Canadian Technical Asphalt Association | CTAA | Association technique canadienne du bitume

2020 Paper Abstracts in Tentative Presentation Order

Paper : **1**

Impact of silo storage on cracking and rutting resistance of plant mixes with high reclaimed asphalt pavement content and rejuvenators

Mohamed Elkashef, John T. Harvey, Liya Jiao, David Jones

During plant production, asphalt mixes may be stored in the silo for a few hours before being transported to the construction site. The high temperature in the silo can lead to additional aging of the mixes which could result in changes in the mix properties. For mixtures containing reclaimed asphalt pavement (RAP), additional blending between the virgin binder and the RAP binder can also continue to occur in the silo due to the high temperature. Additional blending between the RAP and virgin binders would lead to an increase in the available binder content as well as an increase in the stiffness of the RAP/virgin binder blend owing to the high stiffness of the RAP binder. The combined effect of aging and blending during silo storage and the impact of silo storage on the mix properties is not clearly understood. An asphalt mix supplied for a given job can spend different times inside the silo which could potentially lead to inconsistent mix properties. In this study, three field mixes containing different amounts of RAP, with and without rejuvenators, were sampled from different asphalt plants representing different regions across the state of California in the United States. The amount of RAP in the mixes ranged between 40 and 50 percent by weight of dry aggregate. A bio-based rejuvenator and a petroleum aromatic extract rejuvenator were used in two of the three mixes, while one mix contained no rejuvenator. The mixes were sampled at different stages during production; prior to silo storage and after a few hours in the silo. The silo time ranged from 6 to 16 hours. Plant mixes were reheated and compacted in the lab. Plant-mixed lab-compacted samples were then tested to characterize the cracking and rutting performance of the three mixes before and after silo storage. Semi-circular bending (SCB) tests were conducted at a temperature of 25C to determine the cracking resistance, while Hamburg wheel tracking (HWT) test was conducted at 50C to determine the rutting performance. The results clearly showed that, for the studied mixes, both rutting and cracking performance were largely affected by silo storage. The flexibility index (FI) parameter as measured through the SCB test showed a notable reduction due to silo storage, denoting lower cracking resistance. On the other hand, the rutting performance, as measured by the HWT test, improved notably after storage for a few hours in the silo. Based on the findings of this study, it was concluded that the effect of silo storage on the mix properties can be substantial and it is important to further assess that effect. Future testing will focus on trying to separate between the effect of additional aging and blending during silo time, mainly on mixes containing RAP.

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Paper : **2**

A simple binder specification tweak to promote best performers

Pavel Kriz, John A. Noël

The North American bitumen specification system, SuperPave™, is the newest and the most elaborate specification system for bituminous binders. The system was developed and validated for straight-run, refinery-produced bitumen, and it has been implemented in the United States and Canada throughout the 1990s. Since then, there has been increased use of modified grades, reclaimed asphalt pavement and artificial “softeners” such as recycled engine oil bottoms, aromatic or paraffinic oils, bio-based oils, etc. Not all of these compositional changes manifested in adequate bitumen long-term performance in the field. It was demonstrated that the current SuperPave™ system cannot prevent acceptance of some of the lower-quality materials. There has been a significant effort in the US and Canada to improve the SuperPave™ system to address these challenges, more specifically, to prevent premature binder aging and pavement cracking. The current paper shows how binder susceptibility to oxidative aging, physical hardening and poor stress relaxation can be revealed by phase angle measurement and that these properties origin in low phase compatibility. Furthermore, this phase incompatibility can be reliably detected through measurement of rheological phase angle using a dynamic shear rheometer (DSR). It is shown that the DSR test performed on the pressure aging vessel (PAV) residue can be simply modified to exclude phase incompatible binders from passing the specification. Discussion of the evolution of SuperPave™ specification system in North America is also important from the European perspective as Europe is heading towards a rheology-based specification system in the near future.

Paper : **3**

Asphaltenes-Modified Binders for High Modulus Asphalt Concrete Applications

Leila Hashemian, Amirhossein Ghasemirad, Nura Bala

High modulus asphalt concrete (HMAC) is designed to have high strength, great fatigue life, and excellent resistance against rutting. However, HMAC has limited application in cold climatic regions due to its low flexibility and stress relaxation capacity. The current study investigates the application of binders modified with asphaltenes for high modulus base course applications in cold regions. Asphaltenes, obtained from deasphalting operations during bitumen processing, is considered to be a waste material of minimal value with no further applications in the industry. However, as asphaltenes play an important role in asphalt binder stiffness, it seems that modification of a binder with asphaltenes can provide enough stiffness required for HMAC. The binders used in the current study are PG 70-22 (derived from crude oil), four asphalt binders obtained from Alberta oil-sands bitumen, and two polymer-modified binders which are commonly used for high modulus asphalt concrete applications. Asphaltenes were added at different values to each of the unmodified binders. Both asphaltenes-modified and unmodified binders were aged using a rolling thin film oven (RTFO) and pressure aging vessel (PAV) prior to rheological tests. A dynamic shear rheometer (DSR) was used to measure the rheological properties of unaged, RTFO-aged and PAV-aged binders at high and intermediate temperatures. The rheological properties of both asphaltenes-modified, polymer-modified and unmodified binders at low temperatures were investigated using a bending beam rheometer (BBR). The effect of asphaltenes content on the viscosity of the binders was studied using a rotational viscometer (RV). Also, changes in the chemical composition of the asphaltenes-modified binders were studied by SARA analysis, using precipitation and gravity-driven chromatography techniques. The results of rheological tests indicated that the impact of asphaltenes on the performance of binders at high temperatures was more than two times greater than that at low temperatures. Additionally, it was found that the binder type and source did not have a substantial impact on the magnitude of the changes observed in the asphaltenes-modified binders. RV test results showed that there was a noticeable increase in viscosity for all asphaltenes-modified binders, the magnitude of the changes was found to depend directly on the percentage of asphaltenes added. The changes in viscosity were reflected in the mixing and compaction temperatures determined for mixtures composed using these binders. Furthermore, it was determined that by modification with asphaltenes, some binders originating from the Alberta oil-sands could achieve the performance grade required for high modulus asphalt concrete base course applications in cold regions.

