2018 Paper Abstracts in Tentative Presentation Order

Paper : **1**

Development and Field Experience of Performance-Based Low Permeability Asphalt Mixture Used to Overlay Bridge Decks

Sina Varamini, Michael Esenwa, Anton S. Kucharek, Matthew Kennedy

Asphalt mixtures on bridge decks often do not last as intended. Raveling, delamination and potholes are more frequently observed on bridge decks in compared to their adjacent asphalt surfaces. The main cause of such difference in performance could be simply due to inability to achieve proper in-place density by being restricted to static only compaction mode and temperature. Compaction temperature is limited to a certain range to avoid melting any underlying waterproofing membranes that could cause so called “slippage planes”. Compaction mode and temperature restrictions could further complicate the projects when hauling distance between the job site and production plant is far away.

This paper provides information on development of a performance-based low permeability overlay mix to protect bridge decks against the penetration of water and brine/de-icing chemicals. This paper also provides steps employed to develop a performance-based requirement focused on permeability and long-term fatigue behavior under extreme repetitive stresses that would be expected from heavily loaded traffic coupled with extreme temperatures. Production and paving experience with the low permeability mix is also included in this paper, as well as more field performance of a trial section in Southern Ontario.

Paper : **2**

Design and Field Performance of Cold Constructed Asphalt Pavements (CCAP) with Gelled Asphalts

Jason Wielinski, Sina Varamini, Michael Esenwa, Herb Wissel, Anton S. Kucharek

Cold Constructed Asphalt Pavement (CCAP) is a unique asphalt product consist of open-graded aggregates combined with a gelled multi-grade asphalt binder. Gelled asphalt binder produces thick asphalt films on the aggregate creating an improved form of cold mix asphalt with no risk of emulsion draindown often associated with conventional open-graded cold mixes. CCAP can be produced at a wide range of ambient temperatures and stockpiled for months until it is ready for use. This paper provides background information on the properties and benefits of gelled asphalt binder. Furthermore, this paper provides details on the design of CCAP, including (1) specification information on gelled asphalt binders, (2) selection of angular, open-graded aggregates for high level of stability. Case studies discussing production and paving experience with CCAP are also included in this paper, as well as discussion of field performance at different locations across the United States and the province of Ontario.

Paper : **3**

Testing Tack Coat Materials for Curing, Tracking and Bond Strength

Hussain Bahia, Abu Sufian, M. Z. Rahaman, D. Swiertz

Asphalt emulsion is the most widely used tack (bond) coat material in the United States. The main objective of this study is to investigate factors that may affect the curing time, tracking performance and bond shear strength of asphalt emulsion tack coats. The effect of critical factors including emulsion type, humidity, curing temperature and time, residual application rate and dilution rate on the curing time and tracking performance of different tack coats were investigated using mass loss measurements, wheel tracking, and Interlayer Shear Strength Testing.

Results showed that the tracking performance of the tack coat is mainly dependent on the rheological properties of the residue and only marginally on the curing rate. It is found that for all emulsion tested, water evaporation or curing happens in a very short time since the applied layer is very thin in tack coat applications but if the rheological properties are not stiff enough, tracking will continue even after completion of water evaporation. It is also observed that dilution with water will increase curing time for all materials tested but in varying amounts. Shear bonding study was performed for both laboratory and field compacted samples. Results of the bonding study demonstrate that there is a direct relationship between the roughness (texture) of the existing surface and the interlayer shear strength between two surfaces and that even when no tack coat is used in the interface, considerably high shear strength is measured. The results with emulsions, however, showed that could be an effect of the rheology of the emulsion residue when very stiff base is used for emulsion production. Comparing field cores with laboratory produced samples showed no clear relationship between the shear strength of laboratory and field specimens. It is speculated that the difference in compaction of the upper layers and the effect of coring will result in laboratory shear values always higher than field cores values. Findings from the study are used to provide recommendations to modify the exiting tack coat specification and allow better handling of tracking and timeliness of traffic during construction.

Paper : **4**

Development of a performance-based overlay asphalt mixture for usage in a low-budget pavement management system

Sina varamini, Michael Esenwa, Anton S. Kucharek, Joe Masi, Tytus Zurawski

An effective pavement management system should include a full range of cost-effective preservation and rehabilitation techniques to ensure a smooth and durable surface with adequate skid resistance is available to road users. However, insufficient funding or budget cuts at federal, provincial and municipal levels of government does not help road agencies to maintain their network at the desired level of service. These funding shortfalls often result in severely distressed and deteriorated pavements within the network, requiring costly rehabilitation or reconstruction.

In this paper, an innovative overlay solution is presented that can be used as a reactive type of maintenance. This solution is a performance-based flexible asphalt overlay designed to be placed without the need for milling operations. This paper provides steps employed to develop a performance-based requirement focused on low-temperature flexibility and long-term fatigue behavior under repetitive stresses that would be expected from low to medium level of traffic coupled with extreme temperatures. Production and paving experience with the flexible overlay are also included in this paper, as well as more field performance of a trial section in the province of Quebec.

Paper : **5**

THE EFFECTS OF FREEZE-THAW CYCLES AND DEICER SALT ON THE DURABILITY OF RECYCLED ASPHALT MIXTURES

Shahab Moeini, Xiomara Sanchez and Bruce Wilson

In places with severe seasonal variations, such as the province of New Brunswick, asphalt mixtures are subjected to cyclic freezing and thawing during the cold months. Moreover, different types of deicers are frequently used to mitigate the effects of snow, ice, and freezing rain on the pavements to increase the safety of roadways. In partnership with New Brunswick Department of Transportation and Infrastructure (NBDTI), seven different mix designs of plant-produced asphalt mixtures, including recycled and conventional hot mix asphalt, were collected from different projects across the province. These samples were subjected to different conditions simulating extreme weather in New Brunswick before conducting multiple tests including indirect tensile strength, semi-circular bending, and abrasion resistance. It was found that freeze-thaw cycles (FTCs) resulted in a high reduction in the tensile strength of the asphalt mixtures; however, there was not any significant difference between tensile strength of conventional and recycled mixtures. Saturation of the samples in deicer salt brine prior to testing did not result in a significant effect on the tensile strength. Semicircular bending (SCB) tests found that the cracking potential of the samples almost doubled after exposing them to a single freeze-thaw cycle. Finally, abrasion resistance tests showed that conventional asphalt mixtures were more susceptible to abrasion compared to the recycled mixtures.

