Phase 2 of the Red Hill Valley Parkway Inquiry

Response to the Report of Gerardo Flintsch dated November 2022

Prepared by:

Mr. David K. Hein, P.Eng.
Principal Engineer
President
2737493 Ontario Limited

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BACKGROUND

1. I, David K. Hein, have been retained by Lenczner Slaght LLP, counsel for the City of Hamilton, to provide an expert opinion for Phase 2 of the Red Hill Valley Parkway (RHVP) Inquiry.

2. I am a Professional Engineer with over 38 years of experience in the design, evaluation and management of pavements, including measuring, monitoring and analyzing roadway friction. A copy of my curriculum vitae is attached at Appendix A.

3. In providing this opinion, I understand that I have an obligation to be independent and to provide evidence that is fair, objective and non-partisan.

4. I have been asked to evaluate and reply to various opinions expressed by Dr. Gerardo Flintsch, P.E., in his expert report, Analysis of Friction of the RHVP, dated November 2022 [1]. Appendix B provides a list of documents referred to in the preparation of this report.

5. Specifically, I have been asked to address the following:

    1. Comment on the applicability of the MTO's FN(90)R=30 threshold to the RHVP;

    2. Comment on Dr. Flintsch's characterization of the RHVP friction testing results as "relatively low";

    3. Comment on Dr. Flintsch's opinion that the variance in the friction levels on adjacent highway sections at either end of the RHVP and on the RHVP violates driver expectations;

    4. Comment on Dr. Flintsch's opinion that the RHVP should have been micro-surfaced in 2014 and that resurfacing the RHVP was preferable to shotblasting in 2019;

    5. Comment on Dr. Flintsch's view regarding the applicability of the United Kingdom Investigatory Skidding Resistance Levels to the RHVP;

    6. Comment on the reliability of the conversion of the GripTester Numbers (GN) to Friction Numbers (FN(90)R) undertaken by Dr. Flintsch; and

    7. Comment on Dr. Flintsch's opinion that he is unable to the rank the factors that could contribute to wet road collisions on the RHVP as detailed in Mr. David Boghosian's legal analysis.

6. In addition to the above, I understand that the Commissioner granted leave to address Dr. Flintsch's conclusions regarding the aggregate polished stone value figures obtained from the asphalt cores taken from the field by Golder Associates (Golder) in December 2017.

However, I have not addressed this issue in my report to avoid duplication as I understand Dr. Hassan Baaj, P.Eng., will be submitting a report on that topic.

DISCUSSION

Use of MTO's FN(90)R=30

Question 1 – Comment on the applicability of the MTO's FN(90)R=30 threshold to the RHVP.

7. In his report, Dr. Flintsch indicates:

> I do not offer an opinion in respect of the MTO's use of FN(90)R=30 in respect of its friction management practices, but I note it as being a frictional value of some significance to the MTO.

8. In Ontario, I understand that the MTO views FN(90)R=30 or greater to be an acceptable friction value and that generally, results below this may merit further investigation. My opinion is that the MTO's FN(90)R=30 is an acceptable trigger value to initiate a more detailed evaluation of pavement surface friction and its potential contribution to vehicle crashes on the RHVP.

9. In my career, having worked for various agencies, I understand the MTO's FN=30 to be the prevailing guideline to be applied by the industry in respect of roadway friction in Ontario. There has been no suggestion that I am aware of that it is not a suitable benchmark to use for its intended purpose. FN(90)R=30 is a relatively conservative benchmark as it tests at the posted speed rather than 65 km/h, which is the standard under ASTM E274.

10. Further, the RHVP is a divided highway similar to other divided highways throughout the Province of Ontario. I believe it is important to compare Ontario highways with similar characteristics. As examples, MTO requirements for public-private-partnership projects including Highway 407 ETR [2], Windsor Essex Parkway, 407 East Phase 1, 407 East Phase 2 and the Highway 427 North Extension [3] use FN=30 as an investigatory level. The investigatory criteria for friction is identified as FV < 30 (Friction Value) when travelling at the posted speed based on the 500 m average values of friction [4].

11. The MTO's FN=30 is also consistent with investigatory levels used by other jurisdictions. Various state highway agencies in the United States use threshold levels that resemble the MTO's FN=30. Table 1 below summarizes some of the empirical pavement surface friction "intervention levels" used by the state highway agencies [5]. For clarity, there is no standardization in the terminology to establish a point at which further investigation or remedial action is taken. For example, the terms trigger value, intervention, desired, questionable, review and investigatory level are commonly used for that purpose.

Table 1. Intervention Levels of Friction[1]

Agency	Interstate	Primary	Secondary	Local
Illinois	FN65R > 30			N/A
Kentucky	FN65R > 28	FN65R > 25		
New York	FN65R > 32			
South Carolina	FN65R > 41	FN65R > 37		N/A
Texas	FN65R > 30	FN65R > 26	FN65R > 22	N/A
Utah	FN65R > 30-35	FN65R > 35		N/A
Washington	FN65R > 30			
Wyoming	FN65R > 35			N/A

12. I note that the majority of the transportation agencies above measure friction at the ASTM E274 standard speed of 40 mph (65 km/hr). This means that to compare the friction data for the RHVP measured at 90 km/hr, it would be necessary to adjust the FN numbers in Table 1. I understand that the MTO adjusts for speed differences by adding or subtracting 2 FN points for each 10 km/hr speed difference. The RHVP would be categorized as an "Interstate" Highway. Converting those figures to the 90 km/hr RHVP posted speed by subtracting 5 FN points, the levels set out in Table 1 would range from FN=23 to FN=36. The MTO's FN=30 criteria falls roughly in the middle of that range.

[1] The common SHA 'standard' is tested at a speed of 40 mph (65 km/hr) with a ribbed tire. Speed numbers in the table have been converted from U.S. Customary to SI units.

Characterization of Friction Levels

Question 2 – Comment on Dr. Flintsch's characterization of the RHVP friction testing results as "relatively low".

13. In his report, Dr. Flintsch refers on various occasions to the "relatively low" friction test results on the RHVP. I disagree with his interpretation. In my opinion, using the benchmark adopted by the MTO (as discussed in Question 1), the friction values on the RHVP are not "relatively low". The friction test results from the RHVP would be considered to be "acceptable" in Ontario.

Background

14. Canada is unique in that it is one of the few countries in the world that does not have a national agency responsible for the management of its national level road network. The day-to-day management of the nation's road assets is the responsibility of the individual provinces and municipalities.

15. In terms of pavement surface friction testing, the majority of the provincial highway departments do not collect network level pavement friction data as part of their pavement asset management program. Friction testing is generally limited to project level testing for crash investigations, or for field testing of new aggregate sources and hot-mix asphalt and concrete types. As a result, there are no national policies or standards for the assessment of pavement friction in Canada.

16. In Ontario, the Ministry of Transportation (MTO) has collected pavement surface friction information since the 1980s [6]. While the MTO does not have a formal pavement surface friction policy, the MTO's typical practice is to test pavement sections of interest using the locked-wheel tester at the posted speed limit of the roadway. In my experience, the MTO reports the friction data as an average Friction Number (FN) for the section along with other data such as maximums and minimums. As noted above, the MTO views FN(90)R=30 or greater to be an acceptable friction value and results below this may merit further investigation.

RHVP Friction Measurements

17. Several sets of friction measurements using a variety of testing equipment at different times, locations and speeds were taken on the RHVP over the years. This has included locked-wheel testing by the MTO and ARA and GripTester measurements by Tradewind Scientific Ltd. and Englobe.

18. I have reviewed and assessed the locked-wheel friction test results taken on the RHVP. As shown in Figure 2 from Dr. Flintsch's report (Figure 1 below), none of the overall average values by lane fall below FN(90)R=30 and the friction test results had stabilized at least as of 2014.

19. Of particular importance, Figures 2 through 5 show the results of the ARA 2019 testing [7] completed before the asphalt resurfacing separated into 500 metre sections by lane and direction according to the reporting protocols used by MTO.

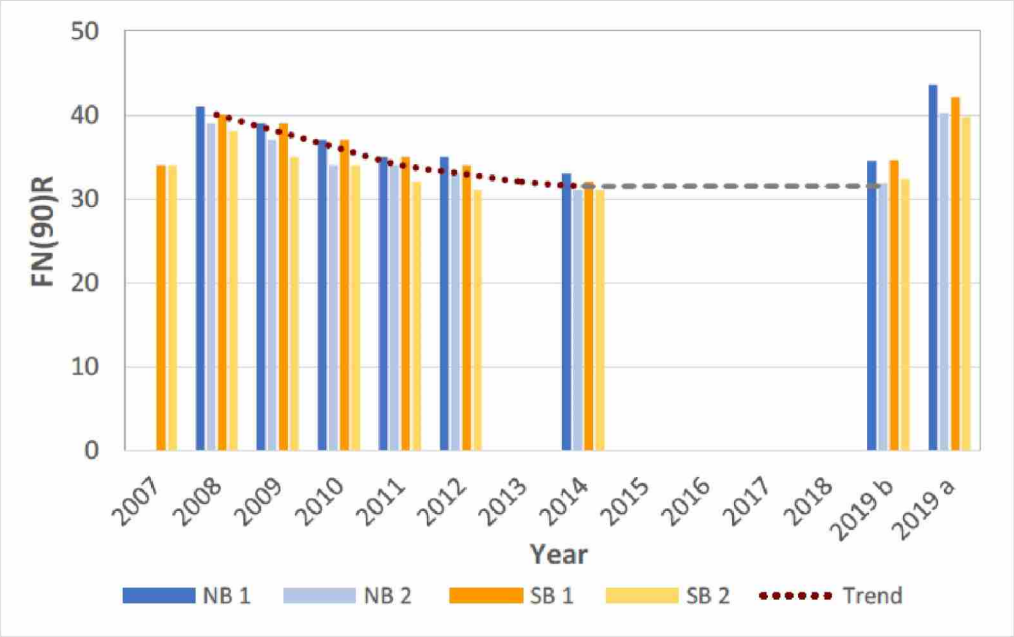

Figure 1. All Locked-Wheel Tester Average Measurements at 90 km/hr: MTO 2007-2012 and 2014 and ARA 2019 Before and After Resurfacing (Figure 2 from the Flintsch Report)