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Paper : **4**

Study of Oxidative and Thermoreversible Aging Effects on Rheological and Failure Properties of Albertan Oil Sands-Derived, Polish, and Venezuelan Asphalt Binders

Lindsay May Young, Chanaka Nawarthna, Ahmad Nawaz Khan, Simon A.M. Hesp

This paper discusses how soft asphalt binders distilled from Alberta oil sands deposits in the Athabasca and Cold Lake regions of Alberta, Canada, compare, in terms of quality and durability, to commercial materials made in the Baltics with heavy crudes from Russia and Venezuela. This study is conducted to explore markets for the estimated 300 billion barrels of ultimately recoverable crude bitumen reserves from Alberta oil sands (Natural Resources Canada, 2020). Such heavy crudes are readily distilled to produce high yields of superior quality asphalt binders, high or low in asphaltenes and low in wax. As one of Canada's largest natural resources, the Alberta oil sands are expected to provide a positive contribution to the Canadian economy for many years to come. By using oil sands-derived binders for the construction of modern flexible pavements—that can positively affect the quality of life for a significant part of the world's population—greenhouse gas emissions will be reduced by diverting a very significant fraction of the crude bitumen from combustion.Spectroscopic and rheological analyses of the oxidative aging of four Athabascan, one Cold Lake, and two outside asphalt cement sources are provided. All binders were aged according to modified pressure aging vessel (PAV) protocols at film thicknesses of 1.5, 3.0, and 4.5 mm, at either 20, 40, or 60 hours. Fourier-transform infrared (FTIR) spectroscopy and proton nuclear magnetic resonance (1H-NMR) spectroscopy as well as dynamic shear rheometer (DSR) tests were performed on all samples.Albertan asphalts generally exhibited similar or slightly larger increases in carbonyl and sulfoxide functional groups to the outside sources, depending on the source and grade of the binder. In addition, slightly higher amounts of aromatic and mildly deshielded protons were observed in the Albertan and outside asphalt cements after PAV aging.The rheological tests were used to calculate the limiting temperatures where the phase angle reached 30° (T(30°)), highlighting the Albertan binders generally provided good quality low-temperature performance, but larger changes upon more severe aging in the PAV. This was likely due to their slightly lower viscosity during PAV aging.Grade spans were calculated as the difference between regular high temperature Superpave performance grades (HTPG) and limiting T(30°). A larger grade span likely translates to better asphalt performance under a wider range of weather conditions. Rheological tests of the seven asphalts showed that binders derived from Athabasca oil sands exhibited similar grade spans compared to the Cold Lake and outside sources. Similarly, comparable limiting temperatures for a stiffness of 60 MPa were also found for the Albertan and outside asphalts.Combining both Athabasca and Cold Lake binders with material recovered from reclaimed asphalt pavement (RAP) demonstrated that atypical Athabascan materials, produced with intentionally low grade spans, were more amenable to pavement recycling.This preliminary investigation illustrates how using oil sand crudes for the production of high quality asphalt binder may divert a significant amount of crude bitumen from combustion, and at the same time improve sustainability for the asphalt paving industry worldwide.

2020 Paper Abstracts in Tentative Presentation Order

Paper : **5**

Comparing the Ability of Different Tests and Rheological Indices to Evaluate the Cracking Resistance of Polymer Modified Asphalt Binders

Mike Aurilio, Pejoohan Tavasotti, Hassan Baaj

SBS modification of asphalt cement is known to be one of the best ways to improve the performance of pavements. The increase in stiffness and elastomeric response of the asphalt cement provides pavements with better rutting and fatigue resistance and may improve resistance to thermal cracking. The original Superpave PG system was designed using unmodified asphalt cement and therefore suffers from shortcomings when characterizing SBS modified asphalt. This has since been addressed by the successful adoption of the Multiple Stress Creep Recovery (MSCR) test and AASHTO M 332 specification. Previous research has proven that the test correlates well with rutting performance and can be used as a fatigue resistance indicator by estimating the concentration of SBS. However, the test has not been designed to evaluate cracking resistance in asphalt cement and research has been undertaken to address this issue.Ontario has begun evaluating the adoption of the ΔTc and cross-over temperature in order to improve the characterization of asphalt cement quality. The ΔTc parameter has also been added to specifications throughout the United States, and the limit commonly used was derived from the Glover-Rowe parameter. The use of low strain tests such as these has been shown to poorly characterize SBS modified asphalt cement due to the elastomeric nature of SBS modified asphalt. The Linear Amplitude Sweep (LAS) has been developed into AASHTO Provisional Specification TP-101. The LAS test is a high strain test that has shown a good capability to evaluate cracking resistance in asphalt cement. Testing with the LAS has shown that the cycles to failure calculated using the Viscoelastic Continuum Damage Model correlate well with the concentration of SBS. The LAS can also be analyzed using fracture mechanics (Pure LAS) and this approach has also shown some correlation with SBS concentrations. The Pure LAS analysis has also been shown to improve upon the characterization of different levels of laboratory aging.This paper presents data showing the ability of each test to characterize SBS modified asphalt cement. The findings suggest that although the LAS and Pure LAS exhibit an improved ability to evaluate SBS modified asphalt, further refinements may be necessary to improve the quality of these test methods. The results also suggest that the ΔTc, cross-over temperature and Glover-Rowe parameter seem better suited to evaluating unmodified asphalt cement and aging. It appears as though the characterization of SBS modified asphalt cement is improving, but it still poses a difficult challenge.

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Paper : **6**

Performance Evaluation of Soybean Oil Derived Additives used in Penetrating Fog Seal for Brittle HMA

Maxwell D. Staver, Joseph H. Podolsky, R. Chris Williams

A major concern in asphalt paving is fatigue and thermal cracking that occurs more easily for aged pavements. Over time the asphalt reacts with the oxygen in the air and forms polar functional groups such as ketones and sulfoxides. These new functional groups increases the polarity of the molecules and causes an increase in the interaction energies. This effect results in a more viscous binder and more brittle asphalt pavement. This oxidation occurs in the top one half inch of the pavement. Frequently this top surface is milled off, and a new layer is overlaid on top to solve this problem. In pavements that have already formed minor cracking, a traditional fog seal can be used.A traditional fog seal uses a thin application of slow set asphalt emulsion to apply a layer of fresh asphalt binder over the existing pavement. This is helpful after the top layer of the existing asphalt has worn away and if small cracks are present. The thin layer of asphalt will help to keep water out of the pavement structure and reduce the rate of degradation of the pavement. If the new layer of asphalt is too thick, it can cause a severe loss in skid resistance. The traditional fog seal only seals the surface, but does not address the brittle behavior of the aged pavement.This paper focuses on a solution to the embrittlement of aged pavements. Many previous studies have shown the effectiveness of sub-epoxidized soybean oil (SESO) and epoxidized methyl soyate (EMS) as a reactive restorative modifier (RRM). A RRM is a modifier for asphalt that is shown to react with the asphalt molecules as well as provide restorative effects to aged asphalt binders. This is a new classification used with the intention of avoiding confusion with the term rejuvenator. Numerous products are referred to as rejuvenators without showing any evidence of reactions occurring with the asphalt or simply acting as a diluent to soften the asphalt by increasing the volume fraction of low molecular weight compounds. Our research group has created a new pavement preservation construction material that can offset the aging effects in the surface of an existing pavement. This new fog seal is created with a cutback produced using 80% epoxidized soybean oil (either SESO or EMS) and 20% asphalt. The cutback will be referred to as a fog seal throughout the paper. Unlike traditional fog seals, this material does not have a solvent or carrier that evaporates away. The fog seal soaks into the existing pavement surface, softening the existing binder and leaving a very thin layer of soft new asphalt to seal micro-cracking. A study was done to test the ability of the fog seal to penetrate into the pavement by applying a light coat to stiff asphalt slabs. The results show that the fog seal can penetrate more than one inch into the paving after one week. Various mix tests were performed with the fog seal treatment to verify the softening effect.