Paper : **6**

Laboratory Investigation of the Characteristics of Rejuvenated Asphalt Binder

Heena Dhasmana, Kamal Hossain, Ahmet A. Sarakas

In order to improve the sustainability quotient of materials being used for pavement construction and facilitate a low initial cost, usage of recycled asphalt products has seen an upsurge. Transportation agencies across the world have increasingly started using Reclaimed Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS). Asphalt recycling, while it is undoubtedly an environmentally favourable practice, includes asphalt binder that is already oxidized. Due to exposure to various environmental conditions, such as temperature, pressure, and humidity, asphalt binder loses its viscoelastic properties. This is called age hardening. Aged binder is highly brittle and becomes a driving factor for cracking related distresses in Asphalt Concrete (AC) pavements. As a result, use of recycled materials can have a debilitating impact on pavement performance, specifically when used in increased amounts and cold climatic conditions. To improve the rheological properties of AC mixtures with recycled materials, rejuvenators are used. Rejuvenators are asphalt additives that have the ability to restore the colloidal structure of aged asphalt by restoring its chemical composition and enhancing the mix performance. In asphalt industry, rejuvenators are used to reduce mix aging and can be blended at a later stage in the recycled materials to improve aged mix properties. It has been found out in previous studies that the type and percentage of rejuvenators used significantly affects the characteristics of rejuvenated aged binders and mixtures. The current study focuses on evaluating the performance of asphalt mixes prepared by blending three different kinds of rejuvenators in already aged asphalt binders. Virgin PG 64-22 asphalt was short and long-term aged using RTFO and PAV and further mixed with the three rejuvenators (R1, R2 and R3) at different percentages by weight of the total binder. To determine the impact of prolonged aging on rejuvenated asphalt binders, the mixed asphalt samples were then aged for 5, 10, 15, 20, 40, and 60 hours in the PAV. TLC-FID and FTIR tests were conducted to evaluate the chemical properties of one of the rejuvenated mixes and parameters such as saturates, aromatics, resins, asphaltenes, carbonyl, and sulfoxide index were determined. Frequency sweep tests in the Dynamic Shear Rheometer (DSR) were also conducted to characterize binder rheology and calculate damage parameters such as Glover-Rowe (GR), crossover frequency, rheological index, and Superpave Rutting. A comparative analysis was carried out to study the impact of increased aging and rejuvenator addition in varying amounts on the performance of asphalt mixes. A strong correlation was found out between the types of rejuvenator used in different dosages and the level of aging in the asphalt binder. Rejuvenators restored the rheological properties of aged asphalt but the rejuvenating impact at different temperatures depended on the type of rejuvenator used. GR parameter was found to increase with aging and correlated well with chemical parameters such as carbonyl index (ICO) and the amount of saturates, aromatics and resins.

Keywords: Long-term aging, rejuvenator, asphalt chemistry, asphalt rheology, cracking potential

Paper : **7**

Calgary Stampede Post-Flood Pavement Assessment & Rehabilitation - 5 years later

Lindsay Johnston, Jadon Pickett, Mike Sharp, Vipin Sharma

In June 2013, Calgary experienced catastrophic flooding that was the worst recorded in the city's history. Located along the Elbow River, the Calgary Exhibition & Stampede grounds were one of the most impacted areas. As a result of the flooding, considerable amounts of the approximately 183,000 m2 of asphalt pavements that comprised the major roads and parking lots of the Calgary Exhibition & Stampede property were showing signs of structural failure. The immediate concerns included developing sinkholes, roadway failures, or other deterioration that could affect public safety or delay events at the grounds. Immediate and temporary repairs throughout the grounds were fast-tracked to prevent cancellation of any major scheduled events, including the 2013 Calgary Stampede.

In 2014, a detailed pavement investigation was performed to determine the impact of the recent flooding events on the structural adequacy and surface condition of the Calgary Exhibition & Stampede asphalt pavements. This investigation included Road Radar data collection, asphalt coring, and visual condition assessments. The investigation was for the entire property, but the rehabilitation focused primarily on two critical pavement sections: the Barn Road access and the Indian Village Parking Lot.

The investigation of the Barn Road, which is the most heavily loaded haul road at the Calgary Exhibition & Stampede grounds and the location of three sinkholes following the flooding, determined that the road was in very poor condition despite the emergency repairs previously undertaken. A concern was raised that the road was too rough to haul in livestock for the Calgary Stampede Rodeo. The Indian Village Parking Lot was also in very poor condition and unable to safely accommodate the travel trailers for the First Nations Families who would be staying there for the duration of the Stampede and would not provide the required accessibility for their Chief who uses a wheelchair.

The Barn Road was repaired using Full Depth Reclamation (FDR) and the Indian Village Parking Lot was reconstructed. This included the repair of 4 sinkholes in these areas and another 12 sinkholes throughout the grounds. The section of Barn Road that was reconstructed in 2014 using FDR ranged in width from 20 m to 83 m and was approximately 600 m in length for approximately 16,500 m2 in total area. The construction schedule for the Barn Road was only six days and the work was completed by the end of the fifth day. An accelerated construction schedule was required because this haul road is needed for all major events and this was the longest time period between the preparation of events. The Indian Village parking lot was over 3,000 m2 and was completely reconstructed on a three-day schedule. Unique construction staging, and planning was established to meet this schedule.

2019 marks five years since most of the rehabilitation efforts were completed. This paper will serve to review the performance of the pavements five years later in relation to the rehabilitation methods used as well as to review those pavements not rehabilitated to assess any long-term effects of the flooding events.

Paper : **8**

Experimental Evaluation of Biodegradable Asphalt Release Agents in Canada

Pezhouhan Tavassoti-Kheiry, Peter Mikhailenko; Hassan Baaj; Lise Eamer

Asphalt Release Agents (ARAs) are used to provide a barrier to the bituminous materials and increase road construction efficiency by minimizing the required cleanup of the equipment. Since the use of diesel fuel has been regulated due to its potential health risks and impacts on the environment, several products have been presented to the market as alternative biodegradable release agents. However, past research has shown that some of these compounds can adversely affect the quality of the bituminous mixes and would contribute to premature pavement distresses such as raveling, stripping, and potholes. To this end, defining an experimental methodology for evaluating the performance of ARA agents in Canada was deemed necessary, and hence was set as the objective of this research. Adhesion and cohesion properties of asphalt concrete mixes directly contribute to the durability of flexible pavements. Therefore, it should be assured that when the ARA comes into contact with the bituminous mix, it would not sacrifice the structural integrity of the asphalt concrete. In this study, a total of five different commercially available ARAs in Canada were investigated with respect to their effectiveness as release agents as well as their impacts on the mechanical properties of the bituminous mixes. Two asphalt concrete mixtures, including a conventional and a polymer modified mix, were used. First, a series of Binder Degradation Tests (BDTs) were conducted on samples of the asphalt cement. BDT was used as a screening tool to evaluate potential interactions between each of the agents and the base asphalt cement. Next, the ARAs were sprayed – at a constant rate – to the surface of the replaceable metal plates in an Asphalt Slide Test (AST) set-up. The AST was performed to evaluate the effectiveness of the ARAs through measurement of the time to beginning of slide, total time to discharge the asphalt concrete sample, and the nature of residues left on the base plates after the tests. Finally, reduction in the indirect tensile (IDT) strength of compacted asphalt concrete specimens was measured after seven days from introducing 2 mL of the ARA to the center of the specimens. Furthermore, the ability of the release agents to work with a polymer modified mixture was also evaluated by performing the slide tests on rubber substrates, instead of the conventional metal plates, to better simulate the challenging scenarios in road construction. The results indicate that the proposed framework can be successfully used to evaluate the existing and new asphalt release products with respect to their effectiveness and their impacts on the quality of bituminous mixtures.

