FIELD EXPERIMENTS IN CPATT'S LONG TERM PROGRAM OF PAVEMENT RESEARCH

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ABSTRACT

A new initiative involving an integrated laboratory and field facility and research program was described in a paper to the TAC conference in Winnipeg in September 2002. This initiative, within the Centre for Pavement and Transportation Technology (CPATT), has received an unprecedented level of federal, provincial, municipal, private sector and university support in a total package amount to $6 million. It is intended that the research infrastructure from this support will provide the capability for tackling a large range of problems and issues in the pavement and transportation field.

A field experiment, constructed in 2002 and consisting of a number of pavement sections, is a major part of the CPATT program. It is located at the Regional Municipality of Waterloo's waste management facility, which provided the opportunity to have the sections subjected to a large number of heavy loads under carefully monitored conditions. Key variables in the experiment included different asphalt mixes (Superpave, SMA, and polymer modified) and key performance measurements include before and after FWD measurements, roughness progression (IRI) and surface distress. As well, extensive materials characterization measurements were carried out.

This paper first briefly outlines the contexts for the field experiments and then describes in detail the experimental plan, the materials types and properties, the structural design, the loading history and the performance record.

INTRODUCTION

Background

The past century has seen massive gains in economic development and social advancement in Canada and many other countries. This advancement is attributable to the physical and management infrastructure for roads, airfields, buildings, water and wastewater, waste disposal, parks and recreation and various other civil facilities. Preserving the existing infrastructure asset base, and adding to it, however, poses major financial, political, environmental, resource and technological challenges.

The technological challenges in roads and pavements are particularly acute and include not only the need for asset preservation but also the provision of adequate levels of service and safety and the need for continuing innovations and advancements in all areas. It is these needs which have formed the basis for an unprecedented and new research initiative involving an integrated laboratory and field-test facility.

Support for the initiative has come from a three-way partnership of public and private sectors and academia. The Canada Foundation for Innovation (CFI) and the Ontario Innovation Trust (OIT) are providing $4.8 million over four years for the research infrastructure. A group of additional partners are providing support in terms of cash, in-kind and endorsement. Among the initial group of these partners are McAsphalt Industries Limited, the Regional Municipality of Waterloo, the Ministry of Transportation Ontario, the Greater Toronto Airport Authority, the Ontario Road Builders Association, the Cement Association of Canada, the Ontario Hot Mix Producers Association, Petro Canada Limited, Stantec Consulting Limited and Polyphalt Inc. The initial partners from academia are the University of Waterloo, Carleton University, Royal Military College and McMaster University. However, linkages are also being established to other universities, including Calgary, Manitoba and Laval.

The cash and in-kind support, additional to CFI and OIT, amounts to $1.2 million, for a total 4-year package of $6 million. It is expected that this will provide a quantum advancement in roads and pavements infrastructure research capability in Canada, and that, in turn, the public sector (federal, provincial and municipal) and the private sector (contractors, consultants, suppliers, manufacturers) will be able to enjoy the most up-to-date, state-of-the-art technology and researchers applied to their grants and contract dollars.

Scope and Objectives

The broad scope of this paper is to describe the CPATT field test site and how it fits into the overall University of Waterloo research program. The paper examines the broad context of the research program which includes both a laboratory and field research facility and then describes the test site and initial field performance results.

Context

The current asset value of Canada's roads and pavements is in the order of $150 billion. Protecting this investment is of critical importance to the movement of goods and the mobility of people. Competing pressure, however, for funding from other segments of society, and having to cope with more costly and diminishing materials resources, requirements for zero-waste management and sustainability, present a real threat to our ability to protect the investment and offer the level of service expected by society. At the same time, though, there is both an opportunity and a critical need to carry out the research and technology development which will advance the planning, design, construction and operation of our roads to a new level over the coming decades [Haas 2002].

This must be accomplished through an effective and long-term partnership between researchers, public sector agencies and private industry. Accordingly our broad vision to meet the challenge involves the following key elements:

- A concentrated focus on emerging and innovative technologies.
- State-of-the-art research infrastructure comprising lab and field facilities with capability of tackling specific problems, developing new technologies and training highly qualified people (HQP).
- A substantive increase in the talent pool of HQP.
- Seeking and sustaining partnerships with individuals and organizations in technology development and applications including commercialization [Haas 2002].

The key priority areas for research at CPATT are categorized as follows:

A. Innovative structural and materials technologies for pavements.
B. Advanced computer applications related to roads.
C. Pavement construction, preservation and sustainable development.
D. Pavement and roadway safety.

Table 1 provides a summary description of these key priority areas in terms of rationale.

THE INTEGRATED FACILITY

The overall structure of the integrated facility and research program is illustrated in Figure 2. It works on a three-way partnership of public sector, private sector and universities. A Board of Directors provides general direction and priorities, with the actual execution being the responsibility of a team of researchers, technical staff and students. Since the program is centered at a university, there are certain policies, including financial and accounting procedures, which apply, as shown in Figure 2. Key areas of the research program are subsequently discussed [Haas 2002].