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Paper : **7**

High-Performance Pavements: A focus on self-healing asphalt technologies

Roberto Aurilio, Mike Aurilio, Hassan Baaj

Cracking at low and intermediate temperatures is one of the most prevalent deterioration modes of flexible pavements. Long-term exposure to traffic loading leads to the initiation of microcracks, and over time these microcracks coalesce into macrocracks which propagate towards the surface. These cracks cause a decline in the pavement mechanical properties while allowing moisture and other materials to infiltrate the pavement which further accelerate deterioration and can eventually lead to failure. Contemporary cracking treatment solutions are reactionary; a more effective, preventative strategy is to use high-performance materials with increased fatigue resistance thus lowering the potential economic and environmental impact. From a grander perspective, a greater ability to mitigate cracking at the microscale, the ability to heal, is a solution to this challenge. Thus, the study and development of materials with self-healing properties has become a growing area of materials science research in recent years. These self-healing materials have the capability to restore a portion of a desired “design” property to its original state after the material is subjected to either gradual or sudden damage. Asphalt cement was first observed to display this type of behaviour in the 1960s when it was found that the introduction of rest periods could extend the service life of the pavement. Since that discovery, the mechanisms of fatigue damage healing in asphalt are still debated. However, modern researchers have begun to draw inspiration from other branches of materials science and the natural world in order to apply the concepts of self-healing materials to asphalt mixtures. Few technologies have been explored in the laboratory or in field trials, and even fewer have been commercialized. This paper will present a state-of-the-art of intrinsic self-healing ability of asphalt cement to heal fatigue damage as well as current research efforts to characterize and improve the self-healing capabilities of asphalt pavements. Ultimately, research into self-healing asphalt pavements using additives, specialized materials, and novel maintenance techniques is paramount. Self-healing asphalts have the potential to improve performance and reduce maintenance over the life of the pavement leading to both economic and environmental benefits. On a practical level, these pavements will provide benefits for motorists by improving rideability, decreasing delays due to construction, and increasing the time between subsequent rehabilitation treatments. The continual development of high-performing self-healing pavements will ensure that the pavements we construct can withstand the challenges of the future while increasing the economic, environmental and societal value of Canada’s road network.

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Paper : **8**

The evaluation of low-temperature cracking resistance of asphalt mixes in Ontario by conducting Disk-shaped Compact Tension (DC(T)) and Semi-Circular Bend (SCB) tests

Saeid Salehi-Ashani, Susan L. Tighe

Low-temperature cracks defined as transverse cracks formed in parallel and distanced equally on the surface of asphalt pavements are the prevalent mode of cracks in cold climate, especially in Canada.Generally, according to Superpave specifications, asphalt binder characterization through conducting Bending Beam Rheometer (BBR) test has been used to evaluate low-temperature cracking resistance of asphalt pavements. Therefore, Superpave specifies controlling two parameters obtained from BBR test: creep stiffness (S) and the rate of change of creep stiffness (m) based on linear viscoelastic analysis. However, to investigate the resistance of asphalt mixes to low-temperature cracking, not only is the characteristics of asphalt binder important, but also the properties of asphalt mixes such as the interaction between asphalt binder and aggregate, the effect of the air void content, the film thickness of asphalt binder, the aging phenomenon and the evolution of cracks in time can be significant.To overcome the shortcoming of Superpave specifications with regard to low-temperature cracking, several fracture-mechanics based tests have been developed among which the most promising are the Semi-Circular bend test (SCB) and the Disc-Shaped Compact Tension (DC(T)) test have been of interest.DC(T) and SCB tests as per ASTM D7313 and AASHTO TP105 standards, respectively, have been utilized in the US. Overall, the significant output of DC(T) test is the fracture energy, while SCB test provides the fracture energy and the fracture toughness. The higher the fracture energy and the fracture toughness values are, the more asphalt mixes are resistant to the low-temperature cracking.In this paper, the low-temperature cracking resistance of five typical surface asphalt mixes paved in Ontario were investigated through conducting DC(T) and SCB tests. Furthermore, BBR test was conducted on the recovered asphalt binders from the asphalt mixes. The statistical analysis of the results of fracture energy from DC(T) and SCB tests show that there is not a significant difference between the results and these two tests can be exchangeable. Also, these two tests can differentiate the low-temperature crack resistance of the asphalt mixes in three temperatures (-18º, -24º and -30º C). Furthermore, the results of BBR test show that there is a correlation between the fracture energy obtained from DC(T) and SCB tests, and BBR test results.

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Paper : **9**

Balanced Mix Design and Approach to Construction of Red Pigmented Dedicated Asphalt Bus Lances with Enhanced Cracking and Rutting Resistance

Taylor Lefebre, Steven Manolis, Selena Lavorato, Porfirio Gutierrez Vela, Yashar Azimi Alamdry

Balanced mix design methodology was utilized to design a red pigmented asphalt mix with enhanced cracking and rutting properties for use in dedicated bus lanes under heavy traffic. Coloured asphalt mixes have been known to suffer from early fatigue cracking in similar applications due factors such as increased dust content from powdered pigment resulting in high dust to binder ratios. During the mix design stage, performance tests were carried out on appropriately conditioned samples to ensure that the mix properties addressed several modes of distress: rutting, fatigue cracking, low temperature cracking, and moisture sensitivity properties. Mix performance testing was beneficial to determine the optimum balance between the aesthetics of the red coloured asphalt and final pavement performance. The standard aggregate gradation for a SP12.5FC2 mix was improved to increase VMA and allow higher asphalt cement content resulting in a mix with increased asphalt film thickness to counter against the potential for high dust to binder ratios resulting from the added pigment. Enhancements to the properties of the asphalt cement binder were achieved by utilizing a PG 70-34 asphalt cement which exceeded the -28°C low temperature performance grade climatic requirement at a 98% confidence level in order to protect against the potential for accelerated aging of the binder by the red iron oxide pigment in the mix. The high temperature performance grade was increased from PG 64 to PG 70 in order mitigate rutting potential under heavy traffic. The asphalt cement binder was also designed with enhanced extended aging, physical hardening, and fatigue cracking properties. Incorporation of warm mix technology improved workability and compaction properties of the mix.The project was constructed in a highly urbanized area with strict traffic control requirements. Paving and rolling operations were modified to achieve compaction targets of the highly polymer modified red pigmented asphalt mixture under tight traffic control time frames. Enhancements to the conventional rolling pattern enhanced compaction results and also mitigated against rubber tire roller pick-up, tracking, segregation, and other surface defects. Unique joint compaction contract specifications required that cores for compaction acceptance testing be taken directly centered on longitudinal joints. Given the difficulty in achieving compaction along longitudinal joints, methods to improve compaction density were executed to remove the low density area arising from an inability to compact at the edge of each paver pass. Utilization of warm mix as a compaction aid also proved beneficial in achieving compaction requirements.