Keywords: Asphalt Release Agents, Asphalt Slide Test, Binder Degradation Test, Biodegradable Materials, Asphalt Concrete

Paper : **9**

Pavement Evaluation of Highwy 97 to Determine Causes of Premature Failure

Vipin Sharma, Christian Babuin; Alan Schmidt

British Columbia Ministry of Transportation retained Tetra Tech to determine the reason behind the premature failure of about 26 km long section of Highway 97 from south of Cottonwood River Bridge to Meadow Creek Road north of Quesnel, BC.

The pavement within the project limits ranged in age from 8 to 10 years and was exhibiting variety of distressed including extreme severity fatigue cracking, ravelling, potholes etc. The most recent rehabilitation strategies included Hot-In-Place recycling, mill and inlay and asphalt overlay. pavement evaluation for the highway included review of the pavement condition data, visual condition survey, asphalt pavement coring and laboratory testing of the asphalt mix from the extracted cores.

Several potential factors likely contributing to the premature failure of the pavement including low asphalt content in the mix, contaminated aggregates, moisture susceptibility of the asphalt mix, sandwich pavement structure, traffic and mechanical wear were determined. Treatment options to rehabilitate the pavement were also developed.

Paper : **10**

Influence of aggregate mineralogy and testing conditions on water damage resistance evaluation of pavement materials

Frédéric DELFOSSE, Justine Vinet, Vincent Gaudefroy, Emmanuel Chailleux, Everett Crews

Performances of pavement material are lowered with time under environmental and mechanical loadings. Among influent factors, water appears to be one of the major element leading to deterioration of the asphalt pavement cohesion. Numerous standardized tests in the world are available to evaluate moisture damage in laboratory. However, most of them show poor correlation with field performances and classification of different formula can change according to the test. In addition to an improvement of the laboratory mix design and mechanical characterization of loosed and compacted mixes, a fundamental understanding of the chemical adhesion between the binder and the aggregate is still needed to predict and prevent the impact of water.

Contrary to wetting, stripping is defined as the shrinkage of the bitumen on aggregate surface. It has been identified as one of the road pavement materials moisture damage mechanisms in presence of water. To observe this phenomenon, a time-lapse image analysis method was used to characterize the dynamic stripping of bitumen droplets on the surface of highly polished mineral aggregates. Nine bitumen-aggregate pairs were used in this study. Firstly this technique allows the bitumen-aggregate pairs to be ranked according to their resistance to moisture damage. Secondly stripping kinetics and loss of the bitumen-aggregate adhesive bond of samples in exactly the same conditions have been calculated. The description of this method and the results has been made in previous report. It was shown that basic aggregates such as limestone showed a good resistance to water whereas acid ones, with high silica content, were very susceptible to water. The higher the water temperature, the higher is the stripping intensity and the faster the kinetic. More precisely, a temperature limit of 40°C under which stripping is not activated is defined. This limit temperature is in relation with the rheology of the bitumen studied.

Additionally, standardized laboratory tests were carried out on loose and compacted mixes to evaluate the discriminating power of test methods and their relevance for stripping evaluation. Boiling test (ASTM D3625) has been identified has both more discriminant and relevant test among the different tested method. About tests on compacted specimen, experimental procedures vary from one to another regarding conditioning process (freeze-thaw cycle for example) and mechanical loading types. If the temperature of the water is higher than the temperature limit previously identified, loss of performances are measured for both aggregates mineralogy. However, the water damage mechanism is different. We observed that non-destructive tests are more adapted to evaluate water damage due to stripping (acid aggregates). At the opposite, destructive tests are more suitable to assess cohesion loss due to water (basic aggregates).

Paper : **11**

Using fine aggregate matrix testing to investigate fatigue performance of asphalt mixtures containing reclaimed asphalt pavement

Mohamed Elkashef, Liya Jiao, David Jones, John Harvey

Fine aggregate matrix (FAM) testing has been shown to correlate with performance of asphalt mixes. FAM constitutes the fine portion of asphalt mixes that contains fines, aggregates and asphalt binder smaller than a given mesh size. Fatigue distresses and crack growth typically occur in the FAM phase of the asphalt mixture; hence FAM testing is considered closely representative of fatigue performance. In this study, FAM mixes, defined as the portion of the asphalt mix passing sieve #8, were tested to characterize asphalt mixes containing reclaimed asphalt pavement (RAP). Incorporating reclaimed asphalt pavement (RAP) into asphalt mixes results in reducing the fatigue resistance of the mix owing to the aged and deteriorated properties of the RAP binder. Rejuvenators can be added to restore the properties of the RAP binder hence mitigating the negative effects of adding RAP. FAM mixes containing 25 percent reclaimed asphalt pavement (RAP) were tested in a dynamic shear rheometer (DSR) using a solid torsion bar fixture to determine their fatigue performance. The RAP was sourced from the hotter Sacramento region in California and was in an excessively aged state as evidenced by its critical high temperature of 109oC. Two different rejuvenators were used at different dosages to restore the properties of the FAM mixes with RAP. The selected dosages were based on a low and a high dosage as recommended by the rejuvenators' manufacturers. The rejuvenators included a bio-based rejuvenator and a petroleum-based rejuvenator. The FAM mixes were compacted using a Superpave gyratory compactor at a height of 50 mm and cylindrical FAM samples measuring 12.5mm diameter were cored. The air void content of the samples was determined prior to testing. To test the FAM samples for fatigue, a linear amplitude sweep testing methodology was devised based on the current AASHTO TP101 standard for binders, with modifications to account for FAM. The linear amplitude sweep testing was conducted at a temperature of 25oC and a frequency of 10Hz. The loading strain was increased from 0.002 to 0.6 using a linear log scale. Three replicates were tested for each mix type. The results of the FAM testing were analyzed using the viscoelastic continuum damage model to plot the damage characteristics curves and to determine the fatigue life. The effect of the rejuvenators and the selected dosages on the fatigue behavior of the RAP mixes was determined. Comparing the damage characteristic curves of the different mixes, it was shown that the rejuvenators helped maintain the integrity of the samples at higher damage levels, denoting better fatigue resistance. The mixes containing the rejuvenators showed a lower rate of damage at higher strain rates. The number of cycles to failure (fatigue life) was shown to increase with the addition of the rejuvenator.

Paper : **12**

Flexible Asphalt Warm Mix for Rural Roads in Canada - Laboratory Results and Case Studies

Saeed Badeli, Ehsan Solatiyan, Alan Carter

Low volume roads rehabilitation is an important part of the pavement jobs done in Canada. Unfortunately, the municipalities have very limited budget for pavement maintenance and rehabilitation. One option to rehabilitate low volumes rural roads is to use flexible asphalt mixes. Those mixes can resist rutting and thermal cracking, but they are flexible enough to move with the subgrade under traffic load or under frost heave.