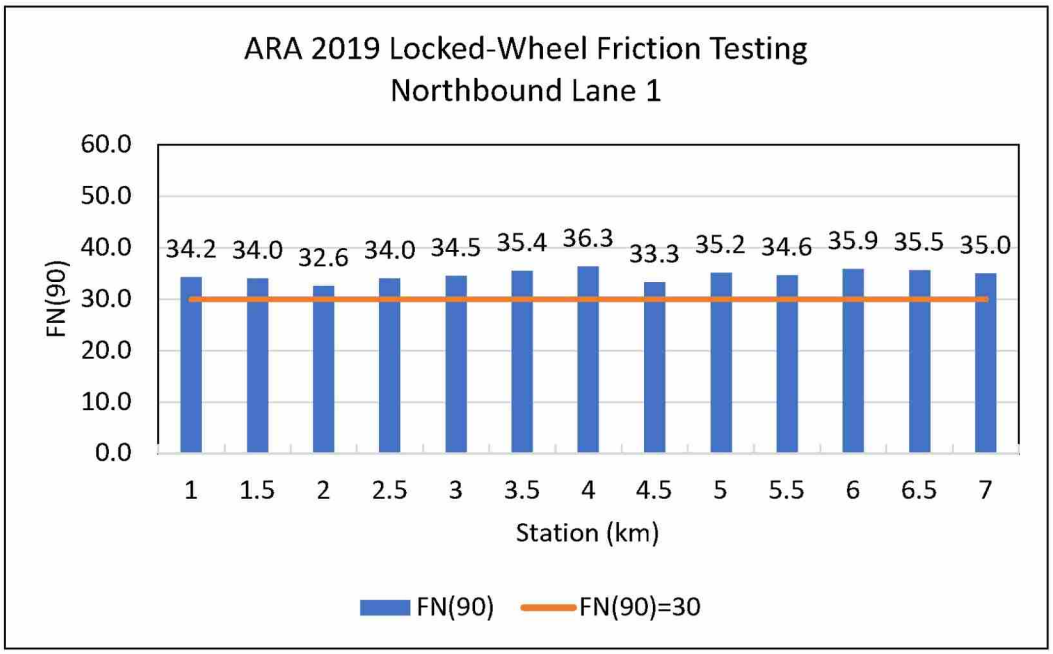

Figure 2. Northbound Lane 1

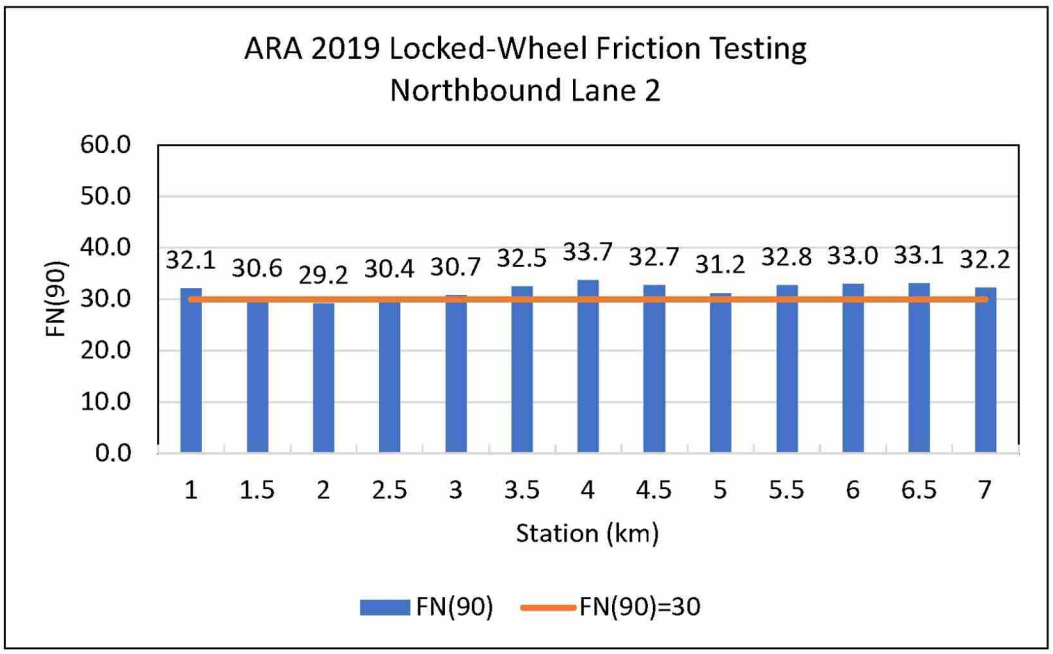

Figure 3. Northbound Lane 2

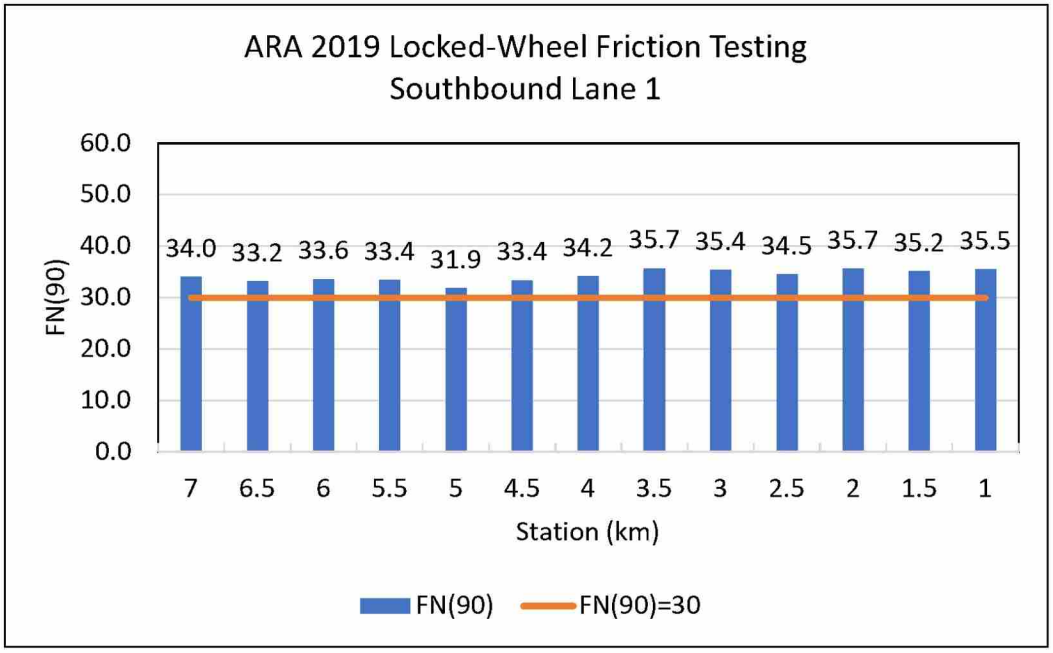

Figure 4. Southbound Lane 1

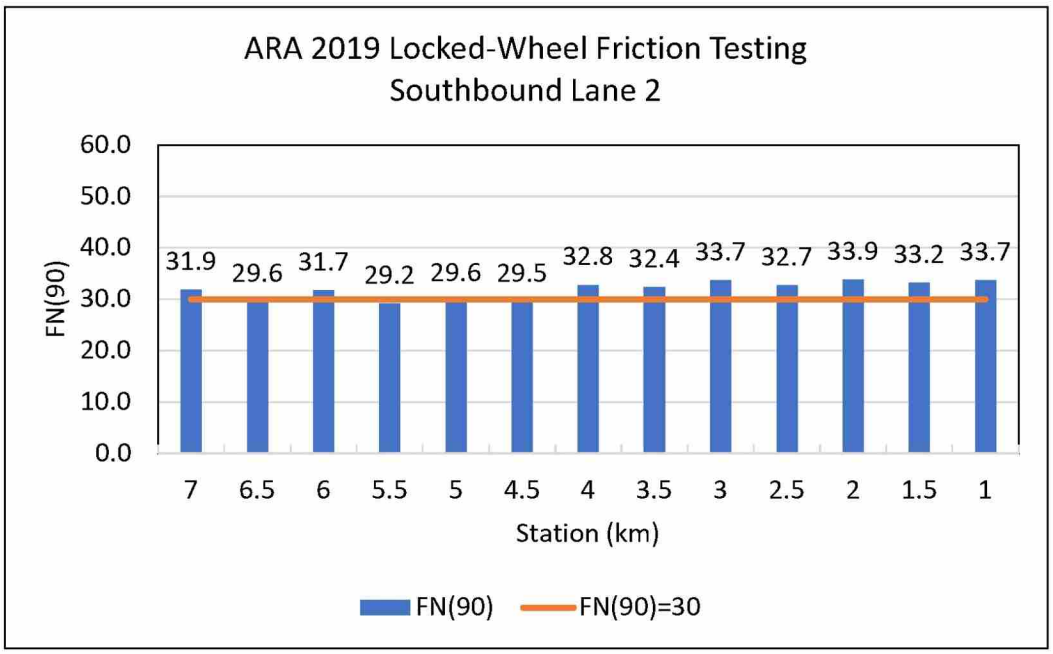

Figure 5. Southbound Lane 2

20. For the northbound lanes, only 1 section had an average section FN(90)R below 30 at 29.2. For the southbound lanes, none of the 500 metre sections in Lane 1 had an average section FN(90)R below 30 with 4 of the Lane 2 sections having an FN(90)R only slightly below 30. I am not concerned by any of the sections with a friction value of below 30 as they are all minor and inconsequential deviations.

21. Further, I have conducted friction testing results on various highways and have seen friction values for other highways in Ontario throughout my career. The RHVP friction test results are consistent on average for its age and are consistent with friction results I have previously seen on other highways.

22. I cannot agree with Dr. Flintsch that the RHVP friction testing results are "relatively low". When viewed from the relevant Ontario guideline used by the MTO, the friction results are acceptable for a pavement of its age. In my view, average friction values in the range of FN20-25 or lower would be considered low. None of the RHVP friction results approach that range.

23. It is worth pointing out that even low friction values do not necessarily equate to higher risks to drivers. It is my experience that pavement surface friction test results provide only one of the many elements that may contribute to vehicle collisions. Traffic accidents are complicated events resulting from a combination of pavement friction and various other factors that are driver-related (e.g., distraction), vehicle-related (e.g., vehicle weight, brake system), pavement-related (e.g., structural and functional distresses, pavement marking issues), roadway-related (e.g., geometry, visibility), and weather-related (e.g., rainfall intensity, fog, ice) [8].

Driver Expectation

Question 3 – Comment on Dr. Flintsch's opinion that the variance in the friction levels on adjacent highway sections at either end of the RHVP and on the RHVP violates driver expectations.

24. In his report, Dr. Flintsch comments:

> In the QEW interchange area abutting the North end of the RHVP, the FN(90)R quickly climbs into the 50's. On the LINC abutting the South end of the RHVP, the FN(90)R also climbs sharply (but not as much) into the mid/high 30's and low 40's. The latter is consistent with the Tradewind Scientific GripTester measurements which, as discussed in the next section, included the LINC. The difference between the friction on the adjacent highway sections at either end of the RHVP compared with that on the RHVP itself makes the relatively low friction on the RHVP even more problematic. Those drivers reaching the RHVP from adjacent highway sections with higher friction may have an expectation of friction levels that are not available on the RHVP.

25. In the above passage, Dr. Flintsch suggests that drivers reaching the RHVP from adjacent highway sections with higher friction may have an expectation of friction levels on the RHVP, which he believes is problematic considering his view that the friction results are relatively low.

26. As noted above, I disagree that the RHVP friction levels are "relatively low". I also disagree that the difference in friction levels between the RHVP and adjacent highways creates any sort of issue for an average driver. In my view, the difference in friction levels is not significant and the average driver would not have an expectation of such differences in the friction levels. A mere difference in friction levels is generally not by itself problematic for drivers where the friction levels are acceptable. What a driver experiences by way of friction levels when travelling from an adjacent highway onto the RHVP is not akin to encountering a hazard such as ice or some other surface contaminant, which would give rise to a significant difference in friction levels.

27. It is important to recognize that drivers are continuously encountering pavement surfaces that provide different levels of friction. These include new versus older pavements, different asphalt mix designs with a variety of aggregate types and proportions, pavement surface types (asphalt versus concrete for instance), pavement surface condition (cracking, patches, ravelling etc.) and geometry (tangent versus curve). Drivers also experience different friction levels from the type and condition of their vehicle tires. For example, the Society of Automotive Engineers (SAE) has published research on the significant differences in braking deceleration rates between economy, touring and performance tires [9]. In a study by Henry et al, it was reported that a decrease in wet friction of 45 to 70 percent was possible for fully worn tires compared to new tires [10].

28. Driver expectations of relatively minor friction level variations are usually appreciated only by specialized drivers, such as a professional race car driver, who rely on pavement surface friction while racing at extremely high speeds and who fully understand tire/pavement interaction.

Necessity of Remedial Measures and Timing

Question 4 – Comment on Dr. Flintsch's opinion that the RHVP should have been micro-surfaced in 2014 and that resurfacing the RHVP was preferable to shotblasting in 2019.

29. In my opinion, it was not necessary for the City of Hamilton to carry out micro-surfacing on the RHVP in 2014.

30. I understand that in 2014, Golder was retained by the City of Hamilton to evaluate the performance of the RHVP five years after construction [11]. The evaluation included a visual pavement surface condition evaluation, asphalt coring and laboratory testing, and pavement surface friction testing, among other things. The friction testing was completed by Tradewind Scientific Ltd. using a Grip Tester with the results summarized in the report. The detailed testing results were set out in an appendix to the report.

31. Golder recommended that about 2.5 kilometres of the RHVP surface course be milled and replaced to address top-down cracking and that, for the remaining portion of the RHVP, the existing cracks in the surface course be routed and sealed followed by the placement of a single lift of micro-surfacing. The treatment of friction (as opposed to cracking) through micro-surfacing appeared to be of secondary importance and without specificity regarding the need for micro-surfacing to address pavement surface friction or a timeline by which micro-surfacing could, or should be, completed.[2]

32. While I agree that micro-surfacing can improve friction levels, in my view it was not necessary at the time. Dr. Flintsch appears to again base his opinion on his characterization of the friction levels as being "relatively low". As I noted above, I do not agree. The RHVP friction levels were acceptable in 2014 and they had levelled off by then.

33. Further, Golder was proposing that the City of Hamilton micro-surface all of the RHVP that would not be milled and resurfaced. In my experience, municipalities take into account the costs/benefits of a particular remedy before choosing a course of action. In this case, micro-surfacing the RHVP would have been a significant expense, perhaps in the order of a million dollars or more with disruption to RHVP users. This was not justified as the friction levels were acceptable.

34. Lastly, the City of Hamilton retained CIMA to complete a safety review of a portion of the RHVP between Dartnall Road and Greenhill Road in 2013. The study resulted in various countermeasures/actions recommended for consideration to improve safety on the RHVP [12]. These measures included signage and speed enforcement among others. While not directly impacting the frictional properties of the pavement surface, many of these countermeasures would have decreased friction demand for the pavement.

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[2] The friction testing completed by Tradewind for Golder introduces confusion to the interpretation of the frictional properties of the pavement. Referring to FN for the Grip Numbers (GN) as produced by the GripTester has the connotation that they are equivalent to the Friction Number (FN) used for the MTO locked-wheel tester. The Grip Tester and locked-wheel tester are materially different methods of measuring friction.

35. I understand that Golder asserts that in March 2018, it suggested shotblasting for areas of concern on the pavement surface of the RHVP. While I do not believe that shotblasting was necessary because the friction values were acceptable, I agree with Dr. Flintsch that if there was a desire to increase friction values, the better and longer-term solution was resurfacing rather than shotblasting.

36. In my experience, shotblasting is a short-term solution with results that sometimes only lasts about six months to one year. It is also not a remedial measure commonly used on asphalt pavements due to its aggressive nature which may result in other pavement surface distresses. Given the above, shotblasting was not necessary particularly as the RHVP was resurfaced in 2019.

Applicability of United Kingdom Investigatory Skidding Resistance Values

Question 5 – Comment on Dr. Flintsch's view regarding the applicability of the United Kingdom Investigatory Skidding Resistance Levels to the RHVP.