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Paper : **10**

Evaluation of Asphalt Emulsion Stabilized Base Course Modified using Asphaltene

Leila Hashemian, Farshad Kamran, Nura Bala

Pavement long-term performance generally depends on the quality of underlying soils and sub-layers such as base courses. These structural layers have a significant impact on improving pavement service life. Stabilization of the base course using an asphalt emulsion is one of the methods for pavement quality enhancement in order to have adequate response to traffic loading during service. Recently, the application of waste materials in pavement structures has become an increasingly important and environmentally friendly process. Asphaltene derived through deasphalting process of Alberta oil-sands bitumen is common waste materials with not yet significant application in pavement industry. The objective of this study is to investigate the impact of asphaltenes on stabilized base courses using an asphalt emulsion. For this purpose, modified mixtures stabilized with asphalt emulsion were prepared by adding different amounts of asphaltenes in powder form to both mixtures and emulsion. A mixing process was suggested based on the observations. Performance properties of the asphaltenes-modified and unmodified mixes were investigated using Marshall stability and flow test and Indirect Tensile Strength (ITS) tests. The moisture susceptibility of the modified mixtures was also investigated by determining the Tensile Strength Ratio (TSR) of the mixes conditioned only in water and TSR of samples subjected to freeze/thaw conditioning cycle. The results obtained from the Marshall stability test indicate a significant increase in stability values for all asphaltene-modified mixtures. Additionally, ITS tests show that mixes prepared with asphaltene-modified emulsions are more resistant to tensile stress compared to conventional mixtures. However, TSR results reveal that the moisture susceptibility of asphaltene-modified mixtures is slightly higher than unmodified samples.

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Paper : **11**

Impact of Asphaltene Addition on Performance-Based Rheological and Failure Properties of Alberta Oil Sands-Derived Asphalt Binders

Ahmad Nawaz Khan, Ahmad Nawaz Khan, Cynthia Lemaitre, Simon A.M. Hesp

The volume of crude bitumen in the ground as part of the Alberta oil sands is approximated at 1.8 trillion barrels, of which 166 billion barrels are proven, recoverable reserves (Natural Resources Canada, 2020). Alberta only follows Saudi Arabia and Venezuela with 267 and 300 billion barrels, respectively (OPEC, 2020). It is estimated that with technological and economic advances, a total of 315 billion barrels of crude bitumen will ultimately be recoverable from the Athabasca, Cold Lake, and Peace River deposits. Current production rates of 3 million barrels of crude bitumen per day suggest that there are enough reserves for another 250 years or more. Alberta oil sands contain heavy bitumen that can be used to produce asphalt binder high in asphaltenes and low in wax. Hence, these materials possess highly desirable properties that can be utilized for the construction of durable, flexible pavements around the world.The quality of binders produced from different oil sands-derived crudes varies in terms of their Superpave™ grades (Kriz et al., 2012). Currently, only crudes derived from Cold Lake sources are thought to provide residues with adequate grade spans that meet typical acceptance criteria. Few if any of the crudes derived from Athabasca or Peace River oil sands deposits are considered suitable for the production of high quality paving grade binders under current Superpave specifications. However, when improved aging and specification tests are employed, a different picture emerges and the ranking of these asphalt sources changes.Athabasca and Peace River materials grade significantly closer to Cold Lake in terms of quality when a limiting phase angle temperature under freeze-thaw conditions is considered, rather than stiffness and logarithmic creep rate (m-value), typically obtained at much lower temperatures under non-equilibrium conditions in the bending beam rheometer (BBR). When residues from solvent deasphalting (SDA) operations are added to atypical binders (i.e., those with intentionally low grade spans), the resulting materials can match and conceivably surpass the properties of straight Cold Lake binder at reduced cost and carbon footprint.In this study, seven asphalt binders distilled from oil sands-derived crude bitumen, sourced from Athabascan (5), Cold Lake (1), and Peace River (1) producers, were investigated for various quality and durability attributes. Aging tendencies of the binders were evaluated by using standard as well as extended pressure aging vessel (PAV) protocols. The rheological performance was evaluated by measuring (1) the limiting high temperature Superpave performance grade (HTPG) where the complex modulus over the sine of the phase angle reaches 1.0 kPa on unaged residue, (2) the limiting temperature where the phase angle reached 30 degrees for PAV residue, and (3) the difference between these two temperatures to provide a grade span. Ductile strain tolerances were determined in a tertiary creep test on a thin binder film in between 8-mm dynamic shear rheometer (DSR) plates at 15°C.Overall, the incorporation of SDA residue appeared beneficial for improving the quality of very soft binders and brings these up to a similar grade level as found for straight run Cold Lake binders.

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Paper : **12**

Investigation of Asphalt Properties for Good Performing Pavements in Ontario

Sayna Yaghooby Namin, Saeid Salehi-Ashani, Imran Bashir, Seyed Tabib, Gelu Vasiliu

