources. A potential new source of aggregate is tested for suitable physical properties and used in a test section, where it is friction tested over a number of years before the aggregate obtains the approved source designation on the Designated Sources for Materials (DSM).

Since the level of friction on the highway network was for all practical purposes ensured by this rigorous "front-end" control, there has not been any need to friction test newly surfaced highway segments, except in rare cases when an error in material selection or construction process took place. While friction changes with traffic and time, because of DSM screening, these changes have been typically minor and pavements have kept a satisfactory friction level throughout the road life-span.

For the above reasons, it has been sufficient for MTO to use only one ASTM E 274 skid trailer with ASTM E 501 standard ribbed tire and rely on one-person operation without a backup. Typically testing has been carried out to monitor new DSM sections, at locations that police highlight as having an exceptional number of wet-weather collisions, for research purposes and predominantly on highway segments where MTO regional staff suspected, based on a purely visual observation, that friction may not be up to expectations.

Once friction testing has been carried out to establish the Friction Number (FN), MTO staff determine what the driver friction expectation on the tested segment likely is (derived from FN on similar roads in the vicinity), what friction demand of the tested segment is (based on geometry of the site and traffic), before reaching a decision whether to rehabilitate the segment's friction or not, and if so, when. Because of these complex considerations, typically involving a multi-disciplinary engineering team, not one FN has been used province-wide as a benchmark (safe / unsafe boundary) to trigger automatic friction rehabilitation.

The environment in which MTO is doing business is changing. MTO is not only being asked to deliver new infrastructure at an ever increasing pace, but to do so with fewer and fewer resources. Out of necessity MTO has been looking at alternative, "hands-off" delivery of new infrastructure and maintenance services. A typical new model involves specifying, for a warranty period, minimum performance criteria, rather than specifying material and construction processes as has been the case for almost 100 years. A decision has not been reached whether to keep or dispense with control over the road surface course aggregate sources listing, which would leave the short and long-term friction performance of the pavement surface in question.

The MTO mandate to maintain safety of our highway network has not changed. The introduction of new models for infrastructure and services delivery may do away with the old standards. It is MTO responsibility, before these new standards are implemented, to devise an over-sight mechanism to ensure that the driver expectations of frictional properties of our highways are not violated by the use of unproven materials and construction techniques.

Public safety must not be affected by changes in MTO infrastructure and service delivery methods. MTO's safety mandate must continue to be dutifully discharged.

Problem Statement

On projects where pavement friction is not to be ensured through careful control over the aggregate source, properties and design mix selection, MTO must devise an over-sight mechanism by which the provision of the expected friction can be reliably monitored in the short and long term.

Under the new models of infrastructure and maintenance service delivery, should MTO discontinue the use of standards restricting the sources of aggregate and pavement surface types, it is highly likely that forced by the lowest bid competition, contractors would utilize the lowest cost surface course aggregate. Such aggregates are likely to deliver only the minimum warranted friction level and not for much beyond the warranty period. In cases where the contractor is found by MTO to be in default of the friction provisions of the contract, due to millions of dollars potentially at stake, the contractor will use every means available to prove compliance with the warranty conditions. It is therefore vital that MTO does its best, before contracts involving surfacing are let, to minimize the potential for disagreements by keeping the friction testing process simple, unambiguous and by avoiding test data conversion or interpretation.

To ensure that the friction test data is obtained and interpreted the same way by all parties, a detailed test standard, speed adjustment, sampling methodology and trend estimation is yet to be documented and made public.

There may be a shortage of third party friction testing providers to independently serve the contractors for warranty compliance control, MTO for warranty testing accuracy monitoring, and both parties for referee testing.

As part of an over-sight mechanism, there is a need for past and future friction test data to be located in an easily searchable repository, so that for every functional classification of roadway, and for every geographic location, there is enough data to establish what friction level is expected.

A mechanism by which the private sector passes information to such a repository must be established, so that from annual testing one can monitor not only compliance with benchmark intervention levels but also ensure that friction performance is adequate beyond the warranty period.