37. In his report, Dr. Flintsch comments:

> As set out in the Primer, I recognize that, unlike in some other jurisdictions (notably as discussed in the Primer, the UK, Australia, and New Zealand, and some U.S. states) there are no published provincial or national standards in Ontario or Canada respecting highway friction investigatory or intervention levels. However, in my view that does not mean standards imported from other jurisdictions for the purposes of evaluating the frictional qualities of pavements have no meaning or ought to be disregarded. To the contrary, the British standards reproduced in Table 1 can provide a good reference.

38. I have practiced pavement design, evaluation and management in Canada for my entire career and have worked with numerous Canadian cities and municipalities. I have not seen the U.K. Guidelines [13] used as a reference to assess the frictional qualities of Canadian roads. In my view, there has not been a basis to rely on the U.K. Guidelines in Canada. Further, it is important to note that Tradewind Scientific is a company focussed on airport pavement friction testing. This has created ambiguity on what friction values should be used to assess the RHVP and how they should be interpreted.

39. My view is that reliance on the U.K. Guidelines in this context is not appropriate. While the U.K. Guidelines may provide a good reference suited towards the specific environment encountered in the U.K., the commonalities/differences of the network settings vis-à-vis the RHVP would need to be identified. Analysis would have to be undertaken to assess factors such as Canadian geometric design guidelines, asphalt mix design and aggregate quality, heavy vehicle types and axle configurations, legal axle load limits, surface wear due to the use of winter sand, and type of friction measuring device, among other factors.

40. The Australian context is particularly helpful to consider in understanding the limitations of applying the U.K. Guidelines to a different jurisdiction. The Austroads friction management program implemented in Australia is fundamentally based on the U.K. friction model. However, it was borrowed only after significant analysis and tailoring to the Australian conditions. In the Austroads report titled, Guidance for the Development of Policy to Manage Skid Resistance, the summary [14] states:

> Current skid resistance monitoring programs and investigatory limits used in Australia were based on systems developed in the U.K. where the climate, traffic intensity and network configuration are very different that that of Australia and New Zealand. These do not necessarily suit Australian conditions and can have high cost implications in terms of monitoring and maintaining surfaces at

> sometimes inappropriate skid resistance levels that are not readily achievable or sustainable in an Australian environment. Austroads recognised a targeted approach applicable to Australian conditions is required and initiated this research project to develop a suitable national approach to skid resistance management. The primary focus of this report is skid resistance management in Australia. New Zealand has a range of climate, geography and traffic densities such that it could form a subset of the conditions in Australia, with one or more of the resulting zones described herein also applying to New Zealand.[3]

41. My expectation would be the same approach would have to be taken in Canada. Before a particular jurisdiction's friction management policy is adopted in Canada, there must be analysis by an appropriate authority as to its applicability. Here, Dr. Flintsch appears to be suggesting that the U.K. Guidelines should be used as a reference point in this Inquiry. However, I have not seen any testing or analysis of its applicability to Canada, and more specifically, to the RHVP. I am therefore unable to support the reliance on the U.K. Guidelines to inform the road surface conditions on the RHVP.

[3] The Austroads report also discussed the impact of seasonal variation and confirmed that skid resistance changes with temperature and seasonal variations. The report concludes that all states, except Queensland, showed substantial seasonal variation of skid resistance. It should also be noted that the investigatory levels shown are based on the four-point rolling average skid resistance for each 100 m section length which recognizes that the "investigation advised" criteria should not be based on single measurement points of surface friction.

GripTester Friction Value Conversion

Question 6 – Comment on the reliability of the conversion of the GripTester Numbers (GN) to Friction Numbers (FN(90)R) undertaken by Dr. Flintsch.

42. In his report, Dr. Flintsch provides a comparison between the GripTester results by Tradewind Scientific Ltd. and Englobe Corp and the MTO and ARA ASTM E274 locked wheel tester results. He undertakes what appears to be for the first time, a multi-step process by converting the Grip Numbers (GN) measured at 50 km/hr to SCRIM readings (SR) and then correcting the SR to the side force friction number (SFN) at 50 kms/hr and then converting the SFN to friction numbers (FN) at 65 km/hr and then correcting the FN(65) to FN at 90 km/hr (FN90).

43. Dr. Flintsch states:

> The Primer contains a section on interconversion of friction measurements (at p.16) in which I indicated that "the interconversions are not very accurate and may not apply to pavements not included in their development". That remains true. However, in the case of the RHVP I am confident that the conversion of GN to FN(90)R, while not exact, is reasonably accurate. This is because the equations listed in this section are current and the converted values agree with the ASTM Locked-wheel measurements. Thus, I believe that the conversions are at least reasonably appropriate.

44. I do not agree that the multi-step conversions are "reasonably accurate". Converting friction values is particularly difficult when passing the data of one device through other non-similar devices and then transforming it to match the desired friction measured at a specific testing speed.

45. While the literature suggests that some correlations of results between different friction measuring devices have been developed, it is my opinion that there are more authoritative studies that show that correlations cannot be reliably made. Attempting to correlate the friction values obtained from the RHVP using different devices by different individuals under different conditions, and considering the number of factors that can influence pavement friction, renders the results highly questionable.

46. It is clear from several international friction harmonization attempts that the development of any common scale for pavement surface friction devices is a significant challenge. As examples:

    (a) In 1992, the Permanent International Association of Road Congresses (PIARC) completed an international experiment to compare and harmonize skid resistance and texture measurements [15]. The project included comparative friction measurements using 37 friction measurement units, and 14 macrotexture devices, at 54 test sites in Belgium and Spain. The PIARC experiment reported the average

correlation coefficient (R2) for the various devices with the IFI Golden Value Friction Number (GF60). The average correlation coefficient between the locked wheel and fixed slip (GripTester type devices) was 0.61 which is considered to have only moderate reliability.

(b) In the early 2000s, a pavement friction experiment called HERMES was organized by the Forum of European National Highway Research Laboratories (FEHRL) [16]. The project included 15 different friction and 7 texture measuring devices and included 61 test pavements in 5 countries. The friction testing devices included 7 fixed slip, 3 locked wheel and 5 side force measuring devices. It was concluded that the improved procedures provide a stable, common scale of friction but that the reproducibility of the EFI values delivered by the different devices remains too large to be considered satisfactory.

(c) In 2008, the European Union funded the Tyre and Road Surface Optimization for Skid Resistance and Further Effects (TYROSAFE) [17]. The TYROSAFE D09 report summarizes the previous attempts to harmonise skid resistance measurement techniques. The primary issue with the previous attempts was finding a mathematical model that could satisfactorily convert actual measured friction values with a common scale while under widely differing measurement principles and operating conditions. The quest was further complicated by issues related to quality control of some of the measuring devices in that the same device measuring the same section of pavement did not result in the same values. This made the correlation with the common scale unacceptably poor.

47. Even the United Kingdom study referenced [17] by Dr. Flintsch to convert Grip Number to SCRIM value states:

> This conversion should be used with caution and only in conjunction with a thorough review of local skid resistance policies.

48. Dr. Flintsch then mixes elements from the U.K. with more recent work completed by him in the U.S. Given the difficulty in developing a reliable method to convert friction values between different testing equipment and speeds, I am highly skeptical that the approach used by Dr. Flintsch is reliable. I am not aware of any testing that was conducted to validate the conversion and I have not seen that multi-step conversion process applied in any Canadian context, or elsewhere.

49. Finally, Dr. Flintsch, in part, bases the reliability of his conversions on the basis that the Tradewind and Englobe to FN(90)R conversion results are generally in line with those measured using both the MTO and ARA locked-wheel test devices. This reasoning is simplistic. Any reliance on this data would not represent good engineering practice to determine if the conversion was accurate, or even reasonably accurate. Further independent testing would be necessary to validate any such conversion.

Contributory Factors to Wet Road Collisions

Question 7 – Comment on Dr. Flintsch's opinion that he is unable to the rank the factors that could contribute to wet road collisions on the RHVP as detailed in Mr. David Boghosian's legal analysis.

50. David Boghosian's legal analysis listed the following in order of greatest contribution to the number of wet crashes:

(a) Slipperiness of the road surface (i.e. the road is slipperier when wet than other roads which leads to greater accidents then on roads with similar large numbers of horizontal curves in wet road conditions);

(b) Speeds exceeding the capability of the highway given the curvature of the road;

(c) Curves in the road (there are a number of sharp curves having design speeds of 100 km/hr, whereas a high proportion of vehicles are substantially exceeding that speed);

(d) The close proximity of on/off-ramps to each other leading to losses of control and/or drivers' errors as traffic attempts to merge onto the highway or cut across lanes to get off the highway.

51. It is my opinion that while some factors influencing vehicle/pavement interaction may be identified, it is not possible to rank these factors on a general basis as suggested by Mr. Boghosian's analysis. Rather, each vehicle collision would have to be carefully examined to make a more specific determination as to the cause of the collision.

52. Pavement friction and its contribution to driver safety is complex. Friction is only one of many potential contributing factors to accidents, and in my experience, it is very rarely the cause of accidents. Vehicle collisions on a roadway such as the RHVP typically are the result of one or more contributing factors, as shown in Table 2 [18].

Table 2. Factors Affecting Available Pavement Friction

Roadway Design	Pavement Characteristics	Traffic	Vehicle Operating Parameters

• Alignment
• Curves
• Terrain
• Number of access points
• Interchanges/intersections
• Signing and safety appurtenances
	• Micro-texture
	• Macro-texture
	• Mega-texture (unevenness)
	• Lateral and side-force friction
	• Material Properties
	• Temperature
		• Volume
		• Speed
		• Congestion
		• Percent trucks
		• Work-zones/construction
			• Slip speed
			• Braking action
			• Driving maneuver
			  ○ Turning
			  ○ Overtaking

Tire Properties	Environment	Visual Distractions

• Footprint
• Tread design and condition
• Rubber composition and hardness
• Inflation pressure
• Load
	• Temperature
	• Climate
	  ○ Wind
	  ○ Temperature
	  ○ Water (rainfall, condensation)
	  ○ Snow and Ice
	  ○ Contaminants
	  • Anti-skid material (salt, sand)
	  • Dirt, mud, debris
		• Glare
		• Nighttime driving conditions

53. Ranking the importance of these factors is a difficult task in a general sense and in many cases, the factors are interrelated. I agree with Dr. Flintsch that there is insufficient evidence to determine any order of contribution on the RHVP.

RESERVATION OF RIGHTS

54. The author of this document reserves the right to supplement this report with additional comments to the extent further information and testimony becomes available.

Prepared and Submitted by:

2737493 Ontario Limited

David K. Hein, P. Eng.
Principal Engineer

Appendix A - Curriculum Vitae

David K. Hein, P.Eng.

Principal Engineer

Education

B.A.Sc., University of Waterloo, 1984

Employment History

- January 2020 to present – 2737493 Ontario Limited (President)
- April 2000 to 2020 (retired) – Applied Research Associates, Inc., Toronto, Canada, Vice-President of Transportation, Infrastructure Division Manager, Principal Engineer, Distinguished Member of the Technical Staff
- January 1986 to February 2000 – John Emery Geotechnical Engineering Limited, Toronto, Canada, Partner, Principal Pavement Engineer
- June 1984 to December 1985, Trow Limited (now "exp"), Brampton, Ontario, Canada, Pavement Engineer

Areas of Expertise

Mr. Hein recently retired from Applied Research Associates, Inc. (ARA) Toronto, Ontario office. He has over 38 years of experience in the design, evaluation and management of transportation infrastructure. While at ARA, Mr. Hein was responsible for 90 engineering and technical staff and operations in Ontario, Illinois, Pennsylvania, Wisconsin, California, Florida and Texas. The diverse group of transportation professionals were involved in geotechnical and pavement engineering design, asset condition evaluation, transportation safety and asset management, software development including the state-of-the-art AASHTOWare Pavement ME design system, airport pavement management and major research projects. Clients included the U.S. and Canadian Federal Governments, State and Provincial Highway Departments, Regional and Local Municipal Agencies, Contractors and Suppliers and numerous Public/Private/Partnership Concessions. Mr. Hein is also extensively involved in the development and delivery of technical courses, workshops, webinars and other training related to transportation infrastructure.

