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ABSTRACTS

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A NEW PAVEMENT STRUCTURE ON LARGE BRIDGE STEEL DECK

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Epoxy–resin–stone (ERS) steel deck pavement technique is an independent innovation and an integrated technique for the steel deck, which includes steel deck pavement response analysis, steel deck pavement design method, the research on ERS materials and pavement performance, procedures for construction, inspection and evaluation standards and so on. ERS steel deck pavement structure is made up of EBCL, RA05 and SMA10. EBCL is the adhesion layer of the steel deck pavement to provide the shear performance and RA05 is a unitizing layer as a stiffness step and a heat insulation layer in the deck pavement. SMA-10 is a function layer to provide the comfortable and safety travelling. The new structure maximizes the excellence of the materials and has a better workability than the other kinds of steel deck pavements. ERS also has a better life cycle cost. The use of ERS on some bridges in China shows the good performance of it.

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EVALUATION OF REHABILITATED PAVEMENT PERFORMANCE TO CRACKING PROPAGATION

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The repetitive loading from traffic and the extreme weather conditions cause the pavement structure failure, that involves the pavement rehabilitation. Cracking is one of the most frequent deterioration modes in rehabilitated pavements. This study aims to evaluate the cracking performance of asphalt pavement rehabilitated with cold in-place recycling (CIR) and full-depth reclamation (FDR) techniques. In a first time, the viscoelastic and fracture properties of CIR and FDR materials, containing respectively 100% and 50 % of Reclaimed Asphalt Pavement (RAP), were evaluated using the complex modulus test and the semicircular bending test (SCB). Fracture properties of CIR and FDR were characterized using the critical strain energy release rate. In a second time, the effect of cement content on the fracture resistance of FDR mixes was investigated using the SCB test. Results have shown that the FDR mixtures are more resistant to cracking as the cement content increases and high percentage of added cement contributes into making the samples behave like brittle mixtures. Then, experimental results of SCB tests were used to simulate the cracking in CIR and FDR materials using the finite element method. A 2D finite element model (FEM) of the SCB test developed using ABAQUS software. The viscoelastic behaviour of the mixes were defined in the FEM using Prony series determined from complex modulus test results. The crack initiation and propagation were modelled using the extended finite element method (XFEM) and the cohesive zone model. The model was calibrated to SCB results to obtain fracture parameters such as cohesive zone strength and fracture energy. The numerical results were validated and showed a good agreement with the crack propagation observed in the laboratory testing. Finally, the rehabilitated pavement structures will be modelled to investigate their performance to cracking. The effect of existing cracks and the fracture properties of materials on rehabilitated pavement will be evaluated.

EVALUATION OF DIFFERENT PRODUCTION PROCESS ON DIFFERENT RAP SOURCES

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Sustainability concerns in the last decade have put pressure on the different construction processes. Roads construction and rehabilitation, as one of the major resource consumers, are domains that are adapting to this new reality. Foamed bitumen as one of the main road rehabilitation techniques burgeoning steadfastly because of it's effectiveness, simplicity and affordability. However, there is still plenty of avenue to investigate to have a universally accepted laboratory protocols which represent the field result accurately.

This study is about comparison of two different raw material, which is RAP in this case, in two different conditions to address some performance behaviour. Indirect tensile test (ITS) and indirect tensile stiffness modules, as representer of the performance have been investigated and results show the different sensitivity of each RAP source to different temperatures, different compaction and different curing methods.

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ASSESSMENT OF REJUVENATOR IMPACT ON COLD RECYCLED BITUMINOUS MATERIALS TREATED WITH BITUMINOUS EMULSION

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With time, as they age, bituminous mixes oxidize, lose their flexibility which leads to cracking, brittleness and, in general, lower mechanical properties of the pavement. Nowadays, cold recycling pavement technologies, which can be made of 100% of recycled materials, are highly in demand. However, one of the major challenges in this process is that, the bitumen included in the recycled materials is not usable in the new mix; the reclaimed asphalt pavement (RAP) is considered a black rock. Therefore, adding a high amount of new bitumen to the base pavement increases the process cost and reduces the environmental benefits. The use of a rejuvenator has the following positive effects:

- It could potentially mobilize the aged binder included in the RAP.
- It would change the behaviour of the mix and asphalt binder leading to higher possible amount of RAP usage in the mixture.