The Ontario Ministry of Transportation (MTO) has previously conducted several studies investigating poor performing asphalt pavements and the correlation between asphalt material characteristics and pavement performance. Previous research showed that there was a correlation between properties of asphalt cement (AC) and pavement cracking. This study expands the previous research, focusing on the good performing pavements with the following objectives:1. Identifying any correlation between in-situ asphalt cement (AC) properties and pavement cracking;2. Identifying any correlation between asphalt mix properties (i.e., Flexibility Index and Fracture Energy) and pavement cracking;3. Comparison of the findings from good performing pavements with those from poor performing pavements;For the purpose of this study, a number of good performing asphalt pavements were selected from various regions, as well as a few poor performing pavements. The pavement distress data was used to determine whether a pavement was a good or a poor performer. The pavement distress data was collected using the Automatic Road Analyzer (ARAN) and through visual pavement condition surveys. Reported distresses included wheel path rutting, transverse and longitudinal cracking, and fatigue/alligator cracking.The studied pavements were constructed between 2005 and 2013. The criteria for selecting pavement contracts for the study included major rehabilitation to minimize any chance of reflective cracking from underlying pavement. For this purpose, contracts with one or two lifts of asphalt pavement over full-depth reclamation (FDR) or Cold-in-Place Recycling (CIR) were selected. Additionally, contracts with two to three lifts of asphalt pavement over a milled surface were included in this study.To analyze characteristics of asphalt material, full depth cores were obtained from the pavements under study. Flexibility Index Test (FIT) and Disk-Shaped Compact Tension (DC(T)) test, that are both fracture mechanics-based, were utilized to evaluate crack resistance of asphalt mixes at intermediate and low temperatures, respectively. Furthermore, the asphalt cement was recovered from the in-service pavement cores for laboratory testing including Ash Content, Multiple Stress Creep Recovery (MSCR), Double Edge Notched Tension (DENT), and Extended Bending Beam Rheometer (Ex-BBR). Preliminary review of the test data showed that there was a reasonable correlation between characteristics of recovered asphalt cement and pavement cracking. Moreover, the correlation between asphalt mix characteristics obtained from these fracture mechanics-based tests and pavement cracking will be explored in this study.This paper will provide details of the testing program, pavement performance, and the findings, along with the conclusions and future work.

2020 Paper Abstracts in Tentative Presentation Order

Paper : **13**

Using Rejuvenating Agents to Improve Hot Mix Asphalt Incorporating Reclaimed Asphalt Pavement (RAP)

Vince Aurilio, Kamal Hossain & Rayhan Bin Ahmed

Reclaimed asphalt pavement (RAP) continues to be the most recycled product in America. A 2018 US survey conducted by NAPA shows that 82.2 million tons of RAP was reused in new hot mix asphalt (HMA) pavements; this equated to an average RAP content of 21 %. Which is similar to estimates in Canada where about 15-20 % of the RAP is reused. The same survey highlighted that at the end of 2018 approximately 110 million tons of RAP was stockpiled, this continues to be problematic from a sustainability point of view in both the US and Canada for many reasons. RAP has been successfully utilized in HMA since the 70's. Over the years properly engineered or designed asphalt mixtures incorporating RAP have been show to perform as good as standard HMA. However, some studies have reported that higher RAP contents can make the asphalt pavements more susceptible to cracking. In this regard, it is well-known that RAP binder is highly oxidized due to its long-term exposure to environments that changes the binder's chemical and rheological properties. Oxidation also decreases the overall relaxation capacity of HMA which can lead to crack formation in asphalt pavements. To address these issues, various rejuvenating agents have been used since the mid 90's. Typically the use of a softer grade of asphalt (generally one-grade softer) has been specified to account for the stiffness of the asphalt contained in the RAP. Rejuvenating agents such as organic compounds (e.g. aromatic oils) generated from petroleum processing have also been utilized to achieve the desired quality. Research continues and the ongoing evaluation of newer recycling agents, (for instance waste or vegetable oil derivatives) has merit for a number of good reasons. This paper looks at the use (past and present) and performance of these products and provides a perspective in to future use. Essentially we want to better understand how to engineer and produce mixtures containing various RAP contents (and in some jurisdictions incorporating RAS – Reclaimed Asphalt Shingles). In general, the focus of this paper is on how to improve cracking performance; the development of a potential framework for the use of rejuvenating agents is presented along with a discussion on the proper design and production of durable quality mixtures using RAP.

2020 Paper Abstracts in Tentative Presentation Order

Paper : **14**

MSCR Impact on Performances- Laboratory Results and Case Studies

Eric Lachance-Tremblay, Daniel Bissonnette, Marc-Olivier Denis

Since 2019, the asphalt cement binders in Quebec province are classified according to Multiple Stress Creep Recovery (MSCR) test results. This classification method based on the PG (performance grade) system incorporates a letter in the binder grade identification to consider a desired level of binder performance, depending on traffic solicitation. According to MSCR standards, a binder must meet three (3) criteria in order to be classified. MSCR binder classification system was introduced in order to have a better prediction of the rutting resistance of asphalt mixes. However, our observations were that for some non-compliant binders, very good rutting performances of the asphalt mixes were obtained. It was also found that the link between modified binders and recycled asphalt pavement (RAP) have to be considered in the mix design process. These observations raised questions about the correlation between MSCR binder performances and the performances of asphalt mixes, and also regarding the test methods used to predict the rutting resistance.The goal of this study was to compare the MSCR test performances of various binder with the performances of asphalt mixtures fabricated with the same binders. To do so, non-modified (PG 58S-28) and modified (PG 64H-28, PG 58H-34, lab modified binder, high recycled asphalt content) binders were submitted to the MSCR test. Then, asphalt mixtures were fabricated in the lab with the tested binder. The following performances of asphalt mixtures were evaluated: 1) rutting resistance, 2) thermal cracking (TSRST test), and 3) stiffness (complex modulus).Overall, the results showed that even though some binders are non-compliant with MSCR standards, very good performances were achieved. In fact, the results showed superior performances for asphalt mixtures with lab modified binder, which was non-compliant to MSCR standards. Moreover, the results showed very good performances for asphalt mixture with high recycled asphalt content. A test section was also realized in order to compare the field performances with lab performances of the asphalt mixtures. The results are presented in this paper.

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Paper : **15**

MTO's Experience with Post-Production Asphalt Mixture Performance Testing

Imran Bashir

Cracking, rutting, and moisture damage are among main critical distresses on asphalt pavements. Cracking, the principal distress affecting the asphalt mix durability, is defined as a type of distress in asphalt pavements that can occur in different modes such as bottom-up and top-down fatigue cracking, reflective cracking and thermal (low temperature) cracking. Cracking of asphalt pavement is a major concern for transportation agencies, which can be instigated by several factors including asphalt cement additives/modifiers, recycled materials content, materials variability, and construction processes. In addition, other factors affecting cracking could include low asphalt cement content, high permeability, and stripping of asphalt from aggregates. Due to the complex nature of asphalt mixtures, it is becoming necessary to evaluate an asphalt mixture as a whole in terms of its ability to resist both cracking and rutting. Therefore, there is a need to establish reliable and practical asphalt mixture performance tests that can distinguish between poor and good quality asphalt mixes. In an effort to evaluate cracking and rutting resistance of various post-production asphalt mixes, and to identify the most promising performance tests suitable for Ontario's materials and conditions, the Ontario Ministry of Transportation (MTO) developed a mixture performance test evaluation program. The goal of this program was to identify practical performance tests and establish acceptance criteria to mitigate fatigue cracking, rutting, and moisture damage. For this purpose, Flexibility Index Test (FIT) using the Semi-Circular Bend (SCB) geometry was selected for evaluation of the cracking resistance at intermediate temperature and Hamburg Wheel-Track test was selected for the evaluation of resistance to rutting and moisture damage of post-production asphalt mixes. Initial findings indicated that the SCB test was able to distinguish between asphalt mixtures with and without Reclaimed Asphalt Pavement (RAP) and was sensitive to the changes to the performance graded asphalt cement (PGAC) grading through the Flexibility Index parameter. In addition, asphalt mixtures with softer grades of PGAC may need test temperature adjustments while undergoing Hamburg Wheel-Track testing. A correlation was also noted between the properties of the recovered asphalt cement and the mix performance test results.This paper will provide an overview of the test methods, test results, analyses, and the findings, along with the conclusions and future work.