Professional Affiliations

- Professional Engineers of Ontario (1986 to Present)
- Association of Professional Engineers, Geologists and Geophysicists of Alberta (1998 to 2019)
- Association of Engineers and Geoscientists of New Brunswick (1998 to 2019)
- Association of Professional Engineers and Geoscientists of Saskatchewan (2005 to 2019)
- American Society of Civil Engineers
    - T&DI Board of Governors, 2015 to 2019 (President (2017/2018)
    - Codes and Standards Committee, T&DI Representative, (2010-2018) and 2022 to Present
    - T&DI Permeable Pavements Committee, Chair (2008 to Present)

  - T&DI Interlocking Concrete Block Pavement Committee, Chair (2012 to Present)
  - T&DI Large Format Paving Slab Standards Committee, Chair (2019 to Present)
  - T&DI Engineering for the Smart City, Electric Bus Pavements Standards Committee
  - Education Council, Co-Chair (2019 to present)
  - Airfield Pavements Committee, (2000 to Present)
- World Road Association Pavements Committee Member, 2002-2012, Past Chair (2008-2012)
- World Road Association Asset Management Committee Member (2016 to Present)
- Transportation Association of Canada (TAC)
  - Pavements Standing Committee, Past Chair, Member (1986 to Present)
  - Education and Human Resources Development Council, Member (2007 to Present)
  - Professional Development Committee, Vice-Chair (2020 to Present)
  - Soils and Materials Standing Committee, Member (1986 to Present)
  - Infrastructure and Asset Management Council, Member (2005 to Present)
  - Green Guide for Roads Taskforce, Member
- Transportation Research Board, Past Member AFD10(2) (Pavement Management), AHD20 (Pavement Maintenance) and Friend ABC40 (Asset Management)
- Falling Weight Deflectometer Users Group, Executive Director (2011 to 2019)
- Asphalt Reclaiming and Recycling Committee (2005 to 2019)

Pavement Engineering

Substantially involved in pavement design, evaluation and management of pavement infrastructure including research studies, design of roadway, highway and airport pavement infrastructure, technical evaluation of the condition of pavements, pavement management system design and implementation, technical face-to-face training and webinars. Representative experience includes:

- Member of the project team that updated the Alberta Transportation pavement preservation and rehabilitation guidelines including an assessment of emerging technologies and life-cycle cost comparison tools.
- Assessment of the impact of high frequency, heavy load container trucks for concrete pavements at the Port of Houston, Texas.
- Best Practices for Pothole Repairs in Canada, including a practice survey of 30 Canadian and European agencies, summary of processes, equipment and materials with a focus on pothole prevention.
- Assessment of the impact of climate change on the performance of pavement assets for the 407 ETR Highway Concession near Toronto, Ontario.
- Subject matter expert and pavement design for the redevelopment of Dundas Square in London, Ontario including interlocking concrete pavers.
- Development of case studies to support the value of bases for concrete pavements, U.S. Federal Highway Administration.
- Roadway asset management planning and programming gap analysis for the City of Calgary.

- Development of a formal pavement friction management plan for asphalt and concrete pavements for 407 Express Toll Route including ASTM E-274 Brake Force Trailer and GripTester equipment correlation.
- Pavement surface friction testing and collision analysis, 407 ETR, 2003 to present.
- Network level pavement friction testing, Huntsville and Owen Sound Districts, 1,800 km of Highway, Ontario Ministry of Transportation, 2005.
- Pavement surface friction testing, various roadways, Region of Durham, Ontario, 1995.
- Pavement surface friction testing, various intersections, Region of York, Ontario, 2006.
- Pavement surface friction testing and analysis, Highway 407 East Phase 1, 2016 to present.
- Pavement surface friction testing and analysis, Windsor Essex Parkway, 2015 to present.
- Pavement surface friction testing and analysis, Highway 407 East Phase 2, 2018 to present
- Delivery and training of a GripTester pavement surface friction tester for the Ministry of Public Works and Communications of the Dominican Republic, 1992.
- Subject matter expert for the design of interlocking concrete pavements for London Dundas Square, Streetsville Village Square (Mississauga), PanAm Games venues (Toronto) and Olympic Village (Vancouver).
- Principal Investigator for the development of pavement design matrices for large element pavers for vehicular applications.
- Project Manager for the rehabilitation design of 10 km of Highway 427 NB Collectors in Toronto.
- Project Manager for the new alignment construction of 40 km of Highway 69 near Parry Sound.
- Project Manager for the life-cycle cost assessment of the benefits of pavement preservation treatments for the State of Ohio.
- Deputy project manager or the Ohio DOT Pavement Selection Advisory Council neutral third-party consultant who developed pavement type selection guidelines for the State of Ohio.
- Assessment of life-cycle costs and roadway surfacing impacts of increasing roadway construction standards to accommodate greater axle loads on local residential streets in the State of Minnesota.
- International scanning tour and development of design and construction best practice guidelines for interlocking concrete block pavement recommendations for the reconstruction of the downtown area of Portland, Oregon.
- Development of design guidelines and material properties for open graded drainage layer aggregates for interlocking concrete block pavement.
- International best practices scan and development of pavement management tools for interlocking concrete block pavements.
- Bridge deck pavement type selection and life-cycle costing, pavement materials selection and specification development for the rehabilitation and widening of the Canada/US international bridge crossing at Queenston/Lewiston in Ontario.
- Pavement Preservation Catalogue for Canadian Airfields. Completed a detailed pavement restoration engineering information study and technical scan to develop a best practices guide for the rehabilitation and maintenance of airfield pavements.

- Value engineering and detailed pavement rehabilitation design peer review including interlocking concrete block pavement design for the upgrade of the Antigua St. John's Airport.
- Pavement management system development and implementation for the City of Niagara Falls, Regions of Niagara and Waterloo, Township of West Lincoln, City of Everett, City of Penticton, Brun-way New Brunswick Toll Highway and Highway 407 ETR.
- Construction materials inspection and testing manager for the construction of Runway 15L/33R, Taxiway Echo and the aircraft deicing facility for the Greater Toronto, Lester B. Pearson International Airport.
- Life Cycle Cost Analysis of Flexible Pavements in Ontario. This study included life cycle cost analysis of flexible pavements ranging from low-volume residential collectors to 400-series highways. The pavement designs used a variety of relatively new materials, such as performance graded asphalt cements, stone mastic asphalts, and large stone binder mixes.
- Preparation of Airfield Pavement Design Manual for the utilization of interlocking concrete blocks for airfield pavements.
- Life-cycle cost analysis comparing interlocking concrete block and flexible pavements including municipal and intermodal pavements in Canada and the United States.
- Evaluation and rehabilitation recommendations for 12 km (10 lanes) of exposed concrete pavement on Highway 427.
- Pavement structural design and construction details for the proposed Deerfoot Trail extension in Calgary, Alberta.
- Benefits of new technologies and their impact on life-cycle models. This project for the Ontario Ministry of Transportation assessed the life-cycle cost impact of pavement technologies such as pavement smoothness specifications, end result specifications, heavy-duty binder course, perpendicular transverse joints in concrete pavement, asphalt cement technologies, open graded drainage layers and stone mastic asphalt.
- Detailed design and pavement structure selection for major design/build projects in British Columbia, Alberta, Ontario and New Brunswick.
- Detailed design and alternative bid pavement design preparation for 10 km of Highway 401 near Tilbury, Ontario.
- California State Route 125 San Diego. Pavement design and life-cycle costing for the construction of a new highway alignment by the design/build method.
- Highway 401 EB Collectors. Field investigation and pavement rehabilitation design for 8 km of Highway 401 in Toronto, Ontario.
- Highway 11 Burk's Falls, Ontario. Field investigation and pavement design for a 30 km new highway alignment from Burk's Falls to Sunridge, Ontario.
- Queen Elizabeth Highway Oakville. Pavement evaluation and design for the rehabilitation and widening of the QEW from Third Line to Burloak Drive.
- Pavement design construction quality monitoring for the 25 km West and 15 km East extension of Highway 407 near Toronto, Ontario.
- F.G. Gardiner Expressway Pavement Evaluation and Design. ARA was part of a multi-disciplinary team developing a multi-year plan for the rehabilitation of 100 lane-kilometers of the Gardiner Expressway in the City of Toronto.

- Detailed design for the rehabilitation of the flexible pavement Highway 20 and rigid pavement Highway 58 in Thorold, Ontario.
- Pavement designs and life-cycle costing for flexible, exposed concrete and interlocking concrete blocks for the C.P. Rail Vaughan Intermodal Terminal.
- Detailed investigation of pavement performance for 40 km of composite pavement on Highway 401 near Windsor, Ontario.
- British Columbia project level pavement design: Completed a technical review of the project level pavement design methodology used by the British Columbia Ministry of Transportation and Highways and provided recommendations for the integration of project level pavement rehabilitation into their network level pavement management system.
- British Columbia pavement structural design: Completed the structural evaluation of over 50 highway sections throughout British Columbia.
- Pavement Preservation and Management Guidelines. Prepared pavement preservation guidelines and an asset management primer for the Federation of Canadian Municipalities through the National Research Council of Canada.
- Developed bituminous thin surface pavement restoration techniques for the National Guide for Sustainable Municipal Infrastructure.
- Pavement Smoothness Testing and Analysis in British Columbia, Quebec, Manitoba, Saskatchewan, Nova Scotia, Newfoundland, and Ontario.
- Pavement evaluation and design for over 30 MTO pavement rehabilitation projects using innovative pavement recycling techniques such as hot in-place recycling, cold in-place recycling, expanded asphalt stabilization and cold in-place recycling with expanded asphalt mix.
- Pavement structural capacity evaluations for over 75 airports in Canada, the United States and overseas.

Transportation Asset Management

Transportation asset management experience includes participation as Canada's representative on the World Road Association Asset Management Committee including international seminars in Bolivia and Kuala Lumpur. Specializes in asset management readiness and gap analysis for highway departments, municipalities and public/private/partnerships. For the Transportation Association of Canada, was responsible for the updating of 5 chapters of the TAC Pavement Asset Design and Management Guide and completed a Synthesis of Asset Management Best Practices for Canada. Representative experience includes:

- Pavement asset management program and operations review and assessment for funding adequacy, City of Calgary, Alberta, 2019.
- Assessment of the repair needs for over 30,000 utility cuts for the City of Toronto, Canada. Included the development of a comprehensive tablet computer application and GIS database to semi-automate the assessment and costing of needs, 2017/2018.
- Transport Quebec International Standards Organization (ISO) 55 000 standard for asset management state of readiness and gap analysis in support of the development of a dedicated asset management group, 2016/2017.

- Detailed review of all of the City of Halifax pavement construction and operations procedures, gap analysis workshop and recommendations for a continuous improvement strategy, 2016.
- Detailed review of the City of Calgary pavement design, construction procedures and specifications, and development of a sustainable improvement strategy, 2016.
- Synthesis of Transportation Asset Management Practices for Canada. Project Manager for the development of a synthesis of asset management practices for Canada including Provincial Agencies, Municipalities, Private Toll Highway Operators and Transit Agencies. Transportation Association of Canada, 2015.
- New York State Thruway Authority, transportation asset management process review and gap analysis, 2015.
- Pavement asset management gap analysis and continuous improvement strategy for the City of Regina, Saskatchewan, 2009-2013.
- Member of the project team and editor for the update to the Transportation Association of Canada Pavement Design and Management Guide, 2014.
- Highway Asset Management System: Gap Analysis, recommendations, implementation plan and continuous improvement strategy. Completed a high-level overview of the current highway asset management practices for Manitoba Infrastructure and Transportation.
- Municipal Asset Management System Gap Analysis and Implementation, the Regional Municipality of York, Ontario.
- Pavement Asset Management System (2002 to present). Completed the engineering design and implementation of a computerized asset inventory and management system for the Regional Municipality of Niagara and City of Niagara Falls, City of Penticton, Bun-way New Brunswick Toll Highway and Highway 407 ETR Toll Highway in Toronto, Canada. The system using MS.NET and MS SQL Server is used to manage over $ 5 billion in transportation assets.
- Municipal Pavement Management System. This project for the Toronto Transportation Department included the development of a computerized pavement management and pavement maintenance management system for the management of over $ 2 billion of transportation infrastructure in the City of Toronto.
- Canadian National Guide for Sustainable Municipal Infrastructure. Principal Investigator for the development of asset management tools for the 5000 member Canadian Federation of Municipalities. Best practices guidelines and tools included: Timely Preventative Maintenance, Priority Planning and Programming for Pavement Management Applications and Thin Surface Restoration Techniques for Bituminous Pavements.
- Project Manager for the development of a highway asset management system and condition data collection effort for the $ 600 million Sea to Sky Highway project developed for the 2010 Olympics in Whistler, British Columbia.
- Development of a whole life costing model for the valuation of all federal, provincial and municipal roadway transportation assets including pavements, bridges and associated features such as lighting, traffic safety devices, line marking, etc. This model was used to establish transportation mode cost benchmarks and funding needs for the entire country of Canada.

- Development of a comprehensive pavement type selection decision model for the Ontario Ministry of Transportation. The model includes pavement, highway design, environmental and business impact inputs to decision the life-cycle cost benefits of various pavement surfacing types.
- Overview and Management for asset management system implementation for over 50 civilian and military airports worldwide.

Research Studies

Principal Investigator or research team member for numerous research studies related to conventional and permeable pavements. Representative experience includes:

- Principal Investigator, Assessment of the impact of SuperHeavy (up to 1.8 million kgs) vehicular loading on the highway pavement infrastructure in Alberta through dynamic finite element modelling.
- Principal Investigator, U.S. Federal Highway Administration, development of a Technical Brief, webinar and workshop for the design, construction and maintenance of pervious concrete and permeable interlocking concrete pavements.
- Permeable Pavement Design subject matter expert for accelerated loading of permeable pavement test sections, University of California, Berkeley Pavement Test Center.
- Principal Investigator, NCHRP Project 25-25, Task 82, Permeable Shoulders with Stone Reservoirs. Development of design, construction and maintenance guidelines for the use of permeable shoulders for roadways and highways.
- Principal Investigator, Evaluation of Overloads on Pavements for Special Permit Guidelines. Determined pavement damage and related user costs for pavements subjected to very high wheel loadings, Ontario Ministry of Transportation, Research and Development Branch.
- Principal Investigator, Pavement structural capacity assessment and assessment of the impact of the use of higher tire and axle loads for ready mix concrete trucks for municipal roadways in the Province of Ontario.
- Principal Investigator, Design lead for the development and construction of Cupolex structural dome system for concrete pavements.
- Guide for Pavement Type Selection, National Cooperative Highway Research Program (NCHRP 10-75).
- Principal Investigator, Development of Best Practice Guidelines for the Use of Design/Build Procurement for Airports, Innovative Pavement Research Foundation.
- Principal Investigator, Development of a pavement condition index procedure for interlocking concrete block pavements. Resulted in the publication of ASTM E2840-11.
- Principal Investigator, Life-cycle cost procedures for exposed concrete, flexible pavements and interlocking concrete block pavements.
- Assessment of the impact of deicing chemicals on the performance of asphalt concrete pavements.
- Principal Investigator, Development of a pavement surface type selection model for low volume roadways for the Ontario Ministry of Transportation.