The first stage of this work is to quantify the influence of a rejuvenator on the RAP. Two sources of RAP from the metropolitan area of the Montreal, virgin aggregate and SYLVAROAD PR1000 commercial rejuvenator are used in this stage. Afterward, the evaluation of chemical bonding between rejuvenators and CRM will be examined to increase the RAP usage in the mixture.

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PHYSICOCHEMICAL AND RHEOLOGICAL CHARACTERIZATION OF BITUMINOUS BINDERS RECOVERED FROM RECLAIMED ASPHALT PAVEMENT (RAP) AND RECLAIMED ASPHALT SHINGLES (RAS)

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The use of recycled asphalt pavement (RAP) and post-consumer asphalt shingles (RAS) in combination with new materials appears to be a good way to achieve economic and environmental gains. The main objective of this work is to establish the effects of the combined addition of RAP and RAS on the thermomechanical behaviour of asphalt mixes and to set optimal weight percentages in RAP and RAS for use in asphalt mix formulation.

An experimental plan was developed on three levels, namely for the formulation of asphalt mixes with recycled materials (characterization of the various base materials, validation of formulations), for the bituminous binders that govern the viscoelastic behaviour of the finished material (determination of the rheological behaviour of asphalt) and for the thermomechanical behaviour of asphalt mixes. Eight formulations containing a mixture of RAP and RAS at a percentage of up to 40% (based on mass) are studied and validated. The validation of the formulations is initially carried out using compactibility/handling tests using the gyratory shear press and rutting resistance tests. The thermomechanical behaviour of the eight formulations that meet the requirements of the Ministère des transports du Québec regarding compaction and rutting is studied.

This poster shows the work done on the bitumen scale. The study of the interaction between virgin binder and binders contained in recycled materials is carried out in collaboration with the École Spéciale des Travaux Publiques de Paris, and its IRC (Institut de Recherche en Constructibilité) research centre, and focuses on the physicochemical, rheological and conventional study of binders. The objective of this study is to evaluate the blending of the three bitumen and to model, predict the mix behaviour from the bitumen behaviour. The results show a good prediction for RAP binder up to 40%, and a good prediction for mixes containing all three binders.

PERMEABILITY AND MECHANICAL PROPERTY MEASUREMENTS OF PAVING FABRICS EMBEDDED IN ASPHALT OVERLAY

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The road network is subjected to repeated loadings from traffic and environment that gradually make the pavement surface deteriorate initially by the appearance of cracking. These discontinuities on the surface provide an accessible path for water to reach to the underlying layers mostly composed of granular materials. In the presence of water, these layers lose their stiffness, which in turn, leads to the decline in durability and structural capacity of the pavement system. To ensure the integrity of the structure during its service life, interlayer materials have been introduced between existing deteriorated asphalt surface and new asphalt overlay to waterproof the pavement system and to retard reflective cracking. One type of such materials is the paving fabric that consists of a membrane non-woven polypropylene geotextile impregnated with bitumen. In order to evaluate the mechanical performance of the paving fabrics, it is essential that the permeability and reinforcement effects of the system after the appearance of cracking, just like what happens in the field, be measured in the laboratory.

In this regard, two laboratory test methods, which both of them are initiative, were developed because there are no standard test methods to do so: first crack generating test, and then to do permeability test. The results of this study show the validity of the developed methods to catch the performance of paving fabrics in practice.