The objective of this paper is to present laboratory results of tests done on warm flexible asphalt mixes that were prepared for low volume roads, and to present different case studies where those mixes were used in Quebec. Those mixes used in Quebec for more than a decade are designed following laboratory performance specifications on air voids, rutting resistance, thermal cracking resistance and stiffness. For flexible mixes, there is a maximum acceptable stiffness measured at three different temperatures. The results shown that it is possible to design warm flexible asphalt mixes that meet the specifications for rutting resistance and for thermal cracking, but it's harder to meet the maximum stiffness requirements. Three successful pavement sections of different age where those mixes have been used are also presented.

Paper : **13**

High performance flexible asphalt pavement for industrial sites

Marc Proteau, Amélie Griggio, Kamal Berrada

Les aires de circulation et de stockage industrielles et portuaires subissent des charges et des contraintes particulières de déformation, de poinçonnement et de cisaillement. Ces structures de chaussées doivent être spécialement conçues et dimensionnées.

Quel que soit le type de véhicules ou d'engins spéciaux qui y circulent, le design de ces structures spécialisées doit être conçu en tenant compte des contraintes et des sollicitations particulières du site, afin d'établir des solutions optimisées du point de vue de leurs performances et de leur usage, ainsi que sur les plans économiques et écologiques. Le présent article porte sur les aires de chaussées industrielles. Il présente : 1) les derniers développements en termes d'enrobés bitumineux hautes performances; 2) les spécifications techniques des plateformes- de support; 3) l'approche de dimensionnement mécanistique; 4) des exemples de structures industrielles et 5) les avantages économiques et écologiques de celles-ci.

Industrial and Port traffic and storage areas are subject to special loads and restrictions for deformations, punching indentation and superficial shearing, These industrial structures must be specially designed and sized.

Regardless of the type of special vehicles or traffic equipment, the design of these specialized structures must be calculated with considerations to the site's particular constraints and solicitations. This will result in optimized solutions from the points of view of their performance and their use, as well as in economic and ecological terms. This article on industrial pavement areas presents 1) the latest developments in terms of high-performance asphalt mix, 2) the technical specifications of support platforms, 3) the mechanistic pavement design approach, 4) examples of industrial structures and 5) the economic and ecological advantages of these structures.

Paper : **14**

Longitudinal top-down cracking - Asphalt Overlays Case Study

Olivier Sylvestre, Martin Lavoie

The longitudinal cracking phenomenon that develops from the surface of an asphalt overlay (top-down cracking) is a form of deterioration that often occurs on the road network under the responsibility of ministère des Transports du Québec (Québec's ministry of transportation). For more than a decade now, work providers have recommended certain technical requirements regarding on-site monitoring techniques that include thermography to improve the quality of asphalt laying and ultimately decrease the rate of occurrence of premature cracking.

Many factors contribute to the generation and propagation of cracking from the surface of asphalt overlays. This paper mainly covers one of those factors, that is, the longitudinal segregation of hot-mix asphalt. Associated longitudinal cracking is attributable to a linear plane of weakness in the overlay created during the laying of asphalt by pavers. The position and alignment of cracks are consistent to those of thermal streaks detected with infrared imagery, those streaks representing planes of weakness in preferential axes. A plane of weakness is a segregation plane with a high concentration of voids in the asphalt, which has a lower resistance to thermal shrinkage compared to adjacent asphalt with a homogenous mix. Longitudinal segregation axes are also a sign of less bitumen content and a lower resistance to thermal stress that affect the pavement transversally. In a context of resurfacing, it is recognized that all types of cracking may occur as the result of the upward propagation of cracks from underlying layers.

Both road sections studied, which had been resurfaced, emphasize the impacts of longitudinal temperature heterogeneity in hot-mix asphalt detected by infrared imagery during on-site monitoring. A few years following milling and asphalt paving on these roads, the occurrence of longitudinal cracking is monitored to explain the cause of premature deterioration. As part of the monitoring, analyses were performed to link the defects observed to the presence of thermal streaks during hot mix asphalt laying and dissociate them from the upward propagation of cracks from underlying layers. In a context of resurfacing, cracking is not exclusively caused by an upward propagation of cracks from underlying layers. The results show the propagation of cracks toward underlying asphalt layers and the lengthening of cracks initially observed over time. Moreover, the upward propagation of cracks in a context of resurfacing is not the main factor that explains the occurrence of longitudinal cracking when thermal streaks are observed during paving. Thermography, which detects temperature heterogeneity in the asphalt mat, is a monitoring method used on worksites that should be preferred both in the context of resurfacing and in other cases of asphalt laying. Premature longitudinal cracking caused by the laying of asphalt layers is likely to impact the effectiveness of all types of interventions.

Paper : **15**

Superpave5: Effect of In-Place Air Voids on Asphalt Mixture Performance

Gerald Huber, Jason Wielinski, Matthew Beeson

Designing asphalt mixtures with four percent air voids dates back at least to the early 1940s during development of the Marshall method of mix design. The concept of leaving air voids of the mix compacted on the road greater than four percent was part of the same system. Superpave carries a shadow of Marshall mix design in that the design air voids are four percent and mix compacted on the road typically has seven to eight percent air voids.

Superpave5 is a variation of regular Superpave (Superpave4) in that the design air void content is five percent and target air voids on the road is the same, five percent. Superpave5 mixtures have the same minimum asphalt content as Superpave4. The mix design criterion for Superapve5 VMA is increased one percent. Design gyrations for Superpave5 have been lowered to allow compaction on the road to be 95% of theoretical maximum gravity (five percent in-place air voids), The promise of Superpave5 is asphalt mixes that have at least the same amount of asphalt binder content as Superpave4, that are compactable to five percent in-place air voids and have at least the same amount of rut resistance.

This paper will review development of Superpave5 and document the construction of two trial sections, one built in 2013, the other in 2016. Performance of the two trials will be compared to performance of Superpave4 control sections. Asphalt binder for the 2013 trial section was recovered from cores and compared to asphalt binder from the regular Superpave section. Results from the two trial sections indicate that asphalt mixtures designed with Superpave5 criteria can be compacted to five percent in-place air voids and performance of the Superpave5 pavements is better than Superpave4 pavements.