The physical home of the program is an integrated field facility and test site and a university housed laboratory. Regarding the former, it is located at the Regional Municipality of Waterloo's waste management site, which has a number of key features, not the least of which is a highly supportive municipal partner. As well, the site, which also is home to a CFI and OIT funded test track and building for fire training and research, has a land area of several hundred

Table 1: Priority Research Areas, Rationale, Example Sub Areas and Expected Impacts [Haas 2002]

Research Area and Rationale	Example Sub Areas	Expected Impacts
A. Innovative Structural and Materials Technologies for Pavements --- changes in traffic loading --- demands for better pavement performance --- diminishing resources --- accelerated distresses --- cold climate effects --- requirements for recycling and reuse --- need for more fundamental engineering and science based technologies	a) Low temperature evaluation of materials • research on engineered asphalts • evaluation of new concrete mix designs and materials • evaluation of new structural designs and resistance to environmental effects • evaluation of recycled materials b) Micro-mechanical modelling • discrete element techniques to simulate particle to particle and binder interactions • improved understanding of fundamental material behaviour	• Generation of substantial cost savings by minimizing premature deterioration due to cold climate effects • Move toward scientific basis for materials selection and mix designs
B. Advanced Computer Applications Related to Roads --- profound changes in the way of designing, building, preserving, evaluating and managing roads triggered by the computer age --- real opportunities for exploiting computer age to gain technical and economic advantages (e.g., automated surveillance technologies, diagnostic analyses, remote sensing) --- need for generating reliable, useable, data bases.	a) Instrumented test sections • strain carriers, deflection gauges, moisture probes, thermistors or thermocouples, weigh-in-motion scales, etc. as required in experimental designs • roadside and remote access data logging b) Automated, high speed image capture • use of LCD technology for image capture • application of fuzzy logic and techniques such as neural networks for distress analysis and diagnostics c) Intelligent Transportation Systems (ITS) applications • research on roadway environmental sensing, emissions sensing and inclement weather warning systems	• Data for developing better performance models for different climatic, traffic loading and structural design conditions • Data for physical distress modelling • Improved consistency and reliability in data acquisition • Improved marketability of Canadian developed technology and equipment • Improved road safety • More effective management
C. Pavement Construction, Preservation and Sustainable Development --- funds required for pavement rehabilitation and maintenance are claiming major share of available budget --- great need for preservation of investment --- danger of decreasing asset value	a) Maintenance and construction methods and automation • development of systematic, cost-effective procedures for pavements preservation and asset management based on reliable distress and performance data • development of automated equipment and procedures for pavement maintenance and construction b) New materials, recycling and waste products • development of methodologies for 100% recycling and reuse of materials • research on properties and performance of new and modified materials	• Moving away from traditional, reactive and worst case first maintenance • Improved construction productivity and cost-effectiveness • Quantum advancements toward sustainable development • Becoming a leader and exporter of new technologies
D. Pavement and Roadway Safety --- increased volumes and traffic density --- need to develop new and better counter measure technologies -- need to integrate technologies with non-technical factors ---	a) Research on sensing technologies • pavement sensors for icing • higher light reflectivity surfaces and delineations b) Research on paved and partially paved shoulders • safety improvements and economics	• Better warning systems • New technologies with export potential

hectares, truck monitoring and weighing capability, access to utilities and water and close proximity (about 5 km) to the University. A building for field test equipment, repair and servicing, data acquisition units, etc. is a part of the site [Haas 2002].

The central lab facility at the University of Waterloo incorporates state-of-the-art equipment for static and dynamic structural testing of materials, characterization of materials (e.g., SHRP) and a cold climate chamber. The latter is a particularly important aspect of the facility and is intended for testing various concrete, bituminous, geosynthetic, composite and other materials (e.g., building components) under simulated low temperature, freeze-thaw and thermal cycling conditions [Haas 2002].

It should be noted that the program intends to have satellite field test sites, which are complementary to the main facility, where and if these are desired as part of a project or research program. The applicability would be primarily to various municipalities and provincial and federal transport agencies [Haas 2002].

As well, the central lab facility intends to have liaison wherever possible with other Canadian, United States and foreign labs again where it makes mutually advantageous sense. This certainly could include private sector labs, and specialized facilities such as at the National Research Council of Canada [Haas 2002].

Key benefits of this initiative include the potential for full scale monitoring and testing of asphalt pavements under accelerated life cycle (torture) conditions induced by heavy truck loading. Through the evaluation of the performance and durability of an in service asphalt pavement, many new developments and potential improvements are being examined including: paving materials, mix design technology, pavement structure, construction techniques, and repair methods. Much field data collection equipment is being used to consider the effects of such factors as traffic loading and the environment. Integrated with the field site, laboratories equipped with state-of-the-art equipment and instruments allow for torture, structural, and climate testing in a controlled environment. In addition, this initiative has allowed for the assessment of geogrid reinforcement and trenchless technology. Many opportunities for new development have been created by this project which has become a training ground for many graduate and undergraduate students.

CPATT FIELD SITE

Test Track Location

The Centre for Pavement and Transportation Technology (CPATT) commissioned the construction of a pavement test track at the Regional Municipality of Waterloo’s waste management facility. Located in the southeast corner of the property, the test track runs from north to south and is identified in Figure 1.