- Project Manager for the update of the Ontario Ministry of Transportation life-cycle cost procedures used for major highway alternate bid projects.
- AASHTO 2002 Canadian National Calibration of the Mechanistic-Empirical Pavement Design Guide for the Transportation Association of Canada.
- Principal Investigator, Transport Canada Estimation of the representative annualized capital and maintenance costs of roadway assets by functional class for all roads in Canada.
- Principal Investigator, Development of structural design standards for interlocking concrete block pavements for low volume roads (Chair of the ASCE Standards Committee for the structural design of concrete block pavements).
- Principal Investigator, Assessment of life-cycle costs and roadway surfacing impacts of increasing roadway construction standards to accommodate greater axle loads on local residential streets in Minnesota.
- Assessment of the impact of central tire inflation pressure on low volume roads in the Province of Manitoba.
- Member of the project team and co-author of the updated to the Transportation Association of Canada Pavement Design and Management Guide.

Construction and Quality Management

Involved in all aspects of pavement construction management including quality plan development, plans and specifications review and development, field inspection, construction materials testing laboratory setup and testing and post construction review and improvement as well as technical course development and delivery. Representative experience includes:

- Subject matter expert for the review of Quality Management processes and procedures for the delivery of the roadway program for the City of Halifax, Nova Scotia.
- Project manager and subject matter expert for the construction of interlocking concrete pavements for London Dundas Square, Streetsville Village Square (Mississauga), PanAm Games venues (Toronto) and Olympic Village (Vancouver).
- Project plans and specifications review and field inspection subject matter expert for the City of Vancouver 2010 Winter Olympic Village.
- Project Manager for concrete pavement construction inspection and testing for the expansion of Highway 407 ETR in Toronto, Ontario. Project construction value = $ 200 million.
- Construction of 69 km of four and six lane Highway 407 ETR Toll Highway, Toronto, Ontario. Development of construction materials quality inspection and testing manual, software for coordination of construction management and pavement and construction materials quality assurance inspection and testing. Project construction value = $ 1 billion.
- Runway and associated features reconstruction, Grand Forks Air Force Base, Grand Forks, North Dakota. Construction inspection and quality assurance for all civil works. Project construction value = $ 30 million.
- Quality plan development, ISO 9001 Certification and construction quality assurance inspection and testing for the green field construction of 200 km of highway between Fredericton and Moncton, New Brunswick. Project construction value = $ 750 million.

- Construction quality assurance manager for the construction of a new runway, taxiway and deicing facility at the Lester B. Pearson International Airport in Toronto, Ontario. Project construction value = $ 200 million.
- Construction quality control inspection and testing for more than 30 pavement rehabilitation projects throughout Ontario.

Value Engineering

Participant and pavement subject matter expert for numerous value engineering projects for State and Provincial Highway departments, municipal agencies and public/private/partnership and design build projects. Representative experience includes:

- Pavement expert for a five day value engineering assignment for the rehabilitation of 33 miles of Interstate 90 near Worthington, Minnesota.
- Seven day value engineering for a multi-billion proposed upgrade of I-94 in Racine and Kenosha Counties in Wisconsin.
- Project Manager for pavement value engineering review, mechanistic design and construction materials engineering, design/build project for $400 million, St. Louis, I-64 upgrade.
- Completed a five day value engineering review for the design of a new 4-lane divided Highway 11 from Burk's Falls to South River, Ontario.
- Completed a pavement design and construction value engineering review for the Derech Eretz Joint Venture for the 86 kilometre long Cross Israel Highway Project.
- Member of multi-disciplinary team responsible for a planning level value engineering review of the proposed rehabilitation of Highway 34 from Van Kleek Hill to Highway 17 near Ottawa, Ontario.
- Fredericton-Moncton Highway Project. Member of value engineering team for flexible and rigid pavement design and life cycle cost analysis.
- Highway 410 Extension Value Engineering Study. Member of a value engineering team reviewing the proposed extension of Highway 410 from Bovaird Drive to Highway 10. The project included a SAVE Level I workshop.
- Toll Highway 407 for Canadian Highways International Corporation. Flexible and rigid pavement design alternatives and life cycle cost analysis. Consultant member of the Dufferin Construction Pavements Committee evaluating pavement design and construction technique value engineering.
- QEW Total Project Management for Total Roadway Engineering Consortium. Flexible and rigid pavement design alternatives and life cycle cost analysis.
- Peace Bridge CVPC. Flexible and rigid pavement design alternatives and life cycle cost analysis for commercial vehicle processing centre and duty-free facility.
- Highway 11, Longlac for Northern Roads Development Corporation. Value engineering and life cycle cost analysis of flexible pavement rehabilitation alternatives, including performance graded asphalt cements.
- QEW, Fruitland Road to Casablanca Boulevard. Member of MTO/Consultant value engineering team. Tasks included life cycle cost analysis of flexible, rigid, and composite

pavement design and construction alternatives including performance graded asphalt cement pavement.
- Highway 416. Value engineering and life cycle cost analysis of flexible, rigid, and composite pavement design and construction alternatives.
- Wellington Street, Ottawa. Flexible (including conventional, PG, and stone mastic), interlocking concrete paving stone, and rigid pavement design alternatives and life cycle cost analysis.

Forensics and Litigation

Pavement design and materials subject matter expert for forensic and legal action projects throughout Canada and the United States. Representative experience includes:

- Subject matter expert for legal action related to pavement engineering and safety for a major highway in southern Ontario, 2019 to present.
- Subject matter expert assessment for legal action for the early age failure of a series of municipal roadways in Southern Ontario, 2018 to present.
- Subject matter expert for a legal action involvement the early age poor performance of a concrete pavement system in Winnipeg, Manitoba, 2019 to present.
- Forensic evaluation for early age failure of an interlocking concrete pavement on 16th Street, Colorado School of Mines, Golden, Colorado, 2019.
- Evaluation and expert witness appearance for the structural capacity needs of a low volume roadway near Durham, Ontario, 2018.
- Forensic evaluation for contemplated legal action for the early age failure of an interlocking concrete pavement roadway in the City of Markham, Ontario, 2016.
- Forensic evaluation and contemplated legal action for the early age failure of an interlocking concrete pavement at the Ka'anapali Beach Hotel, Maui, Hawaii, 2016.
- Legal Defence and court appearance in support of asphalt concrete pavement quality assurance procedures for the Ministère des Transports, de la Mobilité durable et de l'Électrification des Transports (MTMDET), 2016/2017.
- MacKenzie King Bridge deck failure, Ottawa, Ontario. Legal opinion for the early failure of a bridge deck waterproofing system, 2015.
- Detailed evaluation and legal action including arbitration appearance for a significant early age asphalt concrete cracking problem for 407 ETR, Toronto, 2014.
- Engineering assessment for claim related to a wood waste processing plant pavement problem in Bolton, Ontario, 2012.
- City of Elko Nevada, Apron Pavement Failure, forensic investigation and mediation support, 2011/2012.
- Highway 11/17 Thunder Bay, MTO Contract 2009-6007 and Highway 63, MTO Contract 2008-5134 construction arbitration, 2011.
- Labourers' International Union of North America, Local 527 versus Karson Kartage & Konstruction (1994) Limited. This dispute which was brought before the Ontario Labour Relations Board argued the definitional of the word "asphalt". The Union claimed that their labour agreement with Karson required that the "laying of asphalt" was to be completed by union members. A project on Highway 417 in Ontario included the in-place recycling of

the existing pavement using cold in-place recycling techniques which they claimed was the laying of asphalt.

- Aecon design build for Peterborough Airport Apron rehabilitation using full-depth recycling with expanded asphalt stabilization, 2011.
- Legal defence for a major pavement failure on Highway 575 near North Bay, Ontario, 2010. This case, settled in court including the defence of the design and construction management engineering firm involved detailed review of construction processes and records, contractor claims and analysis.
- Peer Review and forensic evaluation of Rosphalt asphalt mix failure for the City of Ottawa Mackenzie King Bridge, Ottawa, Ontario, 2010 and 2013.
- Highway 417 pavement failure and warranty assessment, MTO Contract 2003-4029, McCrimmon, Ontario, 2004 to 2010.
- Assessment of transit mall pavement failure and claims, Salem Area Mass Transit facility, Salem, Oregon, 2006 to 2010.
- Pavement failure assessment, Schweikert Lawyers on behalf of Patrick Stevedores Operations Pty Ltd., Maunsell, Australia, 2008.
- Premature pavement deterioration and claim assessment, Douglastown Boulevard and Route 8 Ramps, Miramichi, New Brunswick, 2006.
- Pavement failure assessment and remediation, Brampton, Williams Parkway from Chinguacousy Road to McLaughlin Road, Brampton, Ontario, 2005.
- Claim analysis and evaluation of the impact of subsoil conditions on the construction of the Moncton-Fredericton Highway, Maritime Road Development Corporation, Fredericton, New Brunswick, 2001.
- Document review, claim analysis and maintenance plan evaluation for performance issues related to the bridge deck waterproofing for the Confederation Bridge, Moncton, New Brunswick, 2001.
- Member of team that completed a detailed summer and winter safety review for Highway 115 between Highway 401 and the City of Peterborough in Ontario. The review included a friction/collision analysis for both flexible and rigid pavement sections.

Permeable Pavement

He has been extensively involved in the structural and hydrologic design of permeable pavements. He has authored 18 papers and completed over 60 workshops and webinars on the subject. He is the Chair of the American Society of Civil Engineers Permeable Pavement Committee that published a standard (ASCE 68-18) on permeable pavements, and committee member, contributor and technical reviewer for an ASCE eBook on permeable pavements. He has also completed design, construction and maintenance guidelines for many agencies in Canada, Australia, South Africa and the United States.

- Subject matter expert, design of permeable pavement alleyway in San Marcos, Texas.
- Permeable pavement webinars and training for the South African Institution of Civil Engineering.
- Design, construction and maintenance manual training for porous asphalt permeable pavement demonstration project in Québec City.

- Design, construction and maintenance needs training for 3 permeable pavement demonstration projects in the City of Ottawa, Ontario.
- Development of life-cycle cost tools and incorporation of off-road benefits of permeable pavements for the Interlocking Concrete Pavement Institute.
- U.S. Federal Highway Administration, development of a Technical Brief, webinar and workshop for the design, construction and maintenance of pervious concrete and permeable interlocking concrete pavements.
- Permeable Pavement Design subject matter expert for accelerated loading of permeable pavement test sections, University of California, Berkeley Pavement Test Center.
- Designer, porous asphalt permeable pavement demonstration project for Baker Park, Calgary, Alberta.
- Principal Investigator, NCHRP Project 25-25, Task 82, Permeable Shoulders with Stone Reservoirs. Development of design, construction and maintenance guidelines for the use of permeable shoulders for roadways and highways.
- Chair of the American Society of Civil Engineers Transportation Development Institute Committee Standard for the Design, Construction and Maintenance of Permeable Pavements (ASCE 68-18).
- American Society of Civil Engineers Environmental and Water Resources Institute – Permeable Pavements Recommended Design Guidelines. External peer reviewer of this extensive manual and ASCE eBook providing guidelines for the design of permeable pavements.
- Permeable Pavement Roadway Design, Allston Way, Berkeley, California. Responsible for site selection guidelines, permeable pavement design, construction inspection, pavement maintenance manual, utility cut restoration manual and on-going monitoring of performance.
- Sarcee Centre, City of Calgary. Workshop delivery and consultations for the design of a large permeable pavement parking area at the Sarcee Centre. Included the development of several pavement variations and test sections and a monitoring program for pavement condition and water quantity and quality monitoring as well as a construction cost estimate.
- Holy Trinity Church, Oahu, Hawaii. Pavement evaluation and permeable pavement design for a church and school parking area in Oahu. The project was completed as a design/build.
- City of Calgary Permeable Pavement Manual. Completed a detailed peer review of the City of Calgary's proposed manual for the design and construction of permeable pavements including guidance documents and checklist for site selection applicability.
- Vancouver 2010 Olympic Village. Design advice and construction management for the permeable and conventional pavement construction for the Vancouver 2010 Olympic Village.
- Longmont, Colorado Downtown Development Project. Design of permeable pavement alleyways for the redevelopment of the downtown area in Longmont Colorado.
- Ft. Carson Battle Command Center, Colorado Springs, Colorado. Design of permeable pavement system to accommodate heavy tank loadings. This included the design of a permeable interlocking concrete test pad that was traversed by loaded M1A1 Abrams tanks.
- Zorinsky Recreation Complex, Omaha, Nebraska. Structural and hydrologic design of permeable parking area pavements for a recreational center.