HOT MIX ASPHALT (HMA) OPTIMIZATION USING ARTIFICIAL INTELLIGENCE

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The empirical procedure of HMA volumetric design consumes time effort. This procedure is a common practice when possible changes regarding aggregates and binder properties imposing upon asphalt plants adjusting the job formula. This empirical method is based on gradation specifications bands which are limited to provide clear correlations between the desire volumetric properties and aggregate gradation, thereby producing a material (HMA) with uncertain performance at which validation test is essential. This work compares 4 gradation factors in which aggregate gradation is quantified as a number. This evaluation permits knowing which gradation factor has the highest correlation with HMA volumetric properties, thereby reducing endeavour implied in the empirical design due to a simple calculation of the factor could produce an effective estimation of volumetric properties. This study applies artificial neural networks (ANNs) based on supervised machine learning method to generalize the phenomenon of aggregate packing under which asphalt binder content produces bulk density changes at the same level of energy compaction for the same aggregate blend. These neural networks are built based on 11 input variables (gradation factors, aggregate and binder properties), 7 output variables (volumetric properties and effective binder content) and 5 hidden layers. These ANNs are training using 85000 pairs collected from the Long Term Performance Pavement (LTPP) database. This research explores to accurately establish a link between aggregate gradation and volumetric properties. Moreover, the generalization of HMA compaction behaviour (algorithm) using ANNs could allow designers to precisely estimate the HMA volumetric properties, thus avoiding running tests to validate the volumetric values. This algorithm may help HMA plants to meet project specifications avoiding expensive asphalt binder aggregate combinations.

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LABORATORY INVESTIGATIONS OF THE PERFORMANCE OF FIBER-MODIFIED ASPHALT MIXES IN COLD REGIONS

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Thermal cracking is caused by contraction of asphalt layers at low temperatures: underthese conditions, tensile stresses build up to a critical point at which a crack is formed. The cracks then propagate under traffic loading conditions. In cold regions, freeze-thaw cycles accelerate the crack propagation within the asphalt. Later, the deterioration in the asphalt layer may lead to the formation of more severe distresses such as potholes. Other typical distresses may appear simultaneously within the asphalt layer, including rutting failure at warm temperatures and fatigue failure at intermediate temperatures.

Fibers have attracted increasing attention within the asphalt industry due to their potential use as asphalt concrete modifiers. The addition of fibers to hot mix asphalt results in a composite material that has a higher tensile strength, along with the ability to absorb greater energy during the fracture process. The fibers within the material also act as a crack barrier, preventing the formation and propagation of cracks in the asphalt mix. Besides these effects, fibers may also increase the fatigue life of hot mix asphalt (HMA) and provide resistance to permanent deformation.

This research focuses on the evaluation of the effectiveness of addition of polymer fibers to HMA to increase resistance to cracking at intermediate and low temperatures, rutting resistance and moisture susceptibility at high temperatures, and evaluate the effect of addition of polymer fibers on fatigue failure of HMA. For this purpose, three different types of polymer fibers, including aramid, polyethylene terephthalate (PET), and polyacrylonitrile (PAN), were added to conventional hot asphalt mixes. The resulting samples were compacted, and the mechanical properties of the fiber- modified HMA were compared to conventional HMA samples in the laboratory. Based on the results obtained, the addition of fiber showed a consistent trend compared to the conventional HMA samples, providing improvements in rutting resistance, better cracking resistance, and increased the fatigue life.

REVIEW OF INSULATIVE BITUMINOUS MATERIALS FOR THE PROTECTION OF PERMAFROST

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Cold regions around the world are experiencing a climatic transition due to increasing global temperatures. This transition is cause for concern as engineered structures will need to be adapted to ongoing permafrost degradation, and this need has only been minimally met in Canada. The heat absorption of cold region pavement surfaces is of interest as the thawing effect can lead to premature pavement failure through differential settlement, permanent deformation and thermal or fatigue cracking. The continued growth in pavement distresses poses higher maintenance and rehabilitation costs to northern agencies. To mitigate permafrost degradation, pavement engineers can adapt emerging pavement materials. This paper will serve as a review of the different innovative road materials being developed around the world for permafrost protection over the last decade, with a particular focus on suitability for Canadian adaptation. This review will also discuss verification models for data analysis and best practices for the monitoring of pavement temperature and active layer thickness.

CHARACTERIZATION OF COLD IN-PLACE RECYCLED MATERIALS AT YOUNG AGE USING SHEAR WAVE VELOCITY

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The use of recycled materials in the rehabilitation of pavement tends to develop, as it is more economical and ecological than hot mixes. However, there are few data describing the behavior of such materials especially at very early age. Cold in Place Recycled (CIR) materials treated with emulsion contains a great amount of water before compaction. Therefore, at early age, usual tests such as Marshall stability, ITS or complex modulus are not suitable.

A non destructive technic using shear waves, the Piezoelectric Ring Actuator Technique (P-RAT), have been used in this study. With this method, the shear wave speed (Vs) is obtained thanks to a frequency analysis.