While to date, network friction testing has not been warranted, should the "front-end" friction control be abandoned (including premium aggregate pre-approval) on more and more warranty projects, network testing, or its equivalent is bound to become a necessity. This is because the long-term friction properties of road surfaces may not last the 15 – 20 years that they used to, but only a year or two beyond the expiration of the warranty period. This would be a likely outcome of no longer controlling the aggregate micro-texture properties through DSM-linked Polished Stone Value (PSV) testing. Should mix design no longer need MTO approval, poorly designed mix can cause the rapid loss of macro-texture through aggregate "sinking" into the asphalt matrix. As a result, in addition to spot-monitoring friction on warranty projects during the warranty period, there is a need to continue to test the warranty projects past the warranty period to ensure that friction has not unduly deteriorated below an acceptable level.

The AASHTO (2008) Guide for Pavement Friction presented a compendium of latest understanding of friction, methodology of friction measurement and friction management. As with similar AASHTO documents, it is not a standard or a policy-setting document. The key recommendation this document gives to U.S. road authorities is: institute friction and texture road network surveys and according to individual state conditions, establish appropriate investigatory and intervention friction thresholds. Thus while this document raises the bar for the North American road authorities of what constitutes due diligence in the management of friction, it recognizes that not all jurisdictions can perform annually surveys of the entire network and allows for a customized approach.

The new business environment and the AASHTO guideline to introduce a form of network testing, bring additional demand on MTO friction testing resources. MTO will need to find innovative ways of using its current testing resources or consider converting to a different testing technology to increase the friction testing capacity.

Many jurisdictions struggle with the dilemma whether to allow different friction testing equipment to be used for network testing, project testing or both. Those that already have it, spend a lot of effort on correlation studies trying to come up with an algorithm that for all weather conditions, road surface and aggregate types come up would support a common standard for friction determination.

Study Purpose

The goal of this study is to examine friction testing technologies with the potential to accommodate new MTO friction testing needs, in particular network friction testing and surface friction testing on the warranty contracts.

The need to evaluate the friction on warranty and other new-generation infrastructure delivery models will stress the current in-house testing resources. It is unlikely that a budget can be found to enhance these, while an outsourced service may be prohibitively expensive. The existing workload is not likely to diminish and even partial network friction testing is beyond MTO capacity for testing with the current methodology.

New technology may offer efficiencies so that the increased friction testing workload could be handled with currently available staff resources. The efficacy of one such technology, Continuous Friction Measurement Equipment (CFME) to meet MTO needs is investigated in this study. With an emphasis on GripTester, the device with the most extensive evaluation record, the study will formulate advantages and disadvantages of CFMEs relative to the currently used MTO equipment.

This study will focus on fixed slip devices since in 2009 FHWA decided to pursue this technology through a generic tender for "loaner" testing devices to kick-start state field testing. The FHWA made a deliberate decision to exclude from the tender variable slip devices that are likely to hinder, rather than enhance harmonization and continuous measurement side-force devices, such as the Sideways Coefficient Routine Investigation Machine (SCRIM) - Figure 1. The SCRIM testing wheel is mounted on a GVW 10 tonne, 2750 litres capacity water cistern / tanker (a full tank is good for about 40km of continuous testing). SCRIM is used predominantly in Britain (12 devices), Australia, New Zealand and 10 other countries. The highest testing speed is 80 km/h with 85 km/h as the maximum.

Figure 1

In Great Britain the SCRIM annual testing encompasses the entire network of about 10,000 km of motorways and dual carriageways and about 3,500 km of single carriageways. While the size of the tested network roughly matches Ontario's 16,000 km of highways, the population density in Great

Britain is far greater than in Ontario, providing more opportunities to fill up the cistern without too much out-of-way travel. The use of so many SCRIMs probably reflects the normal testing speed of 50 km/h and the need for frequent water fill-ups in support of continuous testing.

The Dynamic Friction Tester is a portable stationary device measuring friction when its rubber sliders slow down from the initial spinning speed of 90 km/h on contact with wetted sample surface to 20 km/h.

It makes sense that Ontario should only consider friction testing equipment already commonly used or considered for adoption in North American, rather than tie ourselves to a standard used only in 13 British Commonwealth countries.