- West Vancouver Aquatics Center. Design consultations for the rehabilitation design of a permeable pavement system placed over an underground parking garage.
- Life-Cycle Cost Tools for Permeable Pavements. This tool includes procedures for the development of initial and total life-cycle costs for conventional and permeable pavements.
- Permeable Design Pro Software. This highly acclaimed software application is used for the structural and hydrologic design of permeable interlocking concrete pavements.
- Peer reviewer for Design Pave 2 permeable pavement software from the Concrete Masonry Association of Australia.

Airport Pavement Design, Evaluation and Management

Project manager and subject matter expert for airport pavement design, evaluation, management construction, maintenance and training across North America and overseas. Developed procedures for the structural assessment of pavement bearing capacity, pavement management inspection and testing, pavement preservation catalogs and training for operation and maintenance personnel.

- Contributor and Principal Editor of the American Society of Civil Engineers Monograph/eBook titled "First Ten Decades of the Evolution of Airfield Pavement Design".
- Development of an innovative concrete pavement panel replacement program for the Vancouver International Airport.
- Vancouver International Airport, Custom Course on the Effective Design, Evaluation and Management of Airport Pavements, 2018.
- Calgary International Airport. Forensic evaluation of the concrete apron pavement construction issues.
- Canadian Forces Base Wainwright, Alberta. Forensic investigation during a NATO Maple Flag exercise to assess the impact of softened asphalt concrete due to the application of an asphalt rejuvenator.
- Canadian Airfield Pavement Design with Concrete Pavers. Author of a pavement design manual for the use of concrete paver including international scan, life-cycle cost guide construction specifications in accordance with Transport Canada procedures.
- Transportation Research Board Airport Cooperative Research Program. Project Manager for the development of a synthesis on airport pavement maintenance and rehabilitation practices.
- U.S. Airport Cooperative Research Program, Project 1-16 (Report 69), Asset and Infrastructure Management for Airports: Primer and Guidebook for implementation effective airport asset management.
- Construction quality assurance manager for the construction of a new runway, taxiway and deicing facility at the Lester B. Pearson International Airport in Toronto, Ontario. Project construction value = $ 200 million.
- Jean Lesage International Airport, Quebec. Forensic investigation of asphalt pavement material issues.
- Churchill Airport, Manitoba. Airside pavement structural capacity assessment and pavement management system implementation and updates.

- Thompson Airport, Manitoba. Implementation of innovative pavement stabilization techniques to improve poor subsoils including pavement performance monitoring and airside pavement structural capacity assessments.
- Winnipeg International Airport. Implementation of a MicroPAVER PMS system for all airside pavements.
- Winnipeg International Airport, Manitoba. Runway pavement condition evaluation, forensic testing and structural capacity assessment.
- Winnipeg International Airport, Manitoba. Evaluation of the performance of pavement reinforcing grid products over a 3 year period.
- Winnipeg International Airport. Runway pavement profiling to isolate bump issues.
- Vancouver International Airport. Pavement structural capacity evaluation and rehabilitation plan development.
- Charlottetown International Airport. Pavement structural capacity evaluation and development of rehabilitation alternatives.
- Chatham-Kent Airport, Ontario. Airside pavement evaluation including FWD testing, coring, boreholes and laboratory testing in support of a pavement rehabilitation program.
- Elko Nevada Airport, Elko, Nevada. Forensic investigation for the early age deterioration of a concrete apron.
- Nashville International Airport. Pavement surface condition evaluation and structural capacity assessment of Runway 02R/20L.
- Denver International Airport. Pavement surface condition evaluation, structural capacity testing and implementation of a pavement management system.
- Massachusetts Port Authority, Boston Logan International, Worcester Airport and Hanscom Field airports. Annual airside pavement management condition inspections and monitoring of innovative asphalt pavement construction techniques such as warm mix asphalt and use of recycled asphalt pavement in airside asphalt pavements.
- Houston Airports System, George Bush Intercontinental, William P. Hobby and Ellington Field airports annual pavement management condition inspections, structural capacity evaluations and pavement management system updates.
- Grand Forks Airbase Runway Reconstruction. Project manager for the reconstruction of the main runway at the Grand Forks Airbase in North Dakota. The project included full-time construction supervision and materials testing. Project value $30 million.
- Dover Airbase Runway Reconstruction. Project manager for the reconstruction of the main runway at the Grand Forks Airbase in North Dakota. The project included full-time construction supervision and materials testing. Project value $40 million.
- Lester B. Pearson International Airport. Development and implementation of a pavement management system for the groundside roadways and bridge structures at the airport.
- Lester B. Pearson International Airport. Pavement surface condition evaluations and implementation of a management system.
- Lester B. Pearson International Airport Expansion. Construction quality assurance manager for the construction of a new runway, taxiway and deicing facility at the Toronto Airport.
- Lester B. Pearson International Airport forensic evaluations to address expansion of concrete runway slabs and slab stepping. First Canadian application of concrete pavement diamond grinding to address the stepping issue.

- Lester B. Pearson International Airport. Runway End Safety Area (RESA) probability assessment of runway excursions and undershoots.
- Toronto Island Airport Micro-Surfacing. This project involved the first Canadian use of micro-surfacing for rehabilitation of the primary apron and a portion of the main runway at the airport.
- Vancouver International Airport. Airside apron pavement forensic evaluation including structural capacity and laboratory testing.
- Regina International Airport. Pavement structural capacity and concrete joint load transfer evaluation to determine the effectiveness of an asphalt overlay over an old concrete runway pavement.
- Saskatchewan Ministry of Highways and Infrastructure. International literature survey and preparation of a discussion paper in support of the acceptance of chip seal coat surfaces for airport runways in the Canadian north. Included discussions with Transport Canada to support their acceptance.
- Peer Review for Hornepayne Airport Pavement Rehabilitation. Retained by Transport Canada Central Region to complete a peer review of the proposed pavement recycling rehabilitation design for the Hornepayne Airport.
- Pavement design and rehabilitation of the Sault Ste Marie and Sudbury airside pavements.
- Pavement rehabilitation design, tender document and specification preparation and construction administration for the rehabilitation of the runway and taxiway at the Bombardier Downsview airport facility.
- Thunder Bay International Airport. Pavement rehabilitation design and construction supervision for major airside pavement repairs.
- Ottawa International Airport. Airside pavement structural capacity evaluation.
- Canadian Forces Base Bagotville and Trenton. Evaluation of the use of Skidabrader as an effective tool to remove tire rubber buildup on runway pavements.
- Canadian Forces Base Trenton. Several pavement structural capacity assessments and forensic evaluations involving underground utility breaks and concrete paving issues.
- Canadian Forces Base Mountainview. Runway pavement structural capacity evaluation.
- Canadian Forces Base Comox. Airside pavement evaluation to assist in the development of rehabilitation recommendations for a World War II era concrete runway pavement.
- Canadian Forces Base Cold Lake. Airside pavement evaluation to develop pavement preservation treatments.
- Canadian Department of National Defence. Project Manager for implementation of a MicroPAVER pavement management system for 8 Air Force Bases across Canada.
- Canadian Department of National Defence. Runway roughness evaluation and rehabilitation recommendations for 8 Air Force Bases across Canada.
- Transport Canada Pavement Preservation Guidelines. This research project developed a pavement preservation toolbox and guidelines to assist Canadian airport operators in the management, maintenance and construction of airport pavements.
- Transport Canada Runway Roughness Analysis. Reviewed the current state of the art in analyzing runway roughness. Included field testing and correlation relating various roughness data collection equipment and analysis procedures reporting to the Transportation Development Centre.

- Transport Canada Airside Pavement Structural Capacity Analysis. Two projects included the use of the Falling Weight Deflectometer, and Heavy Weight Deflectometer to develop a correlation with the traditional Transport Canada plate load test. Resulted in a new procedure and acceptance of FWD technology to determine ICAO Pavement Classification Numbers (PCN).
- Henry Rholsen International Airport, St. Croix. Design of new taxiway and apron for private aviation facility.
- V.C. Bird International Airport – Antigua. Principal Investigator and Peer Reviewer for the rehabilitation design of the airside pavements at the main airport in Antigua in the Caribbean.
- Skopje Macedonia International Airport, North Macedonia. Pavement surface condition assessment, materials testing and structural capacity assessment to assist in the development of rehabilitation options for the airside pavements.
- Norman Manley International Airport, Kingston Jamacia. Airside pavement surface condition and structural capacity assessment.
- Punta Cana Airport, Dominican Republic. Pavement smoothness testing and analysis.
- Pavement structural capacity testing and maintenance management plan development, Grantley Adams International Airport, Barbados.
- Development and implementation of web based AirView application for the display of pavement condition, maintenance and construction history information for over 200 airports in the United States.

Technical Courses, Workshops, Webinars and Training

Substantially involved in technical training and development since 1986, including face-to-face learning, webinars, and directed learning courses. This has included training and development courses and webinars for the Federal Highway Administration, American Society of Civil Engineers, Forester University, University of Illinois, Local Technical Assistance programs in Florida, Minnesota, Colorado, New Jersey and California, Centre for Transportation Engineering and Planning, Interlocking Concrete Pavement Institute, Alberta Road and Heavy Construction Association, Association of Professional Engineers and Geoscientists of British Columbia, Association of Professional Engineers and Geoscientists of Alberta, South African Institution of Civil Engineering, International Erosion Control Association, Independent Contractors and Business Association of British Columbia, HalfMoon Education Inc., Transportation Association of Canada, and the Ontario Good Roads Association. Also completed numerous training courses and workshops for private sector clients throughout North America and around the world.

- Workshop delivery (3) on the importance of pavement bases and materials for conventional and permeable interlocking concrete pavements (Toronto, Burlington and Ottawa).
- Completed the National Highway Institute instructor development course (4.5 days).
- Webinar Development and Delivery, FHWA, 2016-Present. Developed FHWA Tech Briefs and delivered webinars in support of the FHWA Concrete Pavement Program.
- Workshop Development and Delivery, Local Transportation Assistance Programs, Minnesota, Colorado, New Jersey, Ohio, Illinois, California and Florida. Developed and

delivered a series of permeable pavement (PICP and pervious concrete) and asset management workshops for LTAP programs.

- Workshop Development and Delivery, Municipal agencies including the Cities of Vancouver, Calgary, Winnipeg, London, Toronto, Ottawa and Montreal in Canada as well as over 25 cities across the United States, 2000 to present.
- Face-to-Face Training Course and Webinars, EPIC, 2003-Present. Developed and delivered over 50 face-to-face training courses and webinars for the EPIC Educational Program. This has included a variety of topics related to pavement design, evaluation and management, transportation infrastructure asset management, life-cycle costing and program delivery.
- Training Course and Webinar Development and Delivery, ASCE, 2010-Present. Developed and delivered over 40 webinars/courses for the American Society of Civil Engineering.
- Webinar Development and Delivery, Forester University, 2012 to Present. Developed and delivered over 30 webinars on stormwater management and the design, construction and management of transportation infrastructure.
- Training Course Development, Centre for Transportation Engineering and Planning, C-TEP, 2010-Present. Developed and delivered 6 2-day training courses for C-TEP in British Columbia, Alberta and the Yukon.
- Training Course Development, Alberta Heavy Road and Construction Association, ARHCA, 2015-Present. Developed and delivered 16 training courses on the production, transportation and placement of asphalt concrete for owners, consultants and contractors.
- Training Course Development, Ontario Good Roads Association, OGRA 2012 to Present. Developed and delivered 10 face-to-face training courses for engineers and technicians involved the management of road infrastructure.
- Custom Training Course Development and Delivery for Canadian Provincial Highway Departments of British Columbia (4), Alberta (1), Saskatchewan (2), Manitoba (2), Ontario (5).
- Training Course Development, Private Sector Clients, 1986-Present. Developed and delivered over 50 training courses on a variety of transportation and stormwater engineering design, evaluation and management subjects.

Honours

- American Society of Civil Engineers, Distinguished Service Award, 2018, Past President, T&DI
- Transportation Association of Canada: Distinguished Service Award, 2017; Committee Chair Award 2004.
- Applied Research Associates, Inc.: ARA Fellow – 2017; ARA Engineer of the Year, 2002; ARA Engineer/Scientist of the Year, 2001; ARA Technical Achievement Award – 2008, 2009, 2015.

Conference Publications and Articles

Mr. Hein has authored/co-authored over 80 technical papers on transportation asset management, pavement design and evaluation and construction materials engineering for international technical conferences and technical journals.