Testing CIR materials with this method, originally used in the geotechnical field, allow to highlight links between Vs, which is an intrinsic parameter, the water loss in tested CIR materials and the amplitude of the received signals. Other studies have also shown some links between Vs and the stiffness in HMA specimens.

The present Ph.D. aim to, first, improve the experimental setup, then, to determine the boundaries of use of the P-RAT method in CIR materials at early ages and, finally, link Vs to other significant CIR parameters such as void ratio, stiffness and CIR components.

CEMENT-BITUMEN TREATED MATERIALS (CBTM) FOR COLD REGIONS: RAP AGGREGATE SOURCE AND LOW PRODUCTION TEMPERATURES

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Cement-Bitumen Treated Materials (CBTM) are typically composed of high amounts of Reclaimed Asphalt Pavement (RAP) together with bitumen emulsion. Ordinary Portland cement is usually added as co-binder. Since RAP aggregates represents almost the entire solid structure, it is important to fully characterize CBTM materials produced with different RAP sources. RAP aggregate is normally employed according to the stockpile availability, without a fixed selection protocol. In particular, an approach that links the RAP aggregate properties (physical and mechanical) to the mechanical properties of the CBTM material is still not known. Hence, it is reasonable to assume that different RAP aggregates could influence the mechanical properties of the CBTM produced.

Moreover, the presence of bitumen emulsion usually requires that the production process should be performed at atmospheric temperature, which is normally recommended by practical guidelines and manuals to be generally higher than 10 °C. However, in cold regions such as Canada, the minimum temperature for production of cold mixes is critically limiting the time gap in which this can happen. Due to the chemical composition of emulsion, production temperatures can be related to the bitumen emulsion properties. As a consequence, different emulsions could have a different response at low production temperatures (below 10°C).

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RESPONSE OF ASPHALT LAYER UNDER SUPER HEAVY LOADS: WORK PLAN FOR CHARACTERIZATION

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The analysis of the effect of super heavy loads (SHL) on pavements represents a challenge in today's engineering practice. The inherent characteristics of the problem make the validity of performance models available in the literature limited. Few efforts have been made to quantify the differences between what was predicted with the models (using a mechanistic-empirical approach) and the expected behaviour of the materials under SHL. This work shows a plan, currently in course, to determine the range of validity of the models associated with the performance of asphalt mixtures in the field (i.e. fatigue and rutting) for the SHL conditions. There will be two phases of analysis: (1) a numerical modelling phase, and (2) a field measurement phase. Considerations taken for these phases, as well as the methodology, are presented in this work.

CHARACTERIZATION OF THE EFFECT OF EVOTHERM ON THE INTRINSIC SELF-HEALING CAPABILITIES OF BITUMEN

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Warm mix asphalt (WMA) technologies reduce the production temperature of hot mix asphalt (HMA) allowing for mixing and paving at lower temperatures. Common WMA technologies include the use of organic wax additives, foaming processes, and chemical additives which decrease the mixing temperature of asphalt mixtures by 15-30°C. The use of warm mix additives has several benefits such improved compaction, improved workability, and lower green house gas emissions during production compared to HMA. The lower production temperature has the added benefit of reducing short-term oxidation in the bitumen caused by prolonged heating at HMA production temperatures, thus, increasing pavement longevity. Despite these benefits, the effect of WMA additives on the intrinsic self-healing of bitumen has not been investigated in depth. The efficacy of bitumen self-healing is dependant on the viscoelastic and chemical properties of the bitumen itself and its interaction with modifiers. Evotherm, a commonly used WMA additive, was used to evaluate the effect of a chemical warm mix additive on bitumen self-healing. Evotherm is a surfactant that is chemically derived from pine tree waste in the production of paper. It is used as a waterless compaction aid as well as an anti-stripping agent. Specimens containing three different concentrations (0.25, 0.5 and 0.75%) of Evotherm were evaluated at five aging levels (unaged, RTFO-163, RTFO-130, RTFO-100, and PAV aged) using the Dynamic Shear Rheometer to determine the self-healing properties. The results indicate that higher concentrations of Evotherm may decrease the self-healing of unaged bitumen due its effect on microcrack closure and wetting ability. It was also observed that samples aged at lower RTFO temperatures (100 and 130°C) have higher self-healing ratios compared to the samples aged at the typical RTFO temperature. Furthermore, it is recommended to investigate the effect of chemical warm mix additives on the self-healing capabilities of asphalt mixtures.