Paper : **16**

Ranking Quality and Performance of Asphalt Binders and Mixes with Various Material Parameters

Amma Wakefield, Susan Tighe

Paving-grade asphalt binders are specified based on their properties in an original state following a specification such as the Performance Graded (PG) Asphalt Binder Specification. However, there has always been an interest in determining the properties of asphalt binder of in-place asphalt mixtures for research or forensic investigation purposes. With the increased use of reclaimed asphalt pavement (RAP), many user agencies are also looking for ways to evaluate the properties of the blended asphalt binder (i.e. new binder and old binder from RAP) since this also has an impact on the asphalt pavement performance.One option is to conduct mixture performance testing. Another option is to conduct solvent extraction-recovery testing on the asphalt mixture and determine the physical properties of the recovered asphalt binder.This research compares the physical properties of the original asphalt binder, that binder extracted and recovered from a plant produced asphalt mix, and the properties of the asphalt mix as determined through performance testing. The purpose to evaluate how the various asphalt binder and mix parameters rank the quality and performance of the asphalt pavement layer and compare with predicted in-service performance of the asphalt pavements.Seven asphalt mixes are included in the study using typical PG grades and surface asphalt mixes used in Canada. Two of the asphalt mixes incorporated 15% RAP for comparison with non-RAP mixes. Performance tests conducted on the asphalt mixtures include dynamic modulus, flow number, and flexibility index, which is a performance index used to predict the asphalt mixture's resistance to cracking obtained from a semi-circular bending (SCB) fracture test.

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Paper : **17**

Evaluation of Several Asphalt Binder Parameters Related to Fatigue and Non-Load Related Pavement Failure

Anton S. Kucharek, Sina Varamini

The relationship between the properties of asphalt binders and non-load related cracking in pavements is well documented. As part of the SHRP Superpave specification, the parameter G*.sin(delta) was adopted as a measure of a binder's susceptibility to fatigue failure. A number of subsequent studies have called into question the validity of this parameter and have shown that its correlation with fatigue behavior of asphalt pavements in the field is poor.Several other tests were developed or correlated with fatigue properties of asphalt pavements over time. Among the more recent ones is the Double Edge Notched Tension (DENT) test, adopted recently as part of the acceptance specifications for asphalt binders in Ontario. The DENT test is conducted at 15□C and is designed to predict a binder's essential work of fracture in the ductile domain, as well as a measure of its strain tolerance. While the DENT test's correlation with pavement performance is still under evaluation, one of its downsides as an acceptance test is its relatively high variability and its poor reproducibility – a well-known attribute of most extensional tests.The current paper presents the laboratory evaluation of several parameters related to fatigue and non-load related cracking of asphalts. A number of tests such as G*.sin(delta), DENT, Binder Yield Energy (BYET) test, Linear Amplitude Sweep (LAS) test, Glover-Rove (GR) parameter and Delta Tc were conducted on a series of neat and modified asphalt cements of different sources and having different rheological properties. Correlations and inter-dependence of several of these parameters are evaluated and their likelihood for predicting fatigue-related failure of asphalt pavements is discussed.

Paper : **18**

Performance of alternative crosslinking systems in polymer modified asphalt blends and paving mixes

Martin Jasso, Brett Lambden, Darren Anweiler

In asphalt industry it is well established that the performance of asphalt pavements is significantly affected by the quality of asphalt binder. Therefore, ever growing requirements for asphalt binders favor the use of polymer modified asphalt for the construction of high-quality pavements. Nowadays, the most dominant modification technology employs thermoplastic elastomers, based on styrene and butadiene, crosslinked with a small addition of sulfur. This technology leads to kinetically stable polymer network as well as to the enhancement of rheological and engineering properties of asphalt binder. The major drawback of using sulfur as a vulcanizing agent is the risk of gelation for some types asphalt - styrene-butadiene-styrene systems. The second drawback is a possibility of evolution of sulfur containing emissions. From this perspective, the use of alternative crosslinking agents can play a pivotal role in formulation of more environmentally friendly pavements.In this study, the effects of three new crosslinking agents (sulfur and non-sulfur based) in soft conventional asphalt binder modified by styrene-butadiene-styrene were investigated and compared to the performance of polymer modified asphalt without any crosslinker, as well as to technology employing elemental sulfur. Although the modification technologies for asphalts were adjusted to meet the same performance grade, significant changes in deformation-relaxation processes as well as in microstructure of prepared modified blends were observed. In order to investigate, which crosslinking system provides the paving materials with the best engineering properties, asphalt mixes were prepared and tested via Hamburg-Wheel Tracking Tester Test, Indirect Tensile Test, Dynamic Modulus and Resistance to Moisture Induced Damage.

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Paper : **19**

Investigation of the adhesion properties of blended bituminous emulsion on flexible pavements

Nidaa Al-Allak, Alan Carter, Cesare Sangirogi

In chip seal or micro-surfacing construction, asphalt emulsions are generally used quite successfully and extensively; however, there are many documented cases where emulsion takes an excessively long time to cure, and so good bonding is delayed. This contributes to shelling the stones from the surface of the ground, sometimes within a few days or even hours after completion. Both forms of deficiencies cut deeply into the budget for highway maintenance / resurfacing. Bitumen emulsion blends were prepared from modified and unmodified bitumen emulsion, an anionic bitumen emulsion (hP-200), rapidly changed polymer cationic asphalt emulsion (CRS-2P), and an emulsified asphalt based on cationic water (CRS-2) with different ratios. Adhesion strength was calculated between asphalt pavement and the blended bitumen emulsions by using a Pneumatic Adhesion Tensile Testing Instrument also known as PATTI. To know the effect of bitumen binder's type of the pavement on the adhesion strength of the blends, two different bitumen binders (unmodified and modified) as variables against the control of a predetermined one type aggregate mix. Air voids and specific gravity were tested for substrates samples before testing the adhesion strength of bitumen emulsion blends. The key findings were that while the adhesion strength between the bitumen emulsion blends can be improved by mixing it and it depends on the type of the binder of the pavement.