- Hein, D.K., "Asset Management Contributions to Road System Resilience in Canada", XVIth World Winter Service and Road Resilience Congress, Calgary, Alberta, 2022.
- Hein, D.K., "Off Road Benefits of Permeable Pavements", International Conference on Concrete Block Pavements, Seoul, Korea, 2018.
- Hein, D.K., "Permeable Pavement Case Study – Alston Way, Berkeley, California", International Conference on Concrete Block Pavements, Seoul, Korea, 2018.
- Hein, D.K., "Canadian Agency Asset Management Best Practices", International Transportation and Development Conference, Philadelphia, Pennsylvania, 2017.
- Hein, D.K., "Pavement Design for Large Element Paving Slabs", Transportation Association of Canada 102nd Annual Meeting, Toronto, Ontario, 2016.
- Kivi, A.K., and Hein, D.K., "An Overview of Best Practices for the Design and Construction of Sidewalks and Trails", Transportation Association of Canada 102nd Annual Meeting, Toronto, Ontario, 2016.
- Khanal, S., Olidis, C, and Hein, D.K., "Modelling Pavement due to SuperHeavy Load Move, Transportation Association of Canada 102nd Annual Meeting, Toronto, Ontario, 2016.
- Hein, D.K., and Smith, D.R., "Accelerated Testing to Validate the Design of Permeable Pavements for Heavy Loads", Stormcon 2016, Indianapolis, Indiana, 2016.
- Hein, D.K., and Smith, D.R., "How Should You be Designing your Permeable Pavements, New ASCE Standard", Stormcon 2016, Indianapolis, Indiana, 2016.
- Aho, B., Hein, D.K., Bessom, R, and Dennechuck, S., "10 Years of Experience Using Warm Mix Asphalt for Airside Pavements—Boston Logan Airport", Transportation and Development Institute, International Conference on Transportation and Development, Houston, Texas, 2016.
- Hein, D.K., and Khanal, S., "Challenges of Effective Management of Pavements for Highway Concessions", Transportation Association of Canada 101st Annual Meeting, Charlottetown, Prince Edward Island, 2015.
- Khanal, S., Hein, D.K. and Schaus, L, "Assessment and Effective Management of Pavement Surface Friction", Transportation Association of Canada 101st Annual Meeting, Charlottetown, Prince Edward Island, 2015.
- Hein, D.K., and Schaus, L., "Guidelines for the Maintenance of Permeable Interlocking Concrete Pavements", 11th International Conference on Concrete Block Paving", Dresden, Germany, 2015.
- Hein, D.K., "Permeable Pavement Design and Construction for Allston Way, Berkeley, California", StormCon Annual Meeting, Austin, Texas, 2015.
- Khanal, S., and Hein, D.K., "Mechanistic-Empirical Evaluation of the Impact of Spring Load Restrictions", Transportation Association of Canada 100th Annual Meeting, Montréal, Québec, 2014.
- Hein, D.K., "How to Successfully Manage our Airport Infrastructure", 2014 ASCE T&DI Airfield and Highways Conference, Orlando, Florida, 2014.
- Schaus, L., Poresky, A. and Hein, D.K., "Permeable Pavements for Roadway Shoulders", StormCon Annual Meeting, Portland, Oregon, 2014.
- Hein, D.K., "Permeable Pavement Design and Construction Case Studies", Transportation Association of Canada Annual Meeting, Montréal, Québec, 2014.

- Hein, D.K., and Schaus, L, "Permeable Pavement Design and Construction. What have we Learned Recently", American Society of Civil Engineers, Green Streets and Highways Conference, Austin, Texas, 2013.
- Smith, D.R, and Hein, D.K., "Development of a National Standard for Permeable Interlocking Concrete Pavement", American Society of Civil Engineers, Green Streets and Highways Conference, Austin, Texas, 2013.
- Hein, D.K., and Smith, D.R., "Permeable Pavement Design and Construction Case Studies in North America", StormCon Annual Meeting, Myrtle Beach, South Carolina, 2013
- Hein, D.K., "Airport Asset Management – What you Need to Know", Federal Aviation Administration, Regional Meeting, Hershey, Pennsylvania, 2012.
- Hein, D.K. and Midyett, M, "Pavement Design for Heavy Tracked Military Vehicles", International Conference on Concrete Block Pavements, Shanghai, China, 2012.
- Hein, D.K.,"10 Years of Experience in the Implementation of Pavement Preservation Techniques for Concrete Pavements", 24th World Road Congress, Mexico City, September 2011.
- Hein, D.K. and Smith, D.R., "Development of a Design System for Permeable Interlocking Concrete Pavement", StormCon Annual Meeting, Anaheim, California, September 2011.
- Holt, A., Hein, D.K., and Sullivan, S., "Life Cycle Cost Analysis of Municipal Pavements in Southern and Eastern Ontario", Transportation Association of Canada Annual Meeting, Edmonton, Alberta 2011.
- Hein, D.K, and Aho, B., "Preserving Our Airfield Pavements", T&DI Transportation Congress 2011, Chicago, Illinois, March 2011.
- Hein, D.K., Swan, D.J., and Wilke, P., "Permeable Pavements for Stormwater Management", ASCE Green Transportation Conference, Denver, Colorado, November 2010.
- Hein, D.K., Swan, D.J., and Schaus, L., "Structural and Hydrological Design of Permeable Pavements", Annual Conference of the Transportation Association of Canada, Halifax, Nova Scotia, September 2010.
- Hein, D.K., Hall, J., Olidis, C. and Jones, J., "Best Practices for Airport Design/Build Procurement", 2010 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, New Jersey, April 2010.
- Christensen, D., Mallela, J., Hein, D., et al, "Effect of Deicing and Anti-Icing Chemicals on HMA Airfield Runways", 2010 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, New Jersey, April 2010.
- Hein, D.K. and Rao, S., "Rational Procedures for Evaluating the Effectiveness of Pavement Preservation Treatments", First International Conference on Pavement Preservation, Newport Beach, California, April 2010.
- Hein, D.K. "Rational Guidelines for the Implementation of a Pavement Preservation Program for Municipal Pavements in Canada", First International Conference on Pavement Preservation, Newport Beach, California, April 2010.
- Hein, D.K. and Smith, D., "Life-Cycle Cost Comparison for Municipal Road Pavements", 9th International Conference on Concrete Block Pavements, Buenos Aires, Argentina, October 2009.

- Hein, D.K., Burak, R and Rada, G., "Development of a National Standard for the Structural Design of Interlocking Concrete Block Pavements", 9th International Conference on Concrete Block Pavements, Buenos Aires, Argentina, October 2009.
- Hein, D.K., Aho, B and Burak, R., "Development of a Condition Rating Procedure for Interlocking Concrete Block Pavements", 9th International Conference on Concrete Block Pavements, Buenos Aires, Argentina, October 2009.
- Hein, D.K., "Fostering Pavement Innovation in Canada", World Road Association PIARC International Seminar on Pavement Maintenance, Cancun, Mexico, August 2009.
- Hein, D.K. and White, C, "Optimization of Concrete Maintenance to Extend Pavement Service Life", National Conference on Preservation, Repair and Rehabilitation of Concrete Pavements, St. Louis, Missouri, April 2009.
- Hein, D.K., Swan, D.J., White, C.D., Corbett, M. and Drummond, S., "The Challenge of Developing Pavement Management Systems to Meet Public Private Partnership Concession Agreements", 7th International Conference on Managing Pavement Assets, Calgary Canada, June 2008.
- Swan, D.J. and Hein, D.K., "Creating Mechanistic Based Performance Models in PMS", 7th International Conference on Managing Pavement Assets, Calgary Canada, June 2008.
- Swan, D.J., Hein, D.K., Lane, B., and Kazmierowski, T., "Validation of the Mechanistic-Empirical Pavement Design Guide Using PMS Data", 7th International Conference on Managing Pavement Assets, Calgary Canada, June 2008.
- Hein, D.K. and Burak, R., "Development and Validation of a Pavement Condition Rating Procedure for Interlocking Concrete Block Pavements", Canadian Society of Civil Engineering, Annual Conference, Québec City, June 2008.
- Swan, D.J., Hajek, J, Hein, D.K. and Jacques, Bruno, "Estimation of Investment Requirements to Preserve the Canadian Roadway Infrastructure', Transportation Association of Canada, Saskatoon, Saskatchewan, 2007.
- Haas, R., Tighe, S.L., Hein, D.K., and Doré, G., "Mechanistic-Empirical Pavement Design Evolution and Future Challenges", Saskatoon, Saskatchewan, 2007.
- Hein, D.K., Burak, R., "Development of a Pavement Rating Procedures for Interlocking Concrete Pavements", Saskatoon, Saskatchewan, 2007.
- Hein, D.K., Swan, D.J. and Hajek, J., "Selection of Surface Type for Low Volume Roads", Saskatoon, Saskatchewan, 2007.
- Leong, P., Hein, D.K., Tighe, S.L, and Rothenberg, L, "Finite Difference Modeling of Misaligned Dowel Bars and Their Effects on Joint Performance", Transportation Research Board Annual Meeting, Washington, D.C., January 2006.
- Hein, D.K., "Resilient Modulus Testing of Open Graded Drainage Layer Aggregates for Interlocking
- Concrete Block Pavements", 8th International Conference on Concrete Block Paving, San Francisco, U.S.A., November 2006.
- Hein, D.K, Leong, P and Tighe, S.L., "Best Practice Design of Concrete Pavers for Canadian Municipal Applications", 8th International Conference on Concrete Block Paving, San Francisco, U.S.A., November 2006.

- Hein, D.K., Tighe, S.L., and Doré, G., "The Development of a Roadmap for the Implementation of the Mechanistic-Empirical Pavement Design Guide in Canada", 10th International Conference on Asphalt Pavements, Québec City, Canada, August 2006.
- Hein, D.K., and Croteau, J.M., "Pavement Preventive Maintenance Concepts and Techniques", 10th International Conference on Asphalt Pavements, Québec City, Canada, August 2006.
- Titus-Glover, L, Hein, D.K., Rao, S. and Smith, K., "Impact of Increased Construction Standards on the Life-Cycle Cost of Low Volume Streets, Transportation Research Board Annual Meeting, Washington, D.C., January 2006.
- Hein, D.K. and Watt, D., "Municipal Pavement Performance Prediction based on Pavement Condition", Transportation Association of Canada Annual Meeting, Calgary, September 2005.
- Hein, D.K, Leong, P and Tighe, S.L., "Pavement Design using Interlocking Concrete Pavers", Transportation Association of Canada Annual Meeting, Calgary, September 2005.
- Hajek, J., Blaney, C., and Hein, D.K., "The Effect of Highway Traffic Induced Vibrations", Transportation Research Board Annual Meeting, Washington, D.C., January 2005.
- Hein, D.K et al, "Priority Planning and Programming for Municipal Pavements", International Conference for Managing Pavements, Brisbane, Australia, October 2004.
- Hein, D.K., Hajek, J and Olidis, C, "Thin Treatments for the Preservation of Bituminous Pavements", Transportation Association of Canada Annual Meeting, Quebec City, September 2004.
- Olidis C. and Hein, D.K., Guide for the Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Materials Characterization, Is your Agency Ready? Transportation Association of Canada Annual Meeting, Quebec City, September 2004.
- Hein, D.K., and Croteau, JM, "Pavement Preservation Treatments", Transportation Association of Canada Annual Meeting, Quebec City, September 2004.
- Hein, D.K., and Beckemeyer, C.A., "Preventive Maintenance for Pavements", Urban and Regional Information Systems Association (URISA), Annual Conference, Atlanta, Georgia, October 2003.
- Hein, D.K., Olidis, C., "Impact of Recent Technology on Pavement Life", Transportation Association of Canada Annual Meeting, St. John's, Newfoundland, September 2003.
- Hein, D.K., "Best Practices – Preventive Maintenance of Municipal Roads", INFRA 2002 Conference, Montreal, Québec, November 2002.
- Hein, D.K., and Cole, R.M., "Establishment and Monitoring of Pavement Load Restrictions in the Province of British Columbia", Transportation Association of Canada Annual Meeting, Winnipeg, Manitoba, 2002.
- Hallin, J., Hein, D.K., and Popik, M., "Input Requirements for the AASHTO 2002 Guide for New and Rehabilitated Pavement Structures", Transportation Association of Canada Annual Meeting, Winnipeg, Manitoba, 2002.
- Hein, D.K., Olidis, C., Magni, E and MacRae, D., "A Method for the Investigation and Validation of Composite Pavement Performance Including the use of the Falling Weight Deflectometer", Pavement Evaluation 2002, Roanoke, Virginia, 2002.