Measurement Differences

Figure 2 shows skid resistance / available friction dependence on tire slip. The function of ABS brakes is based on this phenomenon. ABS prevents the wheels from fully locking by over-riding the brake pedal and almost fully (to within about 15%) restoring free rotation and hence increasing the braking efficiency.

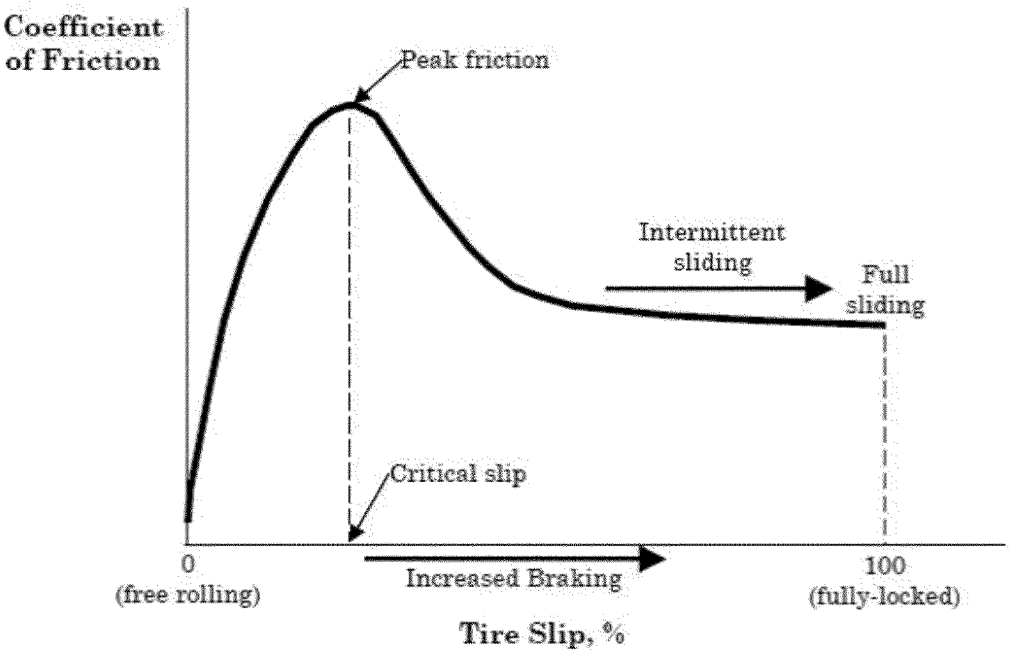

Figure 2

The MTO skid trailer measures at the fully locked position, while all CFMEs test the peak friction. All CFME devices covered in this study use constant slip ratios in the range 13 – 16%.

CFME Devices

There are dozens of CFME devices used for runway friction monitoring. This study will mention only the 3 types of devices submitted to the FHWA 2009 generic tender for road testing CFME "loaner" devices:

1. The GripTester surface friction tester (Figure 3) was developed in 1987 in collaboration with Cranfield University and international acceptance was achieved with the help of the UK TRL, PIARC, the US FAA and NASA. It has over 450 units currently in operation worldwide. The GripTester is a three wheeled device that is (normally) towed behind a vehicle. A braking force is applied to one of the wheels and this is processed to generate a GripNumber (GN), which is a measure of the skid resistance offered by the road surface.

Figure 3

2. The Dynatest Highway Friction Tester model 6875H (Figure 4) is the highway version of the airport runway CFME friction tester Dynatest 6875, with a built-in fifth test wheel.

Figure 4

3. The Halliday RT3 (Figure 5) uses a ribbed test tire. This device has been used on racing tracks only and has not been correlated with any other road friction testing method. For this reason it is not judged to be a strong contender for highway friction testing adoption.

Figure 5

Since the first two contenders both use smooth tires, in this study it shall also be assumed that CFMEs come with smooth tires.

In theory the ASTM E 274 skid trailer could be also used in a continuous testing mode, reducing the distance between tests to a meter or two. This equipment would only support 100% slip ratio. The current tank capacity of 1,060 litres would likely allow about 3.5 km of testing before water refill.

Benefits of CFME

The principal advantage of a CFME device is that it can provide a continuous record of the friction.