Paper : **20**

Effect of Bio Based Binder on the Rheological Properties of Asphalt Mix

Xiomara Sanchez, Heena Dhasmana

Due to a rising global population, the demand for crude oil and its derivative products has seen tremendous growth. As a result, the petroleum crude-oil reserves are decreasing while the costs are increasing. Petroleum-based crude oil is also a major contributor to environmental pollution in the transportation sector. Over the past few decades, there has been a significant surge in the development of alternative transportation infrastructure products. Refineries that produce bio-oil from natural feedstocks have been constructed at a noticeable pace. In this respect, researchers have also produced several works that explored the feasibility of using alternative products to the conventional petroleum-based asphalt binder. Agricultural crops and other residues have been converted to bio-oil using certain thermochemical processes. When incorporated into the asphalt mix as a binder, this bio-oil can be used in different percentages to serve as a complete replacement or a modifier. The current study investigates the properties of bio-oil derived from beer-production wastes as a substitute for conventional asphalt binder in the city of Fredericton, New Brunswick. The city of Fredericton has a flourishing craft beer industry and produces a significant amount of organic waste in the beer production process. After a fixed period of waste accumulation, the material is discarded or donated to farmers as cattle feed. With the help of a major beer producer in Fredericton, waste from the production of a specific beer was collected to generate bio-oil. Dried organic waste was converted to bio-oil using a slow pyrolysis technique. For a rheological study, 5, 8, 10, 15, 20, and 25% of the bio-oil was blended with conventional asphalt binder. The blends were also aged for short and long term using Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV), respectively. High and low performance grades of different binder types were determined on a Dynamic Shear Rheometer (DSR). Multiple Stress Creep Recovery (MSCR) tests were also carried out to evaluate the high temperature performance of asphalt blends. Creep rate and stiffness values were calculated to estimate the low temperature performance of conventional asphalt binder and bio-oil mixes. It was concluded from different tests that asphalt mixes modified with bio-oil can perform better than conventional mixes in low temperature weather conditions. Further studies can be carried out to design the most compatible asphalt mix with bio-oil to promote pavement sustainability.

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Paper : **21**

Studies on the premature cracking of asphalt pavement in the region of Bas-St-Laurent and Gaspesie in Quebec

Martin Lavoie, Jeffrey Young and Christine Duchesne

In recent years, the Ministry of Transportation of Quebec has carried out various specific studies on several segments of flexible pavements with premature cracking in the Bas-St-Laurent and Gaspesie region. Tests on pavement were performed and cores were taken to determine the causes that could explain cracks development and the degradation of part of the road network.A first study carried out on sections of newly built Highway 85, which asphalt layers containing reclaimed asphalt pavement (RAP) was 4 to 5 years old, indicated that the phenomenon of generalized surface cracking could be explained by a loss of essential characteristics for resistance to thermal contractions, mainly associated with the oxidation of bitumen.Another study focused on determining the causes of underperformance of road segments whose last major intervention was 7 to 14 years ago in comparison with segments where the evolution of cracking takes place normally. Cores taken from the pavement demonstrated that the majority of premature cracks were superficial. This cracking which is initiated by the surface tends to propagate more deeply over time. It is mainly limited to the surface layer but can reach the base layers for the most densely cracked sites. The use of a layer adhesion measuring instrument (LAMI) made it possible to realize that there was a certain link between the cracks studied and the lowest adhesion values measured at the interface under the surface layer. However, adhesion deficiency is not the main cause of these cracks, but an aggravating factor. The thermal stresses could be less dissipated over the full thickness of the asphalt pavement layers when discontinuities are present or bonding is defective at the interface.The sampled cores were subjected to CT scans allowing visualization of the voids distribution and the density of the asphalt layers. Laboratory analyzes were carried out to characterize the surface asphalt mix. Bulk specific gravity and maximum specific gravity tests were done to calculate the air voids and compaction percentages in each core sample. These results were compared to those obtained with the CT scans. Quantitative extraction of asphalt binder and mechanical size analysis of extracted aggregate were also carried out. Certain specimens have been selected exclusively to determine the characteristics of the asphalt binder and in particular to measure oxidation. These results allowed determining whether the characteristics of the asphalt mix and the asphalt binder could explain the poor performance of the cracked sites.Following the extraction and recovery of the bitumen, various tests (Dynamic Shear Rheometer, Multiple Stress Creep Recovery, Bending Beam Rheometer and Fourier-transform infrared spectroscopy) were carried out. A recent parameter relating to rheological properties at low temperature, Delta Tc, is an indicator which has also been evaluated. These analyzes have made it possible to clearly demonstrate that bitumens recovered from prematurely cracked sites have a higher level of oxidation than those from sites showing normal evolution.The observation of this widespread problem on the Quebec road network and the conclusions drawn from these studies are now arousing the MTQ to reflect on asphalt mixes production. Among other things, the supervision of the use of RAPs and the establishment of mechanisms to prevent the alteration or overheating of bitumens are subjects that flow from it. Proceedings have been taken to reassess current practice, conduct province-wide plant audit programs and review standards and requirements.

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Paper : **22**

Alberta Case Study - Highway 9 Premature Pavement Failures Caused by Moisture Induced Damage of the Asphalt Pavement

Vipin Sharma, Art Johnston, Cong Luo, Wayne Mah

About 24 km long section of Highway 9:10 close to Hanna, Alberta was last rehabilitated in 2012 and 2013. Pavement evaluation completed prior to selection of the rehabilitation treatments in 2009 and pavement performance indicated presence of a normal aged pavement in need of rehabilitation.As part of pavement rehabilitation, pavement within the project limits was rehabilitated using 50 mm mill and inlay or 50 mm mill and inlay plus 50 mm ACP overlay. Following the 2012/2013 pavement rehabilitation, the pavement started exhibiting localized pavement failures in the form of pothole-like disintegration, which were primarily occurring in the wheelpaths and adjacent to the transverse cracks. In some cases, these distresses were in the form of “upheavals”, particularly in cold weather, then subsided. Once subsided the “weakened” pavement disintegrated resulting in the pothole-like distresses. Once those potholes were repaired, the pavement failures developed next to the newly constructed maintenance patch. The frequency of the maintenance patches required to repair the pavement failures had been increasing year over year. This paper will discuss the reviewed pavement construction history, observations made during the field reconnaissance, pavement strength testing results, review of the extracted asphalt cores, results of the laboratory testing and the findings. Review of the extracted cores, performance of asphalt pavement lifts from various years will also be discussed.The factors likely contributing to the premature distress and failure of the pavement along with the recommended rehabilitation treatment options will also be discussed.