- Hein, D.K. and Fernandez-Lillo, C. "Partnering and Optimization in Pavement Design – The Ontario Highway 407 Experience." 2001 Transportation Association of Canada, Halifax, Nova Scotia, 2001.
- Hein, D.K., Fernandez-Lillo, C. and Saenz-Ormijando, F. "Mechanistic-Empirical Design and Design Validation – Toronto Highway 407 East Partial and Western Extension Freeway Design." 2001 Transportation Association of Canada, Halifax, Nova Scotia, 2001.
- Hein, D., Brooks, D., Uzarowski, L, and Emery J.J., "Municipal Implementation of Superpave Technology", Canadian Technical Asphalt Association, 1998.
- Hein, D., and Jung, F.W., "Assessment of Techniques to Determine Pavement Damage due to Heavy Loading", 1998 Transportation Association of Canada, Regina, Saskatchewan, 1998.
- Ostrander, P., and Hein, D.K., "Design and Construction of Highway 407 Concrete Pavements," International Road Federation, XXIIth World Meeting, Toronto, Ontario, Canada, 1997.
- Carrick, J.A., Fraser, B., Hein D., and Emery, J. "Pavement Performance and Life-Cycle Cost Evaluation of a Polymer Modified Asphalt Cement", CTAA Proceedings, Pages 445-463, 1996.
- Hein, D.K., Emery, J.J and D'Ippolito, R., "Design, Construction and Performance of Micro-Surfacing for Urban Pavements," Presentation at the 72nd Annual Meeting of the Transportation Research Board, Washington DC, 1994.
- Hein, D.K, and Jung, F.W., "Evaluation of Overloads on Pavements for Oversize/Overweight Permit Guidelines," 4th International Conference on the Bearing Capacity of Roads and Airfields, Minneapolis, Minnesota, 1994.
- Hein, D.K, and Jung, F.W., "Seasonal Variations in Pavement Strength Factors," 4th International Conference on the Bearing Capacity of Roads and Airfields, Minneapolis, Minnesota, 1994.
- MacKay, M.H., Hein, D.K, and Emery, J.J., "Evaluation of Frost Action Mitigation Procedures for Highly Frost Susceptible Soils," Presentation at the 71st Annual Meeting of the Transportation Research Board, Washington, DC, 1992.
- Hein, D.K., Burlie, R., D'Ippolito, R and Emery, J.J., "Asphalt Technology for Urban Pavement Construction and Maintenance", Canadian Technical Asphalt Association Annual Meeting, 1992.
- Hein, D.K., MacKay, M.H. and Emery, J.J., "Evaluation and Treatment of Slab Stepping on a Major Runway," Transportation Association of Canada, Winnipeg, Manitoba, 1991.
- Hein, D.K. and Emery, J.J., "Performance of Engineered Asphalt Cements", Canadian Technical Asphalt Association Annual Meeting, 1991.
- Hein, D.K. and Emery, J.J., "Rapid Monitoring of Flexible Pavement Deflections, Moduli and Roughness," Proceedings of the 4th Workshop on Paving in Cold Areas, Volume 2, Sapporo, Japan, September 1990.
- Hein, D.K. and MacKay, M.H., "Analysis of Runway Roughness," Presentation, Transportation Research Board Annual Meeting, Washington, DC, 1990.

- Stolle, D. and Hein, D.K., "Elastostatic Analysis and Back-Calculation Estimates of Pavement Layer Moduli," Canadian Technical Asphalt Association, Winnipeg, Manitoba, November, 1990.

Technical Courses Taught

Mr. Hein is a regular technical lecturer and has led training courses and delivered webinars for over 15,000 individuals. Examples of technical courses taught is outlined below.

- American Society of Civil Engineers Technical Webinar Series, since 2011, over 50 webinars and short courses on a variety of pavement engineering technical webinars including conventional and permeable pavement design, airport pavement management, innovation in pavement engineering, waste and by-product use in pavement construction, flexible and rigid pavement construction, flexible and rigid pavement design, pavement preservation, and pavement construction.
- Forester University, since 2011, over 20 webinars on permeable pavement design and construction including a 4-part Master Series, pavement preservation, innovation in pavement engineering and innovation in pavement design and construction.
- EPIC Educational Series, since 2002, over 30 face-to-face technical courses and webinars on the design, evaluation and management of pavement, sidewalk and recreational trail infrastructure.
- “Sidewalk Design, Evaluation and Management”, Alberta Health Services (AHS), 2021.
- “Pavement Evaluation and Design”, Centre for Transportation Engineering and Planning, Edmonton, Alberta 2020.
- Honolulu and Hawaii Water Environment Association (HWEA) 2019 Water Quality Workshop on the Design, Construction and Maintenance of Permeable Pavements, 2019.
- Vancouver International Airport, Custom Course on the Design, Evaluation and Management of Airport Pavements, 2018.
- “Pavement Inspection, Asphalt Materials, Mix Design, Plant Operations, Transportation and Placement”, Regional Municipality of Halifax, 2018.
- “Asphalt Materials, Mix Design, Plant Operations, Transportation and Placement”, Over 1,000 individuals, Edmonton, Red Deer and Calgary, 2015-2018.
- “Design, Preservation, Evaluation and Management of Pavement Infrastructure”, Yukon Highway Department, Whitehorse, Yukon, 2017.
- “Concrete Materials, Mix Design, Production and Placement, Edmonton and Calgary, 2016.
- “Advanced Pavement Design Course”, Ontario Ministry of Transportation, 2016.
- “Advanced Pavement Design and Rehabilitation Course”, British Columbia Ministry of Transportation, Vancouver, British Columbia, 2016.
- “Design, Preservation, Evaluation and Management of Pavement Infrastructure”, Edmonton, Vancouver and Ft. McMurray, 2016.
- “Permeable Pavement Design, Construction and Maintenance Master Class Series, Parts 1 to 4”, Forester University, 2012-2015.
- “Asphalt Materials, Mix Design and Plant Operations”, Edmonton, Alberta, 2015.

- "Pavement Condition Assessment Procedures", Ontario Good Roads Association, Belleville, Ontario, 2015.
- "Pavement Design, Evaluation and Asset Management", Vancouver, Spruce Grove, Edmonton, Saskatoon, Regina and Ottawa, 2015.
- "Pavement Design, Evaluation and Management", British Columbia Ministry of Transportation and Ontario Ministry of Transportation, 2014.
- "Pavement Design, Evaluation and Asset Management", Ontario Ministry of Transportation, 2014.
- "Pavement Design, Evaluation and Management", Vancouver and Winnipeg, 2014.
- "Life-Cycle Costing for Pavement Design", Toronto, 2014.
- "Pavement Design, Evaluation and Management", Toronto, Vancouver and Edmonton, 2013
- "Permeable Pavement Design, Construction and Maintenance", Alberta Low Impact Development, Calgary, 2013.
- "Pavement Design and Evaluation", Ontario Ministry of Transportation, May 2012.
- "Pavement Design, Evaluation and Management", Toronto, Vancouver and Regina, 2012.
- "Permeable Pavement Design and Construction", Over 40 locations, United States and Canada, 2009-2012.
- "Flexible Pavement Rehabilitation", Ontario Good Roads Association, Brampton, 2011.
- "Evaluation and Rehabilitation of Pavement", Vancouver and Halifax, 2010.
- "Evaluation and Rehabilitation of Pavement", Vancouver, Calgary and Toronto, January/February, 2008.
- "Mechanistic-Empirical Pavement Design", Edmonton Alberta, February 2008.
- "Hands on Mechanistic-Empirical Pavement Design", Winnipeg, Manitoba, May 2007.
- "Basics of Mechanistic-Empirical Pavement Design", Vancouver, British Columbia, March 2007.
- "Evaluation and Rehabilitation of Pavement", Regina and Vancouver, February 2007.
- "Workshop on the International Experience with Mechanistic-Empirical Pavement Design", 10th International Conference on Asphalt Pavement, Québec City, Canada, August 2006.
- "Pavement Rehabilitation and Maintenance", Highway 407 ETR Toll Road 2006 Maintenance Program, Highway 407 ETR, Toronto, April 2006.
- "Evaluation and Rehabilitation of Pavement", Toronto and Calgary, March 2006.
- "Forward Calculation Concepts and Procedures", American Society of Civil Engineers, Denver, Colorado, August, 2004.
- "Procedures Required for the Implementation of the New AASHTO 2002 Mechanistic-Empirical Design Guide", Québec City, Québec, February 2004.
- Full-day workshop with co-presenter from New Zealand on international best practices and innovation on the maintenance and rehabilitation of flexible and rigid pavements, 2004.
- "Evaluation and Rehabilitation of Pavement", Toronto, Vancouver (2), Edmonton, Calgary and Regina, February/March 2004.
- "Airfield Pavement Design", Department of National Defence, Winnipeg, Manitoba, March 2004.

- "Advanced Pavement Design", Ontario Ministry of Transportation, Barrie, Ontario, January 2004.
- "Evaluation and Rehabilitation of Pavement", St. John, New Brunswick, February 2003.
- "Pavement Design and Evaluation using the Falling Weight Deflectometer", Ontario Ministry of Transportation, November 2002
- "Evaluation and Rehabilitation of Pavement", Vancouver, British Columbia, Edmonton, Alberta and Regina, Saskatchewan, February 2002.
- "Evaluation and Rehabilitation of Pavement", Toronto, Ontario, January 2002.
- "Pavement Rehabilitation using Expanded Asphalt", Saskatchewan Highways and Transportation, October 2001.
- "Mechanistic Pavement Design and Utilization of the Falling Weight Deflectometer", University of Manitoba and Manitoba Highways, March 2001.
- "Pavement Design using the AASHTO-Ontario Method", Ontario Good Roads Association, Mississauga, Ontario, February 2001.
- "AASHTO-Ontario Adaptation", Ontario Ministry of Transportation, Toronto, Ontario, December 2000.
- "Pavement Deflection Testing and Data Analysis", Ontario Ministry of Transportation Southwestern Region Geotechnical Section, London, Ontario, June 2000.
- "Pavement Mechanistic Design", Presentation and training sessions for the highway department of the Provinces of British Columbia, 1990, 1992 and 1994.
- "Pavement Mechanistic Design and Falling Weight Deflectometer Operation", Alberta, Transportation and Utilities, Edmonton, Alberta, 1989, 1990, 1992 and 1993.
- "Mechanistic Pavement Design", University of New Brunswick, Fredericton, New Brunswick, 1994.
- "Mechanistic Pavement Design and Falling Weight Deflectometer Operation", Ministère des Transports du Québec, Québec, 1991.
- "Mechanistic-Empirical Design of Highway Pavements and Falling Weight Deflectometer Operation", Taiwanese Highway Department, Taipei, Taiwan, 1994.

Conference Presentations

Completed over 150 technical presentations at conferences and committee meetings.

Appendix B - Sources

Sources

1. Flintsch, G.W. "Analysis of Pavement Friction on the RHVP". (EXP0000191)

2. 407 ETR. "Sale & Concession Agreements – Schedule 20 – Safety and Standards Protocol". https://407etr.com/documents/sales/Schedule_20.pdf. Accessed 2022-12-21. (HAM0064455_0001)

3. Government of Ontario. "Project Agreement – Highway 407 East Phase 2". Toronto, Ontario. 2014. (HAM0064459_0001)

4. Ministry of Transportation of Ontario. "Friction Testing". Downsview, Ontario. 2009. (HAM0064462_0001)

5. Henry, J.J. "Evaluation of Pavement Friction Characteristics NCHRP Synthesis 291". Transportation Research Board. Washington, D.C. 2000. (EXP0000021)

6. Kamel, N and Gartshore, T. "Ontario's Wet Pavement Accident Reduction Program". Inquiry Document RHV0000610. Downsview, Ontario. 1982. (HAM0064461_0001)

7. Red Hill Valley Parkway – Surface Pavement Investigation Methodology Report, ARA, September 11, 2019. (HAM0009630_0001, HAM0009633_0001, HAM0009628_0001, HAM0009634_0001, HAM0009629_0001)

8. Noyce, D.A., Bahia, H.U., Yambo, J., Chapman, J., and Bill, A. "Incorporating Road Safety into Pavement Management: Maximizing Surface Friction for Road Safety Improvements". Report No. MRUTC 04-04. Wisconsin Department of Transportation. Madison, Wisconsin. 2007. (MTO0000395)

9. SAE. "Tire Friction During Locked Wheel Braking". Society of Automotive Engineers. SAE 2000 World Road Congress. Detroit, Michigan. 2000. (HAM0064463_0001)

10. Henry, J.J., Burchett, J.L., Rizenbergs, R.L. and Agrawal, S.K. "Interaction between Vehicles and Pavement Surfaces". Transportation Research Board 788. Transportation Research Board. Washington D.C. 1980. (HAM0064460_0001)

11. Golder. "Red Hill Valley Parkway – Performance Review after Six Years in Service". Golder Associates. 2014. (GOL0002981)

12. CIMA+. "Pavement Friction Testing Results Review – Memorandum to Mayor Fred Eisengerger and Hamilton City Council". February 4, 2019.FEHRL. "Tyre and Road Surface Optimization for Skid Resistance and Further Effects, TYROSAFE – Final Summary Report". Brussels, Belgium. 2010. (CIM0017167.0001)

13. Viner, H., Sinhal, R., and Parry, A. "Review of UK Skid Resistance Policy". Fifth Symposium on Pavement Surface Characteristics for Roads and Airports. Toronto, Ontario, Canada. 2004. (HAM0064456_0001)

14. Austroads. "Guidance for the Development of Policy to Manage Skid Resistance". Austroads Publication No. AP-R374/11. Sydney, Australia. 2011. (EXP0000051)

15. Wambold, J.C., et al. "International PIARC Experiment to Compare and Harmonize Skid Resistance and Texture Measurements". PIARC Publication N 01.04.T, Paris, France. 1995. (EXP0000025)

16. FEHRL. "Tyre and Road Surface Optimization for Skid Resistance and Further Effects, TYROSAFE – Final Summary Report". Brussels, Belgium. 2010. (HAM0064458_0001)

17. FEHRL. "Roadmaps and Implementation Plan for Harmonised Skid Resistance Measurement Methods". TYROSAFE – D09 Report. Brussels, Belgium. 2009. (HAM0064457_0001)

18. Dunford, A. "Grip Tester Trial – October 2009, TRL Published Project Report PPR497". Devon County Council, Berkshire, U.K. 2010. (EXP0000034)

19. AASHTO. "Guide for Pavement Friction". American Association of State Highway and Transportation Officials. Washington, D.C. 2009. (EXP0000020)