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Paper : **16**

Survival Curves - Trends in Rut depth, IRI, and Pavement Deterioration Index of British Columbia Highway Asphalt Pavements

John Laxdal, Babak Arjmandi,Manoj Jogi,Todd Nakazawa

The BC Ministry of Transportation and Infrastructure collects valuable pavement performance data including rut depth, International Roughness Index (IRI), and Pavement Deterioration Index (PDI) on all numbered highway routes every two years. For this study, these three Key Performance Indicators (KPI) were plotted over several years to develop survival curves for various pavement rehabilitation projects, which included the following treatments:

- HMA mill, inlay
- HMA mill, inlay, and overlay
- HMA overlay
- Asphalt Hot-In-Place Recycling (HIPR)

The trend of the survival curve plots was modeled for each of these types of rehabilitation using the Statistical Analysis System software. Survival curves are empirical prediction models that can help in estimating the future rate of deterioration and remaining service life. The asphalt pavement lifespan after different rehabilitation treatments and the critical KPI that would trigger subsequent rehabilitations were determined from the various survival curves.

Typically, asphalt pavement rehabilitations for highways are based upon a 20 years' design life, but survival curves show that the PDI meets the trigger value for the next rehabilitation in less than 20 years for different rehabilitation methods. Pavement design parameters, traffic considerations, quality control procedures during construction, asphalt mix design and asphalt cement binder performance grade selection should be reviewed for potential improvements in asphalt pavement rehabilitation design and construction to improve the reliability of asphalt pavement performance.

Interim results show that HMA overlays provide a greater lifespan compared to the other approaches considered. Possible reasons for this improved performance could be that overlay rehabilitation is applied when the existing pavement is still in good condition and that the overlay installation increases the pavement structural capacity.

Survival curves should be updated with the biennial pavement performance data being collected by the Ministry and used within their pavement management system to plan and prioritize highway pavement rehabilitation.

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Paper : **17**

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

Imran Bashir, Danial Ahmed, Seyed Tabib, and Pamela Marks

Cracking of asphalt pavement is a major concern for transportation agencies, which can be instigated by several factors including the use of some binder additives/modifiers, recycled materials, variability in materials, 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 identify poor quality mixes and durable asphalt pavements.

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 is to identify practical performance tests and establish acceptance criteria to mitigate cracking (fatigue, thermal, top-down), rutting, and moisture damage. For this purpose, a number of the most promising performance tests were selected for testing and evaluation using post-production asphalt mixes. The selected tests are listed below:

- Flexibility Index Test (FIT) using the Semi-Circular Bend (SCB) geometry (intermediate temperature crack resistance)
- Disk-Shaped Compact Tension (DCT) test (low temperature crack resistance)
- Hamburg Wheel-Track test (rutting and moisture damage)
- Dynamic Modulus and Cyclic Fatigue Test (fatigue crack resistance)

Initial findings from some of the mixture performance tests indicated that the SCB test is able to distinguish between asphalt mixtures with and without Reclaimed Asphalt Pavement (RAP), through the Flexibility Index parameter. In addition, asphalt mixtures with softer grades of asphalt cement may need test temperature adjustments while undergoing Hamburg Wheel Track testing.

The study is currently ongoing. This paper will provide an overview of the test methods, test results, analyses, and initial findings. The objective of the study is to determine the best suited mix performance tests for MTO to evaluate cracking and rutting resistance of hot mix asphalt (HMA) and to develop acceptance criteria and a mix performance specification accordingly.

Keywords: Asphalt, HMA, post-production, cracking, rutting, fatigue, SCB, DCT, Hamburg Wheel Track, mixture performance testing, flexibility index, fracture energy, rut depth, asphalt cement content, RAP

2018 Paper Abstracts in Tentative Presentation Order

Paper : **18**

Retour d'expérience sur les traitements de surface (enduits superficiels) québécois à base d'une émulsion anionique de type HFMS-2

Stéphane Trudeau, Frédéric Leblanc, Jean-Martin Croteau

Presque la totalité des traitements de surface avec pierres nettes (Chip Seal) se fait avec des pierres non-lavées. Dans la majorité des guides de dimensionnement, la pierre doit être lavée et le CRS-2 est souvent décrit comme l'émulsion la plus adéquate pour cette technique. De plus, l'option de laver la pierre est souvent impossible à réaliser pour des questions de coût et de temps disponibles. En effet, il est nécessaire au Québec d'avoir un permis du Ministère de l'Environnement pour pouvoir laver la pierre. Dans ce contexte, l'utilisation du CRS-2 traditionnel comme liant n'est pas optimum, car celui-ci a tendance à coller la poussière, n'offrant ainsi qu'un collage partiel de la pierre. Dans le passé, il y a eu plusieurs échecs dus à ce mauvais choix d'émulsion et de pierres poussiéreuses. En s'inspirant de la pratique au Nouveau-Brunswick, une émulsion de bitume de classe HFMS-2 a été développée pour le contexte québécois. Cette émulsion offre un excellent mouillage qui a donc l'avantage de coller la pierre, peu importe la quantité de fine ou de poussière.

L'usage du HFMS-2 pour le traitement de surface avec pierre nette n'est pas nouveau, mais il est très peu utilisé et il n'y a presque pas de documentation à ce sujet. Les risques du HFMS-2 sont principalement liés aux premières phases de la construction. Un temps de rupture plus long est nécessaire et les spécifications d'ASTM ou provenant d'autres provinces ou États ne sont pas une garantie de succès. Une version adaptée du HFMS-2 est même préférable. Certains paramètres comme la viscosité, le résiduel, le mouillage et le temps de rupture ont été adaptés d'un HFMS-2 générique pour améliorer la performance du traitement de surface.

Cela fait trois ans que des projets de traitement de surface avec pierre nette et avec des émulsions de types HF sont faits au Québec. Les deux dernières années ont été faites avec le HFMS-2 de dernière version. Les nombreux projets sont des succès et la technique de réalisation est maintenant bien maîtrisée. Cela commence avec le dimensionnement avec l'aide du guide irlandais, de la préparation des travaux, de l'application du HFMS-2 et de la pierre nette, du compactage et de la remise en service de la route. Le collage au HFMS-2 offre même une certaine résistance aux précipitations hâtive. La matrice granulaire du traitement de surface montre déjà après un mois un bon enchâssement et une grande résistance. La grande robustesse du traitement de surface avec le HFMS-2 est maintenant démontrée.

Almost all surface treatments with clean stones (Chip Seal) are done with unwashed stones. In most design guides, the stone must be washed and CRS-2 is often described as the most appropriate emulsion for this technique. In addition, the option of washing the stone is often impossible to achieve due to cost and time constraints. In Quebec, it is necessary to have a permit from the Ministry of the Environment to be able to wash the stone. In this context, the use of traditional CRS-2 as a binder is not optimal, as it tends to stick dust, thus providing only partial bonding of the stone. In the past, there have been several failures due to this poor choice of emulsion and dusty stones. Based on the practice in New Brunswick, a HFMS-2 grade bitumen emulsion has been developed for the Quebec context. This emulsion offers an excellent wetting effect which has the advantage of sticking the stone, regardless of the amount of fine or dust.

The use of HFMS-2 for surface treatment with clean stone is not new, but it is very little used and there is almost no documentation on it. The risks of HFMS-2 are mainly related to the early stages of construction. A longer breaking time is required and specifications from ASTM or other provinces or states are not a guarantee of success. An adapted version of the HFMS-2 is even preferable. Some parameters such as viscosity, residual, wetting and breakthrough time have been adapted from a generic HFMS-2 to improve surface treatment performance.