CFME devices typically operate with 13 – 16% constant slip ratio. With the majority of passenger cars being equipped with ABS brakes it makes sense to measure the peak friction (Figure 1), rather than locked wheel friction. Some may argue that using the locked-wheel friction represents the worse-case braking scenario and should continue to be used for its built-in safety margin.

GripTester has an excellent correlation with SCRIM and was proven convertible to the PIARC International Friction Index (IFI) in 1992. GripTester adoption would promote harmonization of testing devices with Great Britain, Australia and New Zealand. This would create an opportunity to draw on their experience with the use of investigatory and intervention friction levels.

The option to convert GripTester data into IFI is not seen as an advantage at this moment since it would become useful only if MTO were to allow use of different friction testing devices.

A CFME system allows the road authority to set speed correction factors for each pavement type and speed, so that whenever the speed deviates from the desired (posted) testing speed, such as at the beginning of testing, on steep grades or under heavier traffic, the friction results are automatically adjusted. This allows CFME testing under less than ideal conditions, keeping in mind that the greater the differential between desired and actual test speed, the greater the inaccuracy. The skid trailer software does not support similar functionality and testing is therefore planned for periods when least traffic is expected. While a manual speed adjustment for the skid trailer is possible, the methodology is less proven for GripTester. The CFME speed adjustment is illustrated on Figures 2-4 of the recent paper CFME Data Processing and Analysis Software by E.L. Izeppi et al. presented at the TRB 2011 Annual Meeting.

GripTester can be towed at a speed up to 135 km/h, so operating it at highway speed is not a problem. In this respect it is equivalent to MTO skid trailer.

GripTester tire is much smaller than the full scale tire used on the skid trailer. For this reason, about four times less water is required per road length being tested. The water depth is 0.5mm, the same as the skid trailer uses.

GripTester is fitted with a standard smooth tire. The smooth tire could be an advantage, since it is more sensitive to macro-texture than ribbed tire, and macro-texture dominates as a contributor to friction at high speeds (pre-dominant on the Provincial network). On the other hand, the most commonly used tire in Ontario is the all-season tire (rather than summer tires in the southern half of U.S.A.). Intuitively one would wish a test tire to resemble the most commonly encountered tire on the road.

GripTester is the only CFME device that could be towed by the van currently towing the MTO skid trailer, with only a minor conversion. If CFME devices were to be adopted by MTO, it makes no sense to also continue using the skid trailer, since the results cannot be converted from one system into another and the van would thus become available.

Finally, even though there are no statistics available on collisions indirectly caused by skid trailer testing, the smaller amount of water released by the CFME (about four times less per tested length) and the steady discharge rate may be considered by experts to be safer for the travelling public than the sudden one second long water discharge during each skid trailer testing cycle. The predictable water discharge poses smaller theoretical risk of a driver over-reacting by an excessive evasive action, causing a collision / loosing control.

Disadvantages of CFME

GripTester has been used in North America mostly at airports and only on a research basis on roads. Thus it would be imprudent to pioneer its application in network testing before enough is known of the system's efficacy for this purpose.

The case in point is the length of road that can be tested on one tank. Depending on source of information, GripTester can perform between 11 km and 20km of survey on one 1,000 litre tank. In light of Griptester using the same depth of water ahead of the test wheel as the skid trailer (0.5mm), this range appears credible. The manufacturer's site indicates 100 miles of testing on one tank. It does not say if a 10 tonne cistern tanker is used to tow the device. The sales representative has not responded to the author's inquiries in this regards. Using a cistern tanker or the frequent need to refill with water appears as a major CFME drawback in a network testing application. For this reason CFME could not be towed behind ARAN so as to perform all network surveys in one pass.

By comparison, at the median testing speed of 90 km/h the skid trailer performs about 125 tests (140 at 80 km/h; 110 at 100 km/h). In past surveys conducted in Ontario (Owen Sound and Huntsville), and on current warranty contracts, a 500m long testing interval was specified. With 1,060 litres capacity tank the MTO skid trailer can thus cover some 60 km of road without stopping to replenish its water supply.

It would remain to be seen if GripTester is rugged enough to be used on thousands of kilometres of road – it has never been used for network testing purposes. It may be likely that it would frequently break down and require replacement every one or two years.