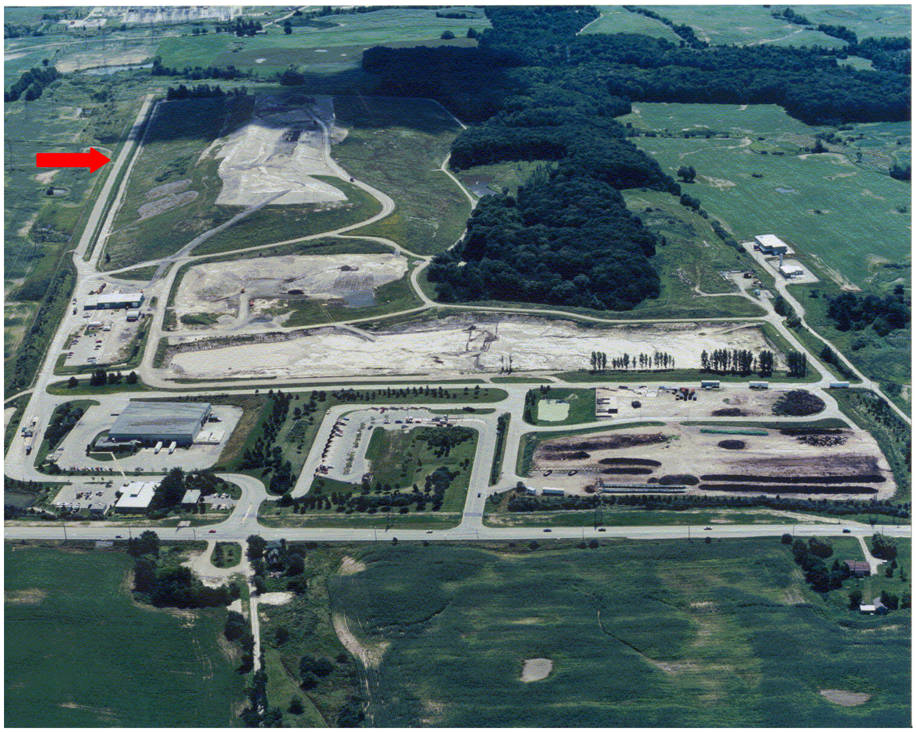

Figure 1: Regional Municipality of Waterloo's waste management facility

Located along Erb Street West in Waterloo, the Region of Waterloo's waste management facility is within close proximity to the University of Waterloo campus making it an ideal location (see Figure 2).

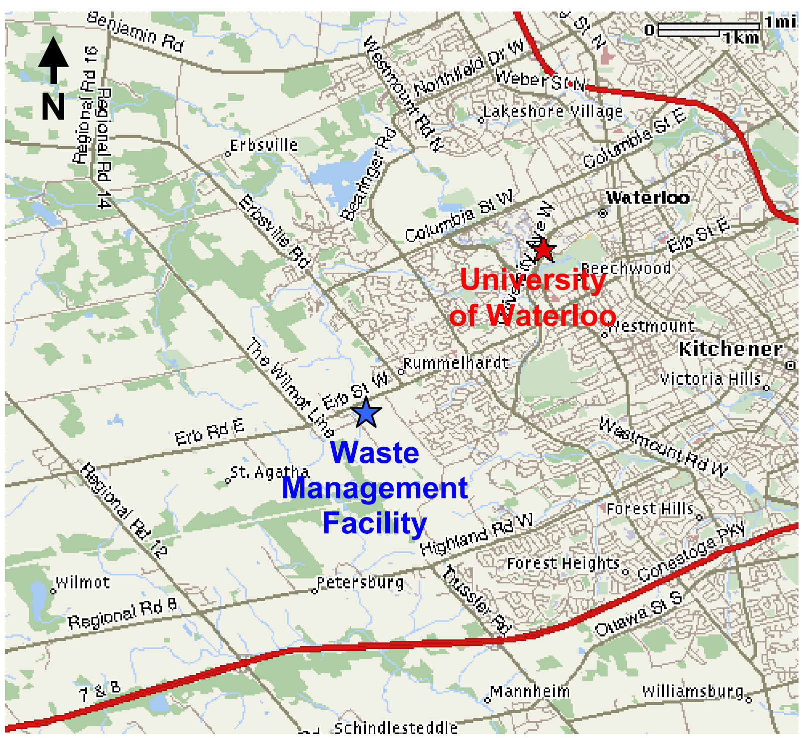

Figure 2: Location of Regional Municipality of Waterloo's waste management facility

Geotechnical Information

The Region of Waterloo is gently rolling, lying on outwash sand accompanied by sand and gravel overlaying glacial tills originating during the glacial period. From three boreholes drilled in the area of the test track, the existing material was determined to be medium to very dense and considered generally moist. Subgrade soils were determined to be mainly clay and sand with trace amount of gravel present. Drainage existed prior to the construction of the test track. It consisted of corrugated steel pipe culverts underneath the road bed with drainage directed easterly into a ditch which runs parallel to the test track towards a stormwater management facility. Since the area is not susceptible to flooding, additional drainage was not warranted. [Krygsman 2002]

Layout of the Test Track

Construction of the test track took place in June of 2002. The design and construction was expedited to take advantage of a major clay haul at the site later that summer. A total of 709 m in length and seven metres in width, this two lane test track is composed of a standard binder mix and four different surface mixes including standard Hot-Laid3 (HL3), Polymer-Modified Asphalt (PMA), Stone Mastic Asphalt (SMA) and Superpave. The binder course consisted of a standard municipal mix which was a HL4. A portion of the test track beyond 709 m was left in gravel to allow the haul vehicles a lead in to get up to speed and remove the majority of the mud from their tires before reaching the test track. The PMA section was further divided into two sections, half of which was reinforced with a BX 1200 biaxial geogrid. A diagram of the layout of these various mix designs can be seen in Figure 3. As noted, two control sections HL3-1 and HL3-2 were placed at each end of the test track.