CHARACTERIZATION OF RECYCLED ASPHALT PAVEMENT (RAP) FROM MONTREAL METROPOLITAN AREA

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In North America and most of the world, the roads built in the past years are coming at the end of their useful life and their reconstruction will be needed. The old bituminous pavement is collected and crushed to produce Reclaimed Asphalt Pavement (RAP). The RAP is then stock in landfills or an asphalt plant in order to use it in new mixes. To limit the quantity of RAP in landfills, some cities impose a minimal use of RAP on all their new mixes. For example, New-York city demands a minimum of 30% by weight of RAP for all their new mixes. RAP in mix design is becoming increasingly common worldwide. Using RAP reduce the environmental impact by saving virgin materials (aggregates and bitumen). The two components of the RAP are the aggregates (around 95% by mass relative to the total mass) and the oxidized bitumen. The oxide ratio of the RAP bitumen depends on many factors, such as age of the pavement and its contact with air. The main objective of this thesis project is to have a better understanding of the mixes behaviour with high content of RAP. The first stage of this research program is focusing on the characterization of several sources of RAP from the metropolitan area of Montreal.

In order to do the characterization, the maximum specific gravity, the particles size distribution (the black curve) and the asphalt content are accomplished on RAP. The bitumen from the RAP sources is extracted with trichloroethylene (TCE) and then the aggregates and the bitumen are tested. The particles size distribution (the white curve) and the specific gravity tests are done on the granular part of the RAP. The properties studied for the RAP bitumen are the viscous and elastic behaviour at high temperatures of use with the Dynamic Shear Rheometer (DSR), the low temperature stiffness and flexural properties with the Bending Beam Rheometer (BBR), the penetration of a sewing needle and the Multiple Stress Creep Recovery (MSCR) on DSR. Those results assign a Performance Grade (PG HTx-LT) gradation of the RAP bitumen. From those results, two sources of RAP will be selected to conduct research on mix design with high content of RAP.

FALLING WEIGHT DEFLECTOMETER (FWD) DATA ANALYSIS BY ALIZE-LCPC PROGRAM

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The falling weight deflectometer (FWD) test is the most widely accepted and used technique for nondestructive evaluation of pavements and has been conducted extensively in the last decades to evaluate structural conditions and to determine the moduli of pavement layers. The FWD data are used as if they are the results of static loads, while the real loads have dynamic behavior. Therefore, the results can vary significantly for flexible pavements.

The objective of this poster is to present the results and analysis of some FWD data, which have been obtained by some FWD tests done in Quebec; in particular, to document the results, which have been backcalculated by Alize-LCPC software. These results can be compared to the results of a new model, which will be developed based on the dynamic analysis in the future by the writer. This comparison will enable us to have more precise and reliable results with the FWD.

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IMPACT OF CLIMATE CHANGE ON PAVEMENT PERFORMANCE IN NEWFOUNDLAND, CANADA

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Most of the researchers agree that the climate change started affecting the existing pavement infrastructure all over the world. Therefore, there is a need for changing the design procedure by considering the climate change. This study focuses on the projection of climate using various models for Newfoundland climate regions, to investigate the impact of climate change on pavement design in the province of Newfoundland and Labrador in Canada. AASHTOware Pavement Mechanistic-Empirical software was used to determine the pavement performance for both historical climate (named as baseline climate) and the projected climate change. In this study, historical climate data are obtained from AASHTOware database. In addition, material, structural design and traffic details for the provincial highways are graciously obtained from the Department of Transportation of Newfoundland and Labrador, Canada. To predict climate change model, an existing statistically downscaled climate change model was taken from the Canadian Centre for Climate Modelling and Analysis (CCCma) website. These models include daily maximum and minimum temperatures only. However, to predict the hourly climate model, two prediction procedures such as Modified Offset Morphing Method (M-IOMM) and Sine (14R-1) are utilized. Similarly, an hourly model was developed for the precipitation using M-IOMM method. These climate change models were incorporated into the AASHTOware ME Pavement software to predict the pavement performance. The change in pavement performance due to climate change was predicted and compared with the baseline pavement performance.