Paper : **23**

GHG Emissions for Asphalt Paving Decision Making

Wayne Mah, Kimberley Edmunds, Marta Juhasz

Much has been made about carbon pricing in Canada and worldwide over the last decade. From the Federal carbon tax, to provincial taxes, there is a growing trend to price carbon in an attempt to curb green house gas (GHG) emissions.This paper presents a description of GHG emissions from various pavement life cycle stages. Different methods to quantify GHG emissions from road construction are compared. A summary of GHG emission baselines for various types of pavement rehabilitation treatments that Alberta Transportation currently uses is provided. The paper concludes with a comparison of the life cycle assessment of GHG emissions of Alberta Transportation equivalent rehabilitation treatments and provides commentary on costs. It is important to note that this paper does not represent policy direction but simply a technical assessment of costs.

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Paper : **24**

Effects of alternate aging methods on neat and blended asphalt binders

John A. Noël, Pavel Kriz; M. Rezwan Quddus

Refining trends and increased recycling rates have led to reduced softer grade binder availability. A variety of softening/recycling agents have appeared on the market to supplement this need. While some might be benign or potentially beneficial, others might age poorly and have been shown to negatively impact the lifetime of roads. As a result, tests such as 40 hr PAV and extended BBR have been introduced to help screen poor-performing binders that would otherwise meet Superpave™ specifications. Although, these tests have the potential to identify some poorly performing binders, implementation of these tests greatly increases the time required for binder certification and can pose a logistical challenge. A suitable alternative that can differentiate between good and poor-performing binders should be implemented. In this work, a neat binder and binders modified with REOB or a bio-rejuvenator were subjected to multiple RTFO cycles and 20 and 40 hr PAV at three temperatures to determine the effect of different methods of aging on binder properties, and whether differences in the aging susceptibility between binders can be discerned using less time-consuming methods. Primary results suggest that in many cases 40 hr PAV can be replicated by 20 hr PAV performed at a higher temperature, however increased PAV temperature may change the performance ranking of binders.

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Paper : **25**

Characteristics of Utility Cuts and Their Impacts on Pavement Serviceability in the City of Saskatoon

Bryan Palsat, Art Johnston, Qingfan Liu, Alan Reggin, Braden Jago

Excessive utility cuts in pavements are causing premature deterioration, pavement weakening, excessive road roughness for the pavement structures, and decrease of pavement asset values. It is with increasing frequency that agencies are faced with the impacts of utility cuts installations have on their roadway networks.Tetra Tech Canada Inc. (Tetra Tech) and the City of Saskatoon (the City) completed a study to demonstrate the difference in pavement performance resulting from the presence of 4406 utility cuts between 2014 and 2017 on the City's roadway network.The primary objective of this study was to determine if the amount of pavement degradation, loss of pavement serviceably and pavement asset value could be quantified using the City's pavement utility cuts database. The study utilized the roadway network condition database which contains pavement condition indices and inventory information such as pavement age and surface type. The secondary objective was to assign a defendable pavement degradation fee for utility cuts to offset the impacts of an accelerated requirement for pavement maintenance and rehabilitation activities for three City roadway classes: local roads, collector roads, and arterial roads.First, Tetra Tech conducted integrated, continuous, high-speed pavement condition data collection with Tetra Tech's Pavement Surface Profiler platform for the roadway network in the City. Roadway condition data (International Roughness Index (IRI) and Pavement Condition Index (PCI)) were assessed for sections with and without utility cuts installed between 2014 and 2017. The features and patterns in the change of IRI and PCI are explored for each roadway class. Regression analysis and t-test analysis were also conducted. Significant differences in IRI and PCI were found between pavement with and without utility cuts.Second, the characteristics of utility cuts including the size of the cuts, pavement age, and the IRI and PCI when the cuts were conducted were analyzed. Distribution of the size of utility cuts, and the percentage of the utility cuts over the roadway segment, the statistical parameters were explored for the cuts. The resultant costs relative to the loss in service life over the pavement lifecycle were determined. Based on pre-utility cut condition instead of pavement age, the apparent impacts and pavement degradation fee of utility cuts were assessed.Finally, linear regression models of IRI and PCI were determined for each roadway class with and without utility cuts. IRI and PCI deterioration curves were developed to evaluate the expenses for utility cuts, loss of service life, pavement rehabilitation cost. Asset value impact matrix were proposed for each roadway class.Conclusions from this study show that the impacts of utility cuts can be quantified, and an associated reduction in roadway asset value and pavement serviceability can be calculated. The information in this study may ultimately be used by the City to assist in determining the costs associated with the utility cuts on their roadway pavement network, and in quantifying the impact of utility cuts on pavement serviceability and the typical loss in pavement asset value.

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Paper : **26**

Comparison of fatigue law parameters using Four-point bending (4PB) and Tensile-Compressive (TC) tests

Mohamed Mounir Boussabnia, Daniel Perraton, Sébastien Lamothe, Hervé Di Benedetto, Marc Proteau, Bertrand Pouteau

Fatigue is the one of the main causes of damage in an asphalt pavement. In this study, we consider two types of test, used in Canada, United States and France, allowing to characterize in laboratory the fatigue performance of bituminous mixes. The objective of this study is to link the results of the Four-Point Bending (4PB) fatigue test on a rectangular beam, standardized in the United States, according to the AASHTO T 321 standard, to the Tensile-Compressive (TC) fatigue test on a cylindrical sample. The samples are made with a High Modulus Asphalt Concrete (HMAC/EME) mix. Also, this study aims to establish an efficient test and analysis methodology to determine the fatigue life, necessary to describe the fatigue law of the material etablished by the Wöhler curve. In this perspective, fatigue tests (4PB and TC) will be carried out in displacement control under cyclic sinusoidal force at 10°C and 10 Hz. The results of the fatigue tests show that the standard analysis criterion, noted Nf50%, associated with a 50% drop in stiffness (modulus) during fatigue test, appears to be limited. However, by adopting a failure criterion, noted NfE_ϕmax, associated with the evolution of the stiffness (|E*|) and the phase shift angle (ϕ) in the Black space, the results then show that the coefficients of the Wöhler curve become more comparable for the two trials. The new approach, based on NfE_ϕmax, appears to be a good option for overcoming the limitations and weaknesses of the classical approach, based on Nf50%. However, the determination of the phase shift angle (ϕ) between the displacement and the force must be defined rigorously during the test to clearly determined the fatigue life established by NfE_ϕmax.