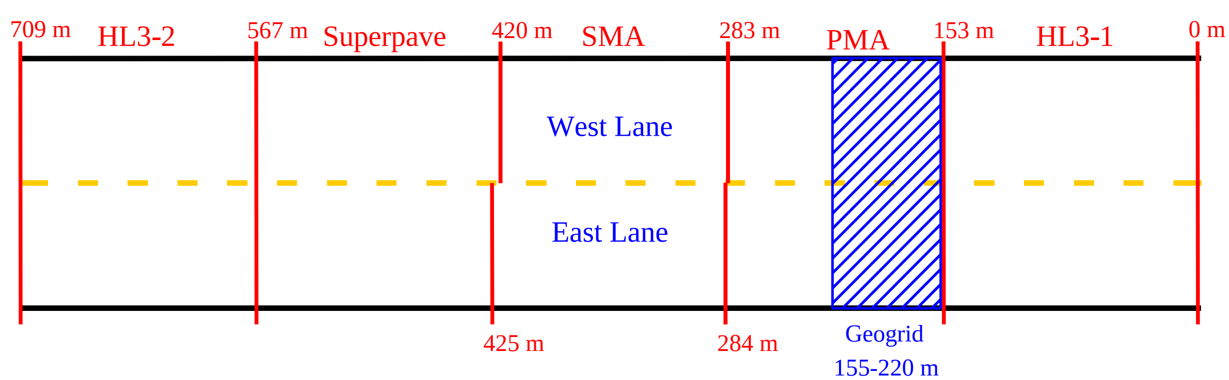

Figure 3: Layout of test track

Test Track Construction

All materials used to construct the test track were supplied by one of two asphalt plants owned by Steed and Evans Limited (S & E). The granular 'A' as well as the HL4 binder course and HL3 surface course asphalt mixes were hauled from the S & E Heidelberg asphalt plant located at the junction of Regional Road 16 and 17 in the Region of Waterloo, northwest of the test track. All remaining asphalt mixes (Superpave, SMA, and PMA) were produced at S & E Kitchener asphalt plant located on Regional Road 6, one kilometer west of Trussler Road, also in the Region of Waterloo and south of the test track.

Taking place over the course of six working days, construction of the test track can be segregated into four stages. Stage 1 involved the placement of the granular 'A' and geogrid (Figure 4a) which was performed mainly on June 7, 2002 with a few additional loads being placed on June 10, 2002. The second stage of construction, taking place on June 11, 2002, involved the placement of a HL4 binder course over the entire length of the test track. Also occurring on June 11, 2002 as well as June 12, 2002 was stage 3 of test track construction, placement of the four different surface mixes. The final stage of test track construction involving the filling and compaction of the shoulders with granular material and took place on June 13, 2002 and June 14, 2002. June 14, 2002 also saw the extraction of core samples from all section, as seen in Figure 4b. Figure 4c shows a long shot of the completed test track with three different surface material sections visible (HL3-2, Superpave, and SMA).


Figure 4a: Geogrid


Figure 4b: Core samples


Figure 4c: Test track

Throughout construction of the test track, the University of Waterloo personnel were present at both asphalt plants and the test track site to inspect and document operations. These personnel were mainly University of Waterloo graduate students supervised by professors in the pavement management group. Students were provided with inspection task lists and an operation recording and sampling strategy. Beyond documenting observations made during construction, inspection tasks included collecting samples of the granular and all asphalt mixes at the test track as well as collecting the components of each of the asphalt mixes from the asphalt plants. During the placement of the asphalt mixes, air and mix temperatures were recorded as well as depths of each layer, both prior to and following compaction.

ANALYSIS OF DATA

Traffic Data

In order to better understand the loading endured by the test track during the clay haul, the potential of the loading to cause damage was measured in Equivalent Single Axle Loadings (ESALs). By considering the total number of trucks of each type involved with the clay hauling, the number of days over which hauling took place, and the number of round trips on average a truck could make in a day, as well as the total ESALs from each truck, considering the contribution of all three truck axles, both loaded and unloaded it was possible to determine the ESALs experienced by the test track. The Ontario Ministry of Transport truck factors were used in calculating ESALs.

From data provided by the contractor performing the clay haul it was determined that the clay haul took place over eighteen days with the number of trucks being used on any one day ranging from four to nine and each truck averaging 36 runs per day. By considering manufacturer specifications for each truck type it was determined that each unloaded truck applied approximately 19 ESALs, while a loaded truck applied approximately 41 ESALs. By considering all these factors, the total ESALs endured by the test track in the summer of 2002 were calculated to be about 296,000.

Material Data

Mix designs for the SMA and Superpave asphalt mixes placed during the construction of the test track were supplied by McAsphalt Engineering Services. The HL4, HL3 and PMA mix designs were provided by Steed and Evans Limited. A break down of each mix into its components by mix percentage can be seen in Table 2. Note that the HL4 includes 19.17% Recycled Asphalt Pavement (RAP) while the SMA included 7.55% filler. SMA contains the greatest amount of virgin asphalt cement while HL4 contains the least. The HL3 and PMA have identical mix design proportions since the PMA is an HL3 with an engineered binder [McAsphalt 2002, Steed and Evans 2002].

Table 2: Mix Design Proportions

Materials	HL4	HL3	PMA	SMA	Superpave
Coarse Aggregate	36.53%	43.70%	43.70%	75.47%	48.52%
Fine Aggregate 1	40.17%	38.00%	38.00%	11.32%	46.62%
Fine Aggregate 2	-	13.30%	13.30%	-	-
RAP	19.17%	-	-	-	-
Filler	-	-	-	7.55%	-
Virgin Asphalt Cement	4.13%	5.00%	5.00%	5.67%	4.86%
PG-AC Grade	PG 58-28	PG 58-28	PG 70-28	PG 70-28	PG 70-28

The gradations for all mix designs used in the construction of the test track are presented in Table 3 below. With the exception of the SMA mix design, the gradation of the mixes are similar.