It has been three years since surface treatment projects with clean stone and HF-type emulsions were carried out in Quebec. The last two years have been spent with the latest version of the HFMS-2. The many projects are successful and the implementation technique is now well mastered. This begins with the sizing with the help of the Irish guide,

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the preparation of the works, the application of HFMS-2 and clean stone, the compaction and the return to service of the road. HFMS-2 bonding even offers some resistance to early precipitation. The granular matrix of the surface treatment already shows after one month a good embedding and a high resistance. The high robustness of the surface treatment with HFMS-2 has now been demonstrated.

Paper : **19**

Evaluation of Oxidative Aging of Asphalt Recovered from Plant Produced Asphalt Mixes

Amma Wakefield, Susan L. Tighe, Vince Aurilio, John MacKay

Asphalt is an organic material composed of many complex molecules. The molecules can be grouped into four main fractions of increasing polarity: saturates, aromatics, resins, and asphaltenes (Petersen 2009, Boysen 2015). Because asphalt is organic in nature, it reacts with atmospheric oxygen, resulting in chemical oxidation or oxidative aging. It changes the concentrations of the asphalt fractions, resulting in an overall increased concentration of asphaltenes in asphalt. Increasing asphaltenes makes asphalt stiffen and become brittle, which leading to cracking. Oxidative aging is one of the critical factors contributing to asphalt pavements performance.

Because oxidative aging that occurs over time, the physical properties of the asphalt as determined on the original sample will not be representative of the physical properties of the asphalt on the road. To simulate oxidative aging and its effect on the asphalt properties, two accelerated conditioning procedures are used in the Performance Graded (PG) grading system: the rolling thin film oven (RTFO) test for short-term (production and placement) aging, and the pressure aging vessel (PAV) for longer-term (in-service) aging.
Research conducted at Perdue University by Galal and White in 1997 compared the relation between PAV-aged asphalt to asphalt recovered from field cores of eight-year old pavements. The data showed that the PAV-aged asphalt properties did not correspond to the properties of the asphalt recovered from the field cores (Galal 1997).

More recently in 2012, MTO conducted a study which showed that properties of the recovered asphalt from field cores showed better correlation to transverse cracking than the asphalt aged in PAV. The study concluded that correlation of current lab tests for low temperature properties can be improved if field aging can be better replicated in the lab (Huber 2012).

This paper compares the oxidative aging that occurs in asphalt during lab-conditioning by RTFO and PAV to the oxidative aging that occurs during asphalt mix production and placement (short term aging. The concentrations of the asphalt fractions (saturates, aromatics, resins, and asphaltenes) are measured through a SAR-AD® separation and used as an indication of degree of oxidation. The outcome of this analysis will show how lab conditioning protocols simulate field short term aging.

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Paper : **20**

Comparison of the aging tendencies for Canadian and Northern European asphalt binders

Kristjan Lill, Karli Kontson, Ahmad Khan and Simon A.M. Hesp

This paper provides a detailed investigation on the aging susceptibility of asphalt cements. A number of materials produced by Canadian, Polish, Russian and Swedish refineries were investigated for their Superpave™ performance characteristics as well as enhanced asphalt quality and durability indicators. Materials were tested according to both the Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR) protocols and aging susceptibility was assessed by extending conditioning times in the Pressure Aging Vessel (PAV) and BBR cold temperature bath. It was confirmed that the grade loss due to additional oxidative aging at high temperatures in the PAV is highly correlated with the grade loss due to isothermal conditioning at low temperatures in the BBR, suggesting that both losses involve the same high molecular weight fraction of the asphalt binder. Grade losses are also correlated with the initial phase angle of the asphalt cement in the intermediate to low temperature range. This property deserves further investigation as a suitable specification parameter for cold temperature and load-induced cracking as it is a sensitive measure of durability, it has shown to be highly correlated with pavement cracking performance, and can be measured with high precision, in a short amount of time, on a small amount of aged asphalt cement. Regular as well as Modulated Differential Scanning Calorimetry (DSC and MDSC) were used to investigate the presence of crystallizable fractions within various binders and how these were affected by oxidative aging. Crude sources low in wax, from both Canada and Venezuela, produce binders that are more durable and thus superior compared to those made from waxy crudes or through air blowing processes. An error of only six degrees in the low temperature binder grade increases the risk of cracking damage in any given winter for a typical location in cold climates from the intended two percent to around 50 percent. Hence, it is imperative to implement precise and accurate specification tests for asphalt binders to obtain optimal life cycles from limited financial resources.

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Paper : **21**

Implementing Advanced Asphalt Technology at Winnipeg Airport for Major Rehabilitation of Runway 13-31

Ludomir Uzarowski, Rabiah Rizvi, Andrew Curwain, Carmine Bello

The aircraft traffic loading continuously increases at Canadian airports, in terms of both the number of aircraft movements and the load levels applied by individual aircrafts. Some of the newer aircrafts such as the Boeing 777 and Airbus 380, or some of the Antonov aircrafts, for example, apply very high stress levels to the pavements. In addition, climate change also has an adverse impact on pavement performance. Temperature increases may cause premature pavement deformations and shear failures.
In the design process of airport pavements, the focus must not only be on the condition of subgrade soil, the number and severity of applied loading, and the initial construction cost. Conventional pavement technology is often not sufficient to meet the always increasing quality demands for airfield pavements. Pavement materials and technologies successfully used on road pavements are often not sufficient to meet the performance needs for airfield pavements.

The pavement on Runway 13-31 at Winnipeg Richardson International Airport in Manitoba has a very complex, variable structure. There are sections with flexible (asphalt), rigid (concrete) and composite (concrete overlaid with asphalt) pavements. Some areas have old layers of concrete or asphalt, or even granular material sandwiched between other types of materials. Due to this high variability, borehole investigation was not sufficient and had to be complemented by a Ground Penetrating Radar (GRP) survey. Based on visual condition inspection and the results of borehole investigation, laboratory testing and GPR survey, pavement design was carried out to address the existing pavement variability and high traffic loading demand. It has been decided that the entire pavement will have asphalt surface.

Considering the anticipated aircraft traffic loading and the need to improve the operations, implementation of advanced asphalt technology was considered necessary, with number of aspects new in Manitoba. It included not only the use of performance graded polymer modified asphalt cement PG64-34 PM. The new asphalt paving specification included significant changes in asphalt mix characteristics, including asphalt cement content, gradations, target air voids, volumetrics, compaction and higher quality demands for aggregates. Significant changes were made in acceptance requirements. The introduced smoothness part is based on the recent FAA and Transport Canada requirements. To meet them and to avoid segregation, the use of Material Transfer Vehicle is required in the specification. Also paving in echelon and producing quality longitudinal joints is required.