MTO has accumulated a wealth of friction data and is currently in the process of uploading the data so that it is easily searchable. Research has shown extremely poor correlation between skid trailer with ribbed tire and SCRIM used in Great Britain, and therefore by extension, poor correlation with GripTester. For this reason it would be impossible to accurately convert our historical data; for all practical purposes the Ontario friction experience would be lost. This would happen at a critical juncture of time, when MTO has to demonstrate what friction levels have been typically achieved under the old (material and construction specifications, designated sources for aggregates) system. It is strongly recommended that MTO hold back on changing all variables at once until the new system of infrastructure procurement / management is proven to provide at least an equivalent level of friction to what Ontario drivers have been accustomed to / expect. Otherwise all accountability would be lost.

One of the reasons for the above mentioned poor correlation with skid trailer (apart from the GripTester utilizing tire slip while breaking and smooth tires) is the mass difference between the two devices. GripTester has a mass of 85 kg while the skid trailer has mass of 492 kg. The difference in mass affects a key friction contributor - rubber hysteresis (distortion caused by aggregate protrusion, mostly macro-texture).

In modelling, the larger the model, the more representative the model test results of the full-scale investigated object. One may argue that the skid trailer with full scale tire, with tire thread closely matching Ontario's pre-dominant all-season tire, and with weight more closely resembling an axle of a passenger car, provides a more meaningful friction reading than the much smaller, smooth tire equipped and lighter GripTester.

The Australian Department of Defence Friction Policy Manual (January 2004) summarizes the CFME application as follows: "It is widely acknowledged that Continuous Friction Measuring Equipment

(CFME) has poor repeatability and can also have calibration problems. Therefore, the use of CFME to demonstrate regulatory compliance is questionable. It is however a valuable tool to assist in the management of runway friction…." Regulatory and warranty needs share the need for measurement accuracy and repeatability. If the same conclusions were to be reached in North America, MTO would have to maintain a dual system, using a CFME device for network testing and the skid trailer for warranted segments of road. This is not advisable, as already presented.

If the accuracy and repeatability of CFMEs were to be judged suitable for MTO, then it is likely that two CFME units would need to be operated – one for network testing and one for production support (emergency requests). Otherwise, production support testing would suffer months of delay since the unit performing a network survey in Northern Ontario would unlikely be recalled back to the Toronto area for a day or two of testing, to subsequently return back north to resume the survey. As was already mentioned, to keep the skid trailer in operation would make it impossible to compare network survey and warranty compliance friction values.

While independent skid trailer testing services are readily available to the private sector now, CFME support service would have to be developed, likely as a single source. It would become a delicate, time-consuming process for MTO to negotiate with such an operator to ensure common data interpretation, once the equipment is in operation.

The use of GripTester to perform network testing would still require the operator to travel the length of the network. The operator would have to be equally skilled to a skid trailer operator to monitor the systems and trouble-shoot. The attention needed to operate the equipment would be no less, since the location markers would require the same identification as is required by the current testing protocol. CFME, while producing more detailed and continuous data, is being operated at the same testing speed and therefore is unlikely to improve the rate at which the provincial network could be tested. If anything, the more frequent water tank fill-ups would hinder progress.

In 2009, the FHWA developed a CFME loan program to allow six DOTs (Connecticut, Georgia, Mississippi, Pennsylvania, South Carolina and Virginia) to evaluate different CFME devices. To this authors knowledge no decision has been reached on which device is preferred.

CFME devices produce an "overwhelming" amount of data that needs to be "translated" by means of software. Ontario is moving towards performance standards linked to a fixed warranty period. Software introduces yet another layer where the road owner and the warrantor may disagree on whether the road meets the warranty-stipulated conditions or requires friction restoration. Development of such software is documented in the recent paper CFME Data Processing and Analysis Software by E.L. Izeppi et al. presented at the TRB 2011 Annual Meeting. Use in Ontario would require a customized software version that suits Ontario warranty contractual enforcement needs and Ontario-specific conditions, such as referencing data segments according to our Linear Highway Referencing System (LHRS). The cost and timeliness of required intensive support (at least initially) would be an issue.