Table 3: Gradation Summary for Mixes

Gradation % Passing Sieve	HL4	HL3	PMA	SMA	Superpave
26.5 mm					
19 mm	100.0				
16 mm	99.3	100.0	100.0	100.0	100.0
13.2 mm	92.7	98.0	98.0	98.1	98.8
9.5 mm	76.9	80.6	80.6	69.6	80.6
4.75 mm	55.1	54.2	54.2	24.2	51.0
2.36 mm	46.9	44.5	44.5	21.3	40.6
1.18 mm	34.6	31.9	31.9	18.3	29.7
600 µm	21.8	19.8	19.8	16.2	22.4
300 µm	10.5	10.3	10.3	13.3	12.5
150 µm	4.4	5.2	5.2	10.6	5.6
75 µm	2.0	3.1	3.1	8.6	3.0

Properties of each mix were also determined to insure compliance with specifications as well as to allow for comparison of the mixes. The Marshall mix design method was used for the HL4, HL3 and PMA. For the SMA and Superpave mix the Superpave mix design method was used. Properties of interest with the Superpave method include the design number of gyrations (N_{design}) as well as the maximum specific gravity at the initial number of gyrations (% G_{mm} @ $N_{initial}$) and the maximum number of gyrations (% G_{mm} @ N_{max}). Other properties of interest include the percentage of the total compacted volume that is air voids (Air Voids), voids in the mineral aggregate as a percentage of the total volume (VMA) and voids filled with asphalt as a percentage of the total void volume (VFA). Flow and stability of the mix are of interest with the Marshall method. In additional, the tensile strength ratio, bulk specific gravity of compacted mixture (G_{mb}) and maximum specific gravity of paving mixture (G_{mm}) were also determined. A summary of these mix properties for each mix design can be found in Table 4 [McAsphalt 2002, Steed and Evans 2002].

Table 4: Mix Design Properties

Properties	HL4	HL3	PMA	SMA	Superpave
N_{design}	NA	NA	NA	100	125
% G_{mm} @ $N_{initial}$	NA	NA	NA	84.76	88.6
% G_{mm} @ N_{max}	NA	NA	NA	97.66	97.47
Air Voids (%)	4.62%	4.62%	4.62%	4.00%	4.25%
VMA (%)	16.40%	14.90%	14.90%	15.98%	14.35%
VFA (%)	71.83%	71.41%	71.41%	74.94%	70.39%
Flow (0.25 mm)	9.6	9.2	9.2	NA	NA
Stability (N)	9500	8915	8915	NA	NA
Tensile Strength Ratio (%)	NA	NA	NA	75.20%	73.20%
G_{mb} - Blend	2.359	2.403	2.403	2.397	2.416
G_{mm} - Blend	2.474	2.510	2.510	2.454	2.479

NA=Not Available

Performance Analysis

Performance measures were taken both prior to and immediately following construction and following the in-service phase. Key measures included Falling Weight Deflectometer (FWD) pavement load/deflection testing performed prior to construction, following construction, and following loading, as well as International Roughness Index (IRI) surveys performed following construction and following loading. Distress surveys were also performed both prior to and following the clay haul.

FWD Analysis

FWD testing was carried out prior to construction of the test track on June 7, 2002, following construction but prior to the clay haul on June 14, 2002, and following the clay haul on November 5, 2002. A Dynatest Model 8002-952 series FWD was used to measure the impact of a force, comparable to a moving tire load, exerted on the asphalt pavement surface. Measurements were taken at 12 m intervals and offsets from the pavement edge of 0.9, 2.7, 5.5, and 6.4 m. At each interval and offset, three different measured loads of magnitude 29, 40, and 53 kN were applied, while deflections were measured by seven geophones spaced at 0, 300, 600, 1200, 1500, 1800, and 2100 mm from the load centre. By adjusting values to a standard load level of 40 kN and applying the backcalculation procedure to process the FWD data, it was possible to determine the structural properties of the pavement layers and subgrade soils in terms of elastic moduli. By considering both elastic moduli and pavement thickness determined from coring results and as-built construction records it was possible to determine the resilient modulus of the subgrade (M_R), overall pavement modulus of elasticity (E_P), and effective structural number of the pavement layers (SN_{EFF}). A summary of these backcalculation results is presented in Table 5 [Stantec 2003].

Table 5: Summary of FWD Backcalculation Results by Section

		June 7, 2002		June 14, 2002		November 4, 2002	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
Resilient Modulus M_R (Mpa)	**HL3-1**	41.86	6.62	51.69	39.37	43.23	32.63
	PMA Geogrid	45.31	40.92	42.53	39.84	39.33	19.89
	PMA Regular	103.31	36.43	120.95	26.92	72.02	17.98
	SMA	51.97	18.24	53.92	22.61	35.27	11.66
	Superpave	32.15	7.91	34.53	6.84	31.90	6.10
	HL3-2	42.03	12.26	43.21	11.53	33.79	4.59
Overall Pavement Modulus E_P (Mpa)	**HL3-1**	155.23	46.73	247.04	41.03	414.02	76.57
	PMA Geogrid	84.67	104.04	150.01	48.26	322.34	66.34
	PMA Regular	146.07	34.47	207.74	22.92	327.72	46.07
	SMA	177.28	37.07	230.84	53.63	356.08	97.06
	Superpave	137.66	45.31	186.77	38.38	344.77	47.33
	HL3-2	146.38	39.14	200.68	35.06	385.10	47.11
Effective Structural Number SN_{Eff}	**HL3-1**	2.94	0.40	3.87	0.23	4.56	0.30
	PMA Geogrid	1.74	0.34	3.46	0.33	4.53	0.32
	PMA Regular	2.29	0.38	3.82	0.14	4.43	0.15
	SMA	2.35	0.16	4.03	0.27	4.66	0.41
	Superpave	2.15	0.24	3.69	0.26	4.56	0.17
	HL3-2	2.19	0.19	3.77	0.20	4.69	0.17

A graphical representation of calculated values for resilient modulus can be seen in Figure 5. Over the course of the three runs, the resilient modulus values ranged greatly, the smallest of which were measured in the PMA section reinforced with geogrid while the largest values were measured in the regular PMA section. These exceptionally high values observed in the regular PMA section may be attributed in part to the subgrade being saturated during testing, in particular, during the first two runs. With the exception of portions of the PMA and SMA sections, little variation between the three runs was noticed. In the PMA and SMA sections where a change was noticed, it was in the form of a decrease in the resilient modulus at the time of the third run performed on November 4, 2002 [Stantec 2003].