From the result, it is noticed that the climate change models are significantly affecting the pavement performance over a design life of 20 years. As there is an effect of climate change on pavement performance, the pavements might experience early failure in the province of Newfoundland, Canada. From AASHTOware analysis, it is found that there is a decrease in predicted IRI for the climate change models, compared to the baseline climate which is mainly occurring due to drastic reduction in freezing index, however, the distresses such as total permanent deformation, BU fatigue cracking, AC permanent deformation are significantly affected by climate change. Due to climate change, AC permanent deformation is increased by 33–40%, which might be because of the constant increase in temperature throughout the design period. In addition, bottom-up fatigue cracking is highly affected by climate change, which is almost equal to an increase of 80%. So, considering climate change is an essential requirement for the pavement design in Newfoundland.

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RUTTING AND MOISTURE SUSCEPTIBILITY CHARACTERISTICS OF ASPHALT MODIFIED WITH CELLULOSE NANOCRYSTALS (CNC)

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For hot mix asphalt pavements, the prevention of thermal cracking is a critical issue for many North American transportation agencies. The tendency to use lower performance grade (or softer) asphalt binders in cold regions such as Canada, as required by the Superpave mix design protocol developed by the Strategic Highway Research Program (SHRP), causes flexible pavements to inevitably undergo severe plastic deformation during the warm summer months.

In recent years, nanomaterials, that is materials with at least one dimension less than 100 nm, have been introduced as potential modifiers of asphalt binders. Nanocellulose is a material of interest for asphalt cement modification, for several reasons. Nanocellulose can be obtained from several different sources. It can also be processed in many ways, ranging from chemical extraction to mechanical disintegration. In recent years, a growing interest has emerged regarding the potential use of nanocellulose for improving the mechanical properties of various composites. Nanocellulose already has been successfully used to increase the fracture energy of concrete materials; however, to date, it has not been widely investigated for asphalt cement modification.

This study focuses on the performance of hot mix asphalt (HMA) produced using asphalt binder modified with different concentrations of nanocellulose. Qualitative techniques were used to evaluate the dispersion of the nanocellulose in the asphalt binder, and the rheological properties of the modified asphalt binder were investigated. The mechanical performance of HMA containing nanocellulose-modified binder was evaluated by performing various laboratory tests, including permanent deformation and moisture susceptibility at high temperatures, and also low-temperature fracture energy, indirect tensile creep compliance, and strength. The results were compared with the results of tests conducted on samples containing the neat asphalt binder.

INVESTIGATION OF THE IMPACT OF RAP GRADATION ON HOT MIX ASPHALT PERFORMANCE

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In the current era of road construction, it is common to add small amount of Reclaimed Asphalt Pavement (RAP) in asphalt mixes without significantly changing properties such as stiffness and low temperature cracking resistance. Not only can these mixes be better for the environment, but they can also improve certain properties like rutting resistance. However, there is no clear understanding of how RAP gradation and RAP bitumen properties impact the mixture properties.

In this study, a single RAP source was separated into coarse and fine particles, and added into a Hot Mix Asphalt (HMA). The Ignition Test was used to quantify the bitumen content in the RAP, while Environmental Scanning Electron Microscopy (ESEM) image analysis was used to visualize the interaction of the virgin and RAP bitumen at a microscopic level. Thermo-Mechanical tests were adopted to characterize the complex modulus, fatigue resistance and thermal cracking resistance. The observed results indicate the recovered bitumen from coarse RAP does not have the same characteristic as the fine RAP, and the interaction of RAP bitumen with virgin bitumen significantly depends on RAP particle size. The amount of active RAP bitumen in coarse RAP particles was higher than in the Fine RAP particles.

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REFLECTIVE CRACKING EVALUATION IN THE PAVEMENT OVERLAY DESIGN

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Most of the work done on pavements in Canada are rehabilitation work. Amongst the different techniques available, milling the damaged surface layer and replacing it by a new mix (call mill and fill or shave and pave) is very common. However, they often do not perform as expected because of existing cracks that propagate through the newly constructed overlay within a short period of time. This phenomenon is called “reflective cracking” and is well identified when an overlay shows a crack pattern identical to that existing in the old pavement. Reflective cracking is the most common failure mode encountered in the hot mix asphalt (HMA) overlays. The reflective cracking is a phenomenon defined as a process of propagation of discontinuities and cracks from an existing distressed pavement surface into the new overlay, due to the horizontal and vertical movements of the overlay.