Segmentation of the CFME friction sites into segments with above and below warranted friction value would require complex, ever evolving algorithms to prevent "too many small segments" being reported. Each evolution of the software would likely lead to a challenge on contracts warranted under the previous version, whether the newer version is apparently more stringent or less.

Harmonised versus standard use of friction testing equipment

To enhance the friction testing efficiency one must consider the option to adopt different friction testing technologies, provided they are linked by a universally accepted harmonized approach to a common standard. This aspect is covered by the Transport Canada Innovation Internet site, as follows: "The World Road Association (PIARC) proposed in 1995 an International Friction Index (IFI) for use in surveys of pavement friction. The IFI acknowledges the speed dependency of braking slip friction on wet pavements and includes measurements of macrotexture. The IFI is in essence a method of harmonizing friction and texture measurement devices. The reference of harmonization is a virtual average performance of the participating devices in an extensive field-test program conducted in 1992. The IFI is a universal, two-parametric index with a friction number related to a chosen measurement slip speed of harmonization and a speed number related to macrotexture measurements. Both the American Society for Testing and Materials (ASTM) and the International Organization for Standardization (ISO) have developed standards for the IFI."

Every jurisdiction that has considered adopting the IFI has found problems with the PIARC proposed algorithm, developed local adjustments for better fit, and in the end not implemented IFI. Europe tried to come up with a European algorithm, so far without a success. Until a consensus among North American jurisdictions is developed on how to apply IFI, the use of IFI in defining friction criteria in warranty contracts or allowing the contractors to use different friction testing devices would introduce ambiguity in interpreting friction test readings and thus create a potential for a dispute.

A recently released (Mau 2011) Austroroads technical report "Review of Skid resistance and Measurement Methods" (AP-T177/11) fully supports the above position. It reaches the following key conclusions:

Only one type of friction testing equipment should be adopted for network testing and site investigations, rather than different types of equipment where the results are "harmonized" through an algorithm.

GripTester tried by Australian jurisdictions for network friction testing has not performed as satisfactorily as the mainstay Australian testing equipment – SCRIM.

"The conclusion of the review was that there is not yet a scale or system that can harmonize the range of devices currently used in Europe with sufficient precision to be of practical application with widespread acceptance".

What prevents Australia from using a single standard device are the cost of replacing existing devices and overcoming the commercial interests of current device manufacturers. Ontario does not have these challenges and should stick with our current testing device. The skid trailer's main advantage is the high slip speed (at 100% it is the testing speed), which unlike other devices (14 – 20%) makes the results less susceptible to the effects of sprayed water depth (differently absorbed / run off by different surface course types) and less affected by the test tire condition (repeatability).

Testing conditions

The above Austroroads report offers the following advice:

"If amounts of highly competitive funding are to be used on improving skid resistance and reducing wet weather accidents, an understanding of the degree of accuracy of the information used in making these decisions needs to be reached."

The same applies to using skid resistance as a performance criterion. We must carefully specify if the FN mean value is to be used in conjunction with standard deviation and an absolute minimum. As a basis for these values we need FN data for each testing speed (function of road), region (aggregate variability) and preferably surface course type. We must also specify what type of samp ling method is to be used. We must limit testing to the period between 1st May and September 30th (to minimize the effect of temperature on the measured FN, where 10 Degrees Celsius difference may represent 2 units of FN and to avoid seasonal impact, such as winter sanding). Testing ahead of May can produce FN more than 5 units higher than in the peak of summer and thus get a project pass the warranty provisions.

Rain after prolonged drought has a profound effect on FN (lowers FN value). Would we allow retesting under "back to normal" conditions, and if, how many times?

Recommendations

The AASHTO Guide for Pavement Friction (2008) does not recommend that the entire provincial network be friction tested annually. MTO thus has the freedom to set up friction network testing to suit Ontario conditions and in light of the benefits and drawbacks of CFMEs found at this stage, the author recommends:

1. Re-evaluate CFME devices in 3-5 years. By that time FHWA, in co-operation with the states that received CFME devices on loan would have completed their evaluation of the technology's suitability for network surveying.

In the meantime there is nothing wrong in continuing to use the MTO friction skid tester. Based on the NCHRP Document 108, a corollary to the FHWA Guide for Pavement Friction and FHWA's release of Tech Advisory on Pavement Friction (June 2010), the locked wheel is the preferred method of pavement friction measurement in North America. According to the advisory, 'fixed and variable slip methods are not currently widely available or used on US highways'.