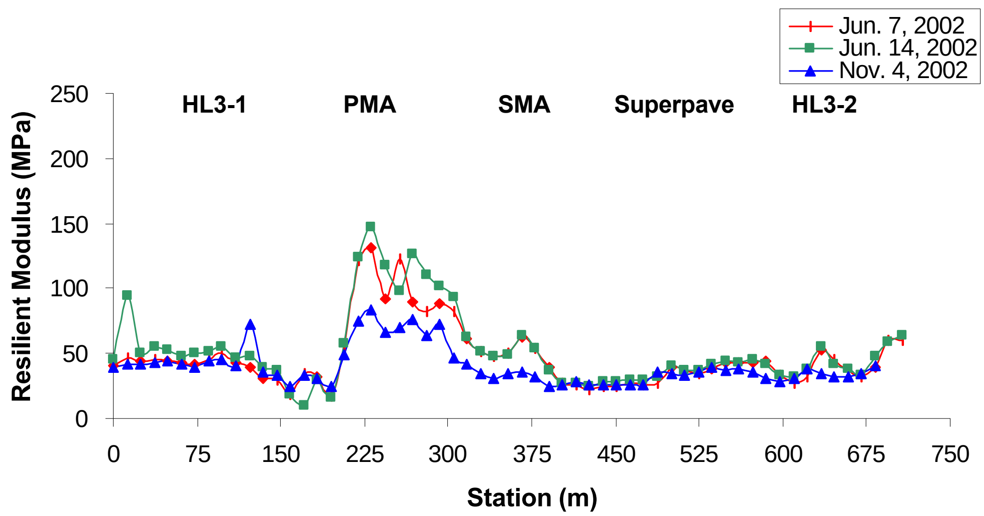

Figure 5: Subgrade resilient modulus

Figure 6 displays backcalculated results for the overall pavement modulus of elasticity for all three runs. The lowest values were measured during the first run, prior construction, in the PMA section to be reinforced with geogrid. Results from the second round of testing that took place following construction showed an increase in the pavement modulus values in all sections, indicating an increase in stiffness throughout. The PMA section reinforced with geogrid continued to have the lowest pavement modulus values. Third round testing results taken following the clay haul on November 4, 2002 revealed an even greater increase in the pavement modulus values, the highest values being measured in the HL3-1 section (the exceptionally high value recorded in the SMA section was considered an outlier). In the third run, the greatest increase in pavement modulus, relative the second run, was in the PMA section reinforced with geogrid, while the least increase took place in the regular PMA and the SMA sections. Two factors that could be contributing to this increase in stiffness revealed in the third run are that the stiffness of the pavement layers increased with time or the ground was partially frozen during testing, producing misleading results [Stantec 2003].

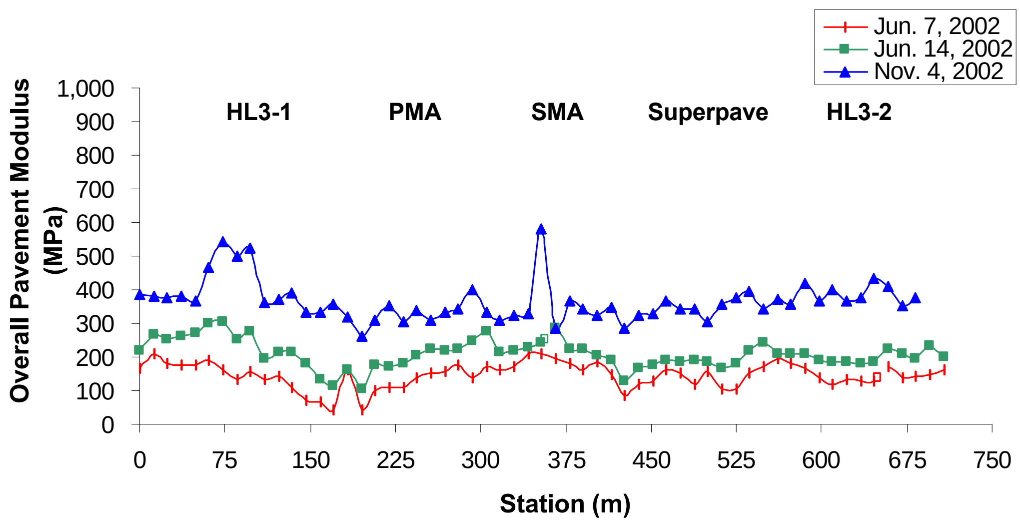

Figure 6: Overall pavement modulus of elasticity

The effective structural number of pavement layers was calculated for all section and is presented in Figure 7 for each run. A similar trend to Figure 6 is observed, with the values increasing over the course of the three runs. Once again, the lowest values for both the first and second run were recorded in the PMA section enforced with geogrid. The greatest increase in effective structural number in the third run, relative the second run, was once again observed in the reinforced PMA section while the regular PMA and SMA sections experienced the smallest increase. Little fluctuation in results was seen in the second and third runs due to little variation in material thickness, with the exception of the outlier in the SMA section where the binder material thickness was much greater [Stantec 2003].