In this project we are going to study the simultaneous effect of, overlay thickness, traffic load, and freeze-thaw cycle on reflective cracking after rehabilitation in the presence or absence of reinforcements.

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ANALYSIS OF THE ENVIRONMENTAL AND ECONOMIC ASPECTS OF THE INCORPORATION OF RECYCLED GLASS IN ROADWAYS

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Public awareness regarding global environmental issues and sustainable development has increased since the beginning of the new millennium. Global warming is a major concern, as well as the more local scale urban heat island effect, a threat to human health for which mitigation solutions must be developed. Pavement surfaces represent as much as 45% of a city's surface area. Schoolyards, roads and parking spaces are some examples of large urban paved areas, often covered with asphalt and also other dark materials that absorb most of solar radiation. Another major challenge for pavement engineering worldwide is to meet the ever-growing demand for sustainable physical resources needed for construction and maintenance.

The efforts to find solutions to minimize the effects of global warming and its localized scale as well as consumption of virgin materials have become a greater priority in the pavement field. Also, the need to recycle more wastes and to diminish the use of landfills is considered. The disposal of useless glass in landfills is a significant environmental challenge that many countries face around the world. Using waste glass as an alternative for aggregate has been considered in many countries. Although little studies have been done to explain Urban Heat Island from life cycle assessment approach (throughout a product's life) because of its complexity, there is still a challenge to include recycled crushed glass in life cycle assessment of a pavement system.

The main objective of this study is to develop a method to integrate urban heat island effects as a metric in Life Cycle Assessment of pavements and proposing a comprehensive environmental and economic framework associated with the use of recycled glass in flexible pavement during its life cycle.

PRELIMINARY INVESTIGATION OF USING NANOCELLULOSE IN BITUMINOUS MATERIALS

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In Canada, the three most costly modes of pavement distress are thermal cracking, fatigue cracking, and permanent deformation. Unpredictable increases in heavy vehicle traffic, and more extreme fluctuations in temperature caused by climate change are playing a major role in the acceleration of pavement distresses. The increase of these distresses leads to higher infrastructure costs, increased safety concerns and a greater negative impact on the environment. Numerous studies on innovative bitumen modification have been carried out in order to improve pavement performance. Some of these studies have focused on using nanomaterials, defined as materials with at least one dimension within the nano-scale (1- 100nm), to modify bitumen to mitigate deterioration and extend the pavement service life.

The small scale of nanomaterials gives them exceptional properties such as high functional density, large surface area, high sensitivity, catalytic effects, and high strain resistance. Previous studies using nanoclay, nanocarbon, or nanosililca as bitumen modifiers demonstrate an improvement related to the rheological properties of the bitumen materials and, consequently, its mechanical properties such as elasticity, flexure strength, and tensile strain. Due to its benefits, a type of nanomaterial that is renewable and sustainable is ideal. Cellulose is the main building block of trees and plants. When processed into nanocellulose, it is a green material that has been successfully used to reinforce concrete due to its excellent mechanical properties and biocompatibility. As a result, nanocellulose is being evaluated as a bitumen modifier in the present study.

Following the bitumen modification, nanocellulose modified bitumen was short-term aged using the Rolling Thin Film Oven (RTFO) test. The aged bitumen is then used in the Dynamic Shear Rheometer tests (DSR) to determine the rheological properties of the bitumen, specifically stiffness and elastic response at high and intermediate temperatures based on the Superpave system. Multiple Stress Creep Recovery tests (MSCR), Linear Amplitude Sweep tests (LAS), as well as the Temperature Frequency Sweep master curve are used to further investigate the outcomes of the addition of nanocellulose on bitumen performance.

The preliminary results of nanocellulose investigation demonstrate that nanocellulose has very little impact on the rheological properties and acts as a filler in the bitumen. Nevertheless, the results support the need for further testing of the modified mixtures in order to have a better understanding of the impact of nanocellulose on the performance of bituminous mixes.