NCHRP document 108 provides the background and supporting data to the Guide. The report recommendations state: Locked wheel friction test method has been tried and tested for many years and has proven to be accurate and reliable.

Of the 45 state agencies surveyed in 2008, 41 use ASTM E274. Of the remaining 4, 3 do not test for friction. Of the 41, 23 use ribbed tire, 6 use smooth, 12 use both (ribbed for network level, smooth for investigatory purposes).

2. In the meantime MTO should develop targeted network friction testing (Note 1 below), as follows:

   Every spring a multi-disciplinary regional team consisting of Geotechnical and Traffic experts would recommend to MERO road segments to be friction tested. The network testing would be based on current practice and new, additional components (in italics):

   Black-spot Testing Network (BTN) comprises all highways where, as determined by regional visual inspection, there is a suspicion that Friction Numbers (FN) may be inadequate or where OPP identifies the road segment as being a noted wet weather collision spot (where low FN needs to be eliminated as a possible causative factor or FN is required in an OPP forensic investigation / Coroners Inquest).

   DSM Testing Network (DTN) comprises road segments where new aggregate source is being long-term monitored as a part of aggregate source pre-qualification process (Designated Sources for Materials – DSM).

   Research Testing Network (RTN) comprises segments where new materials and paving methods are being field tested, for example Stone Mastic Asphalt – SMA, friction restoration techniques and high friction surfaces. Data is required to assess the early-life or whole-life performance of the material / methodology. There is also a policy support component of RTN, for example establishment of texture-friction relationships and monitoring the impact of studded tires.

   Core Testing Network (CTN) comprises all 400-Series and TransCanada Highways. Every year 30 segments (minimum 5 km long, each segment representing a historical paving contract) would be tested. This rate represents approximately a 7 year testing cycle.

   Warranty Testing Network (WTN) comprises new infrastructure and maintenance services contracts under new models of delivery where friction levels are under warranties and ad-hoc compliance verification is required.

Secondary Testing Network (STN) comprises road segments where a need to test has been identified on a theoretical basis. Every year up to 20 segments are to be selected, where:

- Wet-to-dry (3-year average) collisions ratio is greater than 0.45 (50% above the provincial network average of 0.3);
- Wet collision rate per 100 million km traveled is greater than 55 (50% over the provincial network average of 37).
- Texture-FN relationship (see Note 2 below), yet to be established in the proposed 2-year research study, predicts low FN;
- Road segments are assessed to have a particularly "difficult" or unexpected features (where there is a known or perceived above average level of risk presented to the network user);
- Road segments are surfaced with the course or aggregate type that is associated with low FN elsewhere in Ontario;
- Road segments where previous monitoring indicates atypically rapid FN decline;
- Road segments previously tested with low FN that due to low risk remained without friction restoration and where FN should be monitored every 2-3 years for no longer acceptable FN values;
- Road segments with AADT greater than 500 (other than surface treated), longest without friction testing.

NOTE 1: The above methodology emulates the New South Wales, Australia network friction testing. The additional testing can be performed with the current MERO equipment and manpower, utilizing the reserve capacity of about 50 tests per year.

NOTE 2: The recently refurbished ARAN vehicle is scheduled to capture the network surface course macro-texture as of next year. An in-house 2-year research study is proposed to attempt finding a texture-friction relationship that, if established, could be used to identify sites for inclusion in the Secondary Testing Network, targeting road segments where the estimated friction values appear low.

3. Regardless of the technology adopted, the author does not recommend adopting different testing devices and converting their data.
4. Whether CFMEs are adopted or not, modelled on the British example, investigatory and

intervention levels should be established for each highway functional category, for different friction demand circumstances, and perhaps for each region based on different regional driver expectation. To use the same friction level as a cookie-cutter benchmark to suit the entire province would not be appropriate.

To ensure that friction resources are not being wasted, a framework must be developed under which Minimum Oversight (Min-O) projects where the upgraded surfaces are relatively small or discontinuous (patching, strip repairs), friction testing should be performed on a random basis only.