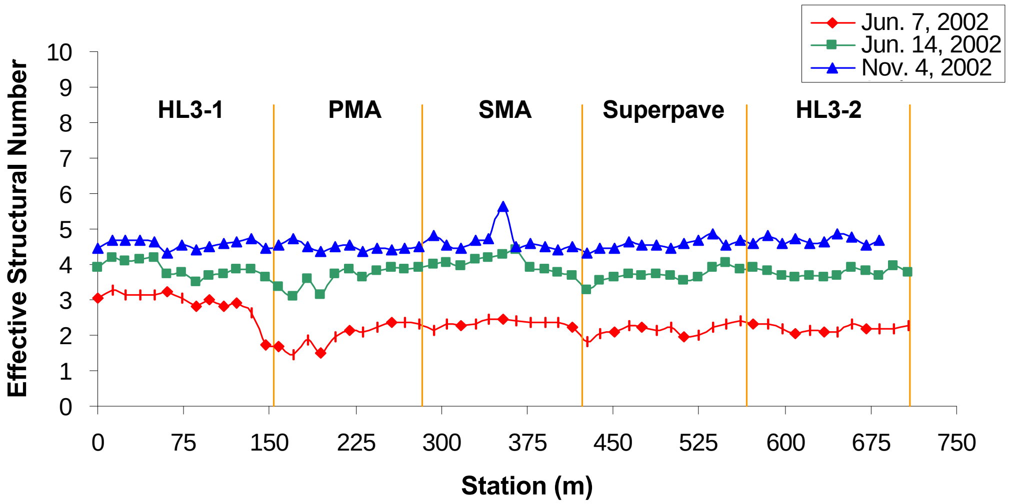

Figure 7: Effective structural number of pavement layers

Another FWD survey is planned to be performed in the spring of 2003 when it is certain the ground is thawed. This will provide results for further analysis.

IRI Analysis

Profiling of the roadway in order to collect roughness data was performed on June 20, 2002, prior to the commencement of the clay haul, as well as on September 1, 2002, following the completion of the clay haul. A SC L009 Class I profiler, equipped with 32 kHz bumper mounted lasers was used. Three passes of each lane of the road were performed, collecting surface profiles in both the right and left wheel path at 82 mm intervals. By applying an algorithm to the surface profile data, IRI values were determined at 5 m intervals for all three passes in either wheel path of the two lanes. In order to obtain IRI values on such a small interval, it was necessary to remove the 90 m wavelength usually used in the algorithm. This portion of the algorithm is typically used to eliminate an increase in measured roughness values resulting from variation in the elevation of the roadway being profiled. It was possible to remove the 90 m wavelength from the algorithm for the analysis of this particular profiling data because of the limited variation in elevation over the length of the test track.

A field survey of the centreline of the test track revealed there to be a variation of 5.5 m in elevation over the length of the test track. These results were confirmed by applying the algorithm on a 50 m interval both with and without the 90 m wavelength. The results were compared and very little variation was noted between either technique. To acknowledge that all IRI values considered in this paper were calculated using a slightly modified algorithm (no 90 m wavelength), the notation IRI’ will be used from this point forward.

To ensure the accuracy of the data collected, some additional provisions were taken. Since data collected while a profiling vehicle is getting up to speed are inaccurate, the first 50 m of each run was dismissed as unacceptable data. Note these sections are both control sections consisting of HL3 surface course over HL4 binder course. As well, to insure accurate division of the data into respective sections, the data contained in a small transition zone between sections was eliminated. This measure also insured that roughness associated with the joint between sections did not impact results

Figure 8 compares the average IRI' values calculated using the profile data collected during the two runs. A sharp increase in IRI' values following the clay haul is visible from approximately 150 to 225 m in the PMA section reinforced with geogrid. As well, smaller sharp increases are also apparent from about 430 to 450 m and 510 to 530 m in the Superpave section. Although it is difficult to be certain from Figure 8, it appears as though there is little change in the IRI' values in the remaining sections over the course of the two runs.

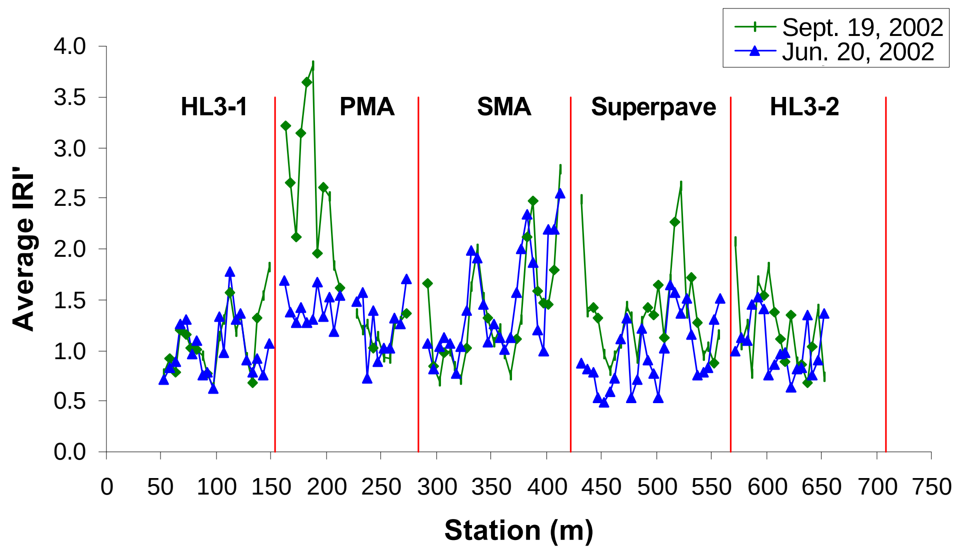

Figure 8: IRI' values for the two runs

To obtain a better understanding of the IRI' data obtained from the test track, Analysis of Variance (ANOVA) was performed on the IRI' results. First, to insure consistency between lanes, ANOVA was carried out comparing the IRI' values determined for the eastbound lane to the westbound lane for each of the sections. If the $F_{Calculated}$ value was determined to be smaller than the $F_{Critical,}$ then the lanes are statistically the same and vice versa. A summary of the results can be seen in Table 6. IRI' values calculated for the east and west lanes of each section were statistically the same on June 20, 2002. With the exception of the Superpave section, the IRI' values calculated on September 19, 2002 were also statistically the same. The reason for the IRI' values for the two Superpave lanes not being the same may relate to one lane experiencing more deterioration than the other lane due to a weaker subgrade as well as a variety of other factors. Since for the most part it appears as though the IRI' values calculated for the eastbound and westbound lanes are statistically the same, it is reasonable to combine them and treat them as a whole.

