GRINCH

GROUPE DE RECHERCHE
EN INGÉNIERIE DES CHAUSSÉES

PAVEMENT ENGINEERING RESEARCH SYMPOSIUM

APRIL 26TH, 2019 | 1 - 4 PM

ALUMNI HALL, ST PAUL'S UNIVERSITY COLLEGE
UNIVERSITY OF WATERLOO
190 WESTMOUNT RD N, WATERLOO, ON N2L 3G5

Information Package

Hosted by

UNIVERSITY OF WATERLOO

FACULTY OF ENGINEERING
Department of Civil and Environmental Engineering

CPATT
CENTRE FOR PAVEMENT AND TRANSPORTATION TECHNOLOGY

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LCMB LABORATOIRE SUR LES CHAUSSÉES ET MATÉRIAUX BITUMINEUX

UNIVERSITÉ LAVAL

arquluk
Permafrost engineering research program
Programme de recherche en ingénierie du pergélisol

i3C Phase 2
Chaire de recherche industrielle du CRSNG sur l'interaction charges lourdes-climat-chaussées

UNB EST. 1785

MEMORIAL UNIVERSITY

ARTEL ADVANCED ROAD & TRANSPORTATION ENGINEERING LAB

UNIVERSITY OF ALBERTA

IRRF INTEGRATED ROAD RESEARCH FACILITY

UNIVERSITY OF MANITOBA

UNIVERSITY OF SASKATCHEWAN

Poster courtesy of Michelle Liu Technical & Graphic Design

Scientific Committee (*In Alphabetic Order*)

Hassan Baaj, *University of Waterloo*

Ali-Reza Bayat, *University of Alberta*

Jean-Pascal Bilodeau, *University of Laval*

Alan Carter, *École de Technologie Supérieure (ÉTS)*

Guy Dore, *University of Laval*

Leila Hashemian, *University of Alberta*

Kamal Hossain, *Memorial University of Newfoundland*

Leonnie Kavanagh, *University of Manitoba*

Daniel Perraton, *École de Technologie Supérieure (ÉTS)*

Xiomara Sanchez-Castillo, *University of New Brunswick*

Ahmed Shalaby, *University of Manitoba*

Haithem Soliman, *University of Saskatchewan*

Pezhouhan Tavassoti-Kheiry, *University of Waterloo*

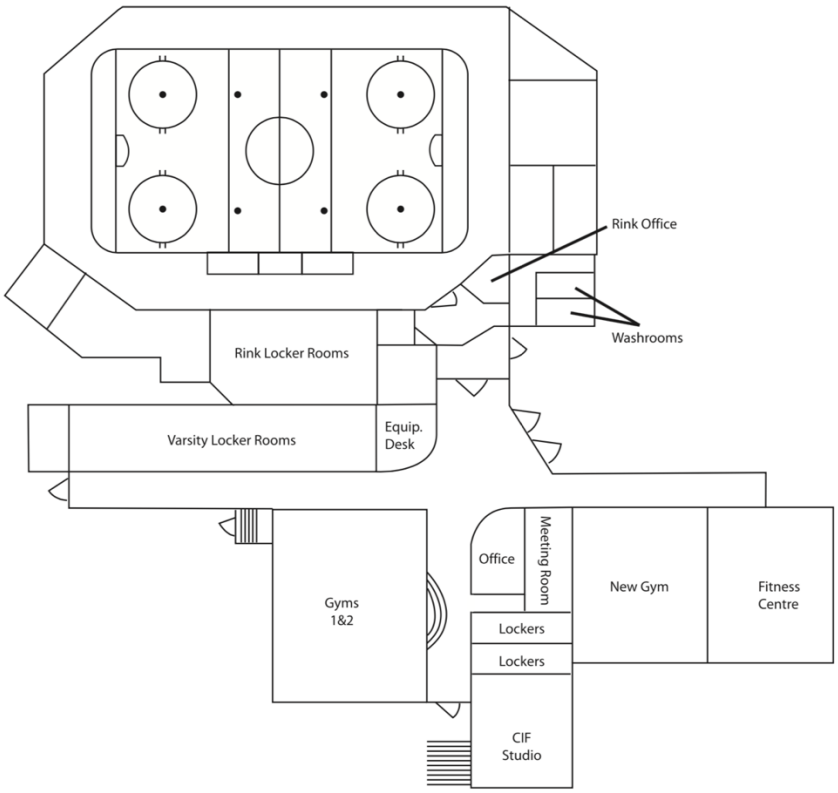
Susan Tighe, *University of Waterloo*

Michel Vaillancourt, *École de Technologie Supérieure (ÉTS)*

GRINCH Group Meeting (First Day) Program (Thursday, April 25, 2019)

Time	Activity Description
14:00 – 17:00	Scientific Meeting of Grinch Faculty and Research Members
14:00 – 17:00	Athletic Activities Organized by the Students [1]
17:00 – 18:00	Free Time
18:00 – 21:30	Dinner and Social Activities [2]