Since in the past the Airport had to exercise significant effort to maintain good frictional characteristics of the pavement, it was decided to specify the surface course mix that will offer good skid resistance. In order for a source of the surface course asphalt aggregates to be approved, it has to meet the Polished Stone Value (PSV) requirement first.

There were also significant changes made in the granular layers specifications. Although it is obvious that the implementation of the advanced technologies poses some challenges, the contractor's response was positive. As in majority of cases, the key to success is in good team work that includes the client, the contractor and the consultant.

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Paper : **22**

THE ROLE OF BINDERS IN CRACKING RESISTANCE OF MIXTURES MEASURED WITH THE IFIT PROCEDURE

Hussain Bahia, Hui Chen, Yuan Zhang

The SCB Flexibility Index (FI) has been reported as well related to controlling field cracking of asphalt pavements. Extensive research has been conducted on the effects of flexibility index on identifying long-term pavement performances for different types of asphalt mixtures, with limited work focusing on the role of binder's properties in the mixture's flexibility index and. The understanding for the correlation between binder properties and the FI can contribute to the proper development of effective binders' specifications. In this study, the role of binders in cracking resistance of mixture measured with the IFIT procedure are investigated by determining relationship between binder's fatigue life and mixture's flexibility index.

A set of asphalt blends including two control binders (neat and polymer modified asphalt), three blends with Bio-Oil (with different doses), and three blends with Recycled Engine Oil Bottoms (with different doses), were prepared and used to produce eight asphalt mixtures. These mixtures were aged at three aging levels which were the Short-Term Oven Aging for 2 hours (STOA), Long-Term Oven Aging for 6 hours (LTOA6), and extreme Long-Term Oven Aging for 14 hours (LTOA14), and then compacted for producing testing specimens. Their flexibility index was measured with the IFIT procedure at 25 ºC. Afterwards asphalt binders were recovered from tested specimens using solvent extraction. The fatigue resistance of recycled binders was measured with the Linear Amplitude Sweep (LAS) test at the same temperature. The binders' fatigue life has a certain correlation with the mixtures' flexibility index. This correlation increases as strain level used for determining the fatigue life of binders increases. With the results of binder fatigue life estimated at 15% strain, a very good agreement with was found between the binder fatigue life and flexibility index of various mixtures.

In addition, the Pressure Aging Vessel (PAV) testing was conducted on four distinct binders from these eight blends at three levels: 20 hours aging (PAV20), 40 hours aging (PAV40), and 60 hours aging (PAV60). Their fatigue life measured with the LAS test were firstly compared to the fatigue life of recycled binders from the mixtures with the same blends. It was found that both the fatigue life of PAV aged binders (PAV20, PAV40, and PAV60) all have a high correlation with the fatigue life of recovered binders from the LTOA6 and LTOA14 mixtures, expect for those from the STOA mixtures. The PAV20 and PAV40 binders show close aging extents to the recovered binders from LTOA6 and LTOA14 mixtures, respectively. Based on the findings, the results of four extra binders after PAV20 aging and their mixtures (with different designs) after a Long-Term Oven Aging were compared. It was found that the agreement between the binder fatigue life and flexibility index were weakened. This indicates that the cracking resistance of mixtures depends not only on binder properties, but also the mix design.

Keywords: Asphalt Binder, Linear Amplitude Sweep, Mixture, Oven Aging, Flexibility Index, Correlation, Cracking

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Paper : **23** Asphalt adsorption by different aggregates: A case study in Eastern Quebec

Saeed Badeli

Asphalt binder absorption by aggregate is one of the essential parameters in the LC method of mix design in the Québec province. It is also proved that the asphalt mixes are sensitive to water which might deteriorate the adhesion bond between the aggregate and mastic which results in the loss of durability and long term performance of a mix due to the effect of freeze-thaw cycles. In the present study, the aggregates have been analyzing from different quarries. Four different types of aggregates have been used in this project as well as 3 large sources of quarries near Quebec City. Volumetric measurement based on the norm proposed by Le ministère des Transports de la Mobilité durable et de l'Électrification des Transports du Québec (MTQ) have been carried out by each type of aggregates to calculate the percentage of absorbed binder. On the other hand, other volumetric parameters such as the volume of voids between the aggregate particles, and the percentage of air voids have been investigated. This study can be useful to understand the impact of quality of aggregate types in the mix design practice. It is also useful to utilize the results for the performance analyses to verify the impact of the aggregate types in the durability and long term performances of asphalt mixes.

Paper : **24** Research on Algorithm of Loose Asphalt Mixture Aggregate Distribution Uniformity

Wei Yu, Susan Tighe, Naixing Liang

Hot-mix asphalt (HMA) segregation is a common problem throughout the world. Three types of segregation have been identified: gradation segregation, temperature segregation and aggregate-asphalt segregation. The distribution of aggregate is essential to ensure the strength and performance of base and surface layers in pavements, and conditions surveys have observed distress arising from segregation and other types of non-uniformity.

Three traditional non-destructive methods are used to characterize segregation: visual identification, sand patch testing, and nuclear density gauges. Sand patch and nuclear density gauge testing are applicable only after compaction, which is undesirable due to the difficulty of remediating problematic mixes. Conversely, while visual inspection is applicable to loose asphalt mixtures (LAM), it is subjective and prone to inspector error and differences between parties. The proposed method uses image processing techniques to quickly identify LAM issues prior to compaction, which reduces the remediation time. The objectives of the research are to develop methods for defining, detecting and measuring segregation for LAM, and the proposed technique does so by processing a binary image in order to identify aggregate distributions which are applied to a uniformity algorithm.

The new method is based on a binary image in which the LAM aggregate is identified. This image is used to establish a computational model based on four-side static moment theory. In this model, particle area and spatial position coordinates are the most critical parameters. Subsequently, the actual and ideal uniform distribution of aggregate are defined, and a formula for calculating the total static moment (TSM) of all the aggregates to each edge of the image is derived. In order to define the uniformity of the aggregate distribution (UA), the least uniformity state submodel is established. The TSM of each edge is derived. Finally, based on the above parameters, a formula for the UA is defined. 1000 images were randomly selected from 1085 images of LAM collected at the construction site, and processed using the method to determine the value of the uniformity criterion UA. The remaining 85 images were used to verify the plausibility of the criterion. The results indicate that when the value of UA is greater than or equal to 0.91, the LAM can be considered as uniform, vice versa.

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NOTE: The following three papers will be included in the Proceedings but may not be presented during the conference.

Paper : **100**

Determination of the Field Calibration Coefficient (kc) of a High Modulus Asphalt (HMA) for Cold Regions

Samuel Proteau Gervais, Marc Proteau, Daniel Perraton, Sébastien Lamothe

Only mechanistic-empirical (ME) pavement design methods, such as the French Pavement Design-FPD (Alizé: SETRA-LCPC), effectively utilize the mechanistic properties of a new mix. In doing so, those methods promote research and development of innovative products our field of work desperately needs. The poor state in which Quebec's road network is proves exactly that. Nevertheless, establishing the plus-value of a new product via a ME design method comes with its load of work. In fact, to use those methods, empirical calibration coefficients are used to link the laboratory and the field behaviors of the mix. The main goal of this paper is to present a method leading to the determination of the field calibration coefficient of a new and innovative mix: an HMA for cold regions. The field calibration coefficients used in the FPD method only cover reference mixes. So, the use of a trial section comparing the fatigue behaviors of a known mix and the innovative mix will lead to the determination of the field calibration coefficient of the latter.

The following sequence to determine the field calibration coefficient (kc) is vastly inspired by the one used at IFSTTAR Nantes for their fatigue test track. First, preliminary designs are made for both mixes using their complex modulus and their fatigue resistance established from laboratory investigations. The evolution of the percentage of fatigue cracking is plotted against the traffic load (number of ESALs). In order to have enough fatigue cracking on the field and to limit the duration of the test, experience dictates that the designs for both mixes have at least 50% of fatigue cracking at the final number of ESALs (approximately 1 000 000). Secondly, the comparative trial section is built as accurately as possible regarding the preliminary designs. The construction insures that the trial section is free from any heaving, freeze and thaw damages. Also, an extensive instrumentation (temperature sensors, strain sensors and soil pressure cell) is installed to monitor the trial section. Thirdly, the test section behavior is monitored while suffering from the effects of traffic. This monitoring includes temperature, rutting, structural rigidity, fatigue cracking and horizontal and vertical strains. Fourth, the ''As Built'' designs are modelized back in the ME pavement design software in order to retro-calculate the modulus of the unbound granular materials and the subgrade. The final designs are validated comparing the calculated and the measured strains. Fifth, a trial section calibration coefficient (kts) is established in order to quantify the effect of the trial section explaining the difference between calculated and measured fatigue cracking. This calibration coefficient is calculated for the reference mix with a known kc. Based on the IFSTTAR expertise, this coefficient is not negligible. Finally, the validated design of the HMA and the trial section calibration coefficient (kts) lead to the determination of the field calibration coefficient (kc).

With the field calibration coefficient (kc) in hand, engineers can design pavements with more accuracy and confidence in regard to the innovative mix.

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Paper : **101** Application of Nano-Sized Materials in Asphalt Pavements

Thomas Johnson, Leila Hashemian, Sidharth Parta, Azar Shabani

Researchers and engineers have explored the potential of enhancing asphalt cement properties using nanomaterials for many years; however, to date, these materials have not been widely used for asphalt mix modification. This is not only partly due to the novelty of the technology but also due to the complexity of the equipment and relatively high costs of currently available nanomaterials. The cost of the nanomaterials, at least, is one factor that can be reasonably expected to decrease over time as a result of improvements in manufacturing technologies. Furthermore, it is expected that superior long-term performance of modified asphalt materials will result in high performance to price ratio and thus a low life-cycle cost relative to other materials. With the high-performance potential of nanomaterial-modified asphalt cement in mind, along with the projected decrease in cost of nanomaterials, it is important to have solid data available regarding the rheological and mechanical properties of asphalt mixes containing these materials.

Previous studies suggest that nanoclay, although not widely used as asphalt additives, has the potential to enhance the low-temperature properties and performance of asphalt cement. Nanocellulose is another material of interest for asphalt cement modification and may be obtained from several different sources. It can be processed in many ways, ranging from chemical extraction to mechanical disintegration. In recent years, a growing interest has emerged regarding using nanocellulose for improving the mechanical properties of various composites. Nanocellulose has been successfully applied to increase the fracture energy of concrete material; however, to date, it has not been widely used for asphalt cement modification. Literature shows that including a small amount of nanocellulose in asphalt cement (1% by weight of asphalt cement) could decrease its thermal susceptibility, increasing the shear modulus at high temperature and increasing asphalt cement toughness at low temperature.

This research focuses on the rheological properties of asphalt cement modified using two different types of nanoclay and nanocellulose at various temperatures. Microscopic research techniques were used to investigate the appropriate dispersion of nanomaterials in the asphalt cement. The mechanical performance of asphalt mixes containing nanoclay and nanocellulose including permanent deformation at high temperature creep compliance at low temperatures and indirect tensile strength after subjecting the samples to freeze-thaw conditioning was evaluated and compared with unmodified asphalt mixes.

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Paper : **102**

Comparison of fatigue's law parameters using 2 points bending flexion and Tensile/compressive tests

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

Fatigue is the main cause of degradation in asphalt pavement. In this work, we consider various standardized tests in Europe and in Canada to characterize the fatigue performance of asphalt in the laboratory. The literature has established that biasing effects (thixotropy, heating and other undetermined effects) occur during fatigue testing due to the cyclic nature of the solicitation and viscoelastic behavior of bituminous mixes, which contributes differently to altering the values measured according to the tests considered.

The purpose of this paper is to tie the results of the two-point bending fatigue test 2PD on trapezoidal prisms, standardized in France according to standard NF 98-261-1, to the Tensile/Compressive fatigue test on cylindrical test piece. The specimens are made with high modulus asphalt, namely called in French EME. This paper proposes to establish an efficient test methodology and analysis to determine the fatigue life required to describe the fatigue law of the material (Wöhler's Law). For this purpose, fatigue tests will be carried out in displacement control under sinusoidal cyclic loads at 10°C. The T/C tests will be performed at 10 and 25 Hz and the 2PD tests will be performed at 25 Hz. The T/C tests performed at two different frequencies will make it possible to determine the importance of the frequency with respect to fatigue resistance of the EME mix.

The results of the fatigue tests show that the parameters of the fatigue's law depend on the choice of the failure criterion. The standard analysis criterion Nf50%, associated with a 50% drop of module relative to the initial module, appears as non-intrinsic and limited. However, by adopting a failure criterion NE-ϕmax associated with the evolution of the modulus and the phase shift angle in the black space, the results show that the coefficients of the fatigue's law become more comparable for the two. trials. The approach using NE-ϕmax appears as a good option to overcome the limitations and weaknesses of the conventional approach. However, the determination of the phase shift angle between the evolution of the deformation signal and that of the stress must be defined with rigor during the tests in order to delimit the value of NE-ϕmax.The results of the fatigue tests show that the coefficients of the fatigue's law depend on the choice of the failure criterion. The standard criterion Nf50%, associated with a 50% drop of the module relative to the initial module, appears to be very limited and non-intrinsic. However, by adopting a failure criterion NE-ϕmax associated with the evolution of the modulus and the phase angle in the black space, the analysis of our results gives the same coefficients of the fatigue law for the two testing methods (T/C and 2PB). The approach using NE-ϕmax appears as a good option to overcome the limitations and weaknesses of the conventional approach. However, the determination of the phase angle between the evolution of the deformation and the stress signal must be defined with rigor during the tests in order to delimit the value of NE-ϕmax.