Table 6: IRI' ANOVA Results for East Lane vs West Lane

	June 20, 2002		September 19, 2002	
	F Calculated	F Critical	F Calculated	F Critical
HL3-1	0.499	4.098	2.163	4.098
PMA Geogrid	2.480	4.351	0.006	4.351
PMA Regular	1.450	4.414	2.915	4.414
SMA	1.136	4.057	0.691	4.057
Superpave	1.303	4.034	7.859	4.034
HL3-2	2.892	4.149	0.216	4.149

To ensure the accuracy of the observations made from Figure 8, ANOVA was used to compare the IRI' values collected prior the clay haul to those collected after. A summary of these results is shown in Table 7. As previously observed from Figure 8, both the PMA section reinforced with geogrid and the Superpave section are not statistically the same. Thus, these two sections experienced the greatest change in roughness over the course of the clay haul. The IRI' values for the remaining section were determined to be statistically the same before and after the clay haul indicating limited impact on the roughness of these sections from the loading.

Table 7: IRI' ANOVA Results for June 20, 2002 vs. September 19, 2002

	F Calculated	F Critical
HL3-1	0.695	3.963
PMA Geogrid	18.777	4.073
PMA Regular	0.271	4.098
SMA	0.417	3.945
Superpave	11.492	3.938
HL3-2	3.035	3.986

Although it has been shown that some surface materials reacted differently than others to loading, comparison of the various surface materials were carried out. This ANOVA involved comparing the IRI' results for the two HL3 section to ensure the two control sections were statistically the same. Once this was established as shown in Table 8 for both before and after the clay haul, the combined IRI' results for the HL3 sections were compared to the various other surface materials. A summary of these results can also be found in Table 8. As would be expected, the IRI' values collected from the two HL3 sections were statistically the same on both profiling dates. However, on June 20, 2002 the IRI' values collected from both the reinforced PMA and the SMA were not statistically the same as those collected from the HL3 sections. On September 19, 2002, in addition to the sections not statistically the same on the previous profiling data, the IRI' values for the Superpave section were also not statistically the same as those from the HL3 sections. These results tell us that the roughness of these surface materials were differences, especially over time.

Table 8: IRI' ANOVA Results for HL3 vs. Other Surface Materials

	June 20, 2002		September 19, 2002	
	$F_{Calculated}$	$F_{Critical}$	$F_{Calculated}$	$F_{Critical}$
HL3-1 vs. HL3-2	0.109	3.974	0.962	3.974
HL3 vs. PMA Geogrid	11.348	3.936	77.526	3.949
HL3 vs. PMA Regular	2.548	3.938	0.354	3.953
HL3 vs. SMA	18.570	3.917	7.586	3.925
HL3 vs. Superpave	1.540	3.915	6.238	3.922

Distress Surveys

Various visual distress surveys were performed both prior to and following the clay haul to identify problem areas and monitor progression. Following construction of the test track fat spots were observed in random locations throughout the SMA, however, no other distresses were visible at this time. Once the clay haul was complete more distresses had begun to appear. These distresses included segregation in portions of the Superpave section and raveling in some parts of the SMA. As well, faint cracking was noticed in the PMA section reinforced with geogrid, while a very noticeable road deformation had begun to form in the Reinforced PMA section and the HL3-1 section. Some correspondence is noticeable between IRI and distress survey results.

FUTURE MONITORING

As previously mentioned, it would be of great benefit for FWD testing to once again be performed on the test track this spring once the ground is entirely thawed. These results will allow for further analysis that has to this point been restricted due in part to the high probability that the FWD results obtained on November 4, 2002 were skewed by the ground being partially frozen. In addition, performing IRI profiling at a similar time this spring would also be of great benefit, allowing for examination of the impact of the winter conditions on the pavement.

CONCLUSIONS

This paper has described a new initiative in roads and pavement research involving an integrated laboratory and field facility and an unprecedented level of federal, provincial, municipal, private sector and university support to create the necessary infrastructure.

A context for the research initiative has been established and it focuses on a number of key issues, the driving forces which impact on these issues, and the resulting opportunities and future prospects. Within this context, a broad vision has been formulated with the following major elements: emerging and innovative technologies, state-of-the-art research infrastructure, increasing the talent pool of highly qualified people and establishing sustained partnerships with the public and private sectors and the universities.

An overall structure for the integrated facility and program are described, as well as examples of the key, priority areas within the program. These areas have been grouped as follows: (A) Innovative structural and materials technologies, (B) Advanced computer applications related to roads, (C) Pavement construction, preservation and sustainable development and (D) Pavement and roadway safety. As well, the philosophy and required skill sets underlying the formation of the research team have been described.

The design parameters and construction data from the UW CPATT test track have been presented in this paper. Initial results from IRI, deflection and distress surveys have also been presented and analyzed. Monitoring of the test track will continue over time and this data will be used to develop performance models for the various asphalt mixes.

Finally, this project will provide substantial improvement in the relative strength and capability of pavement research in Canada and is aimed at increasing the supply source of skilled professionals and technicians. The overall goal is to advance technology development, strengthen Canadian based research capability overall and create an organized alliance for technology interchanges and a unified strategy for succession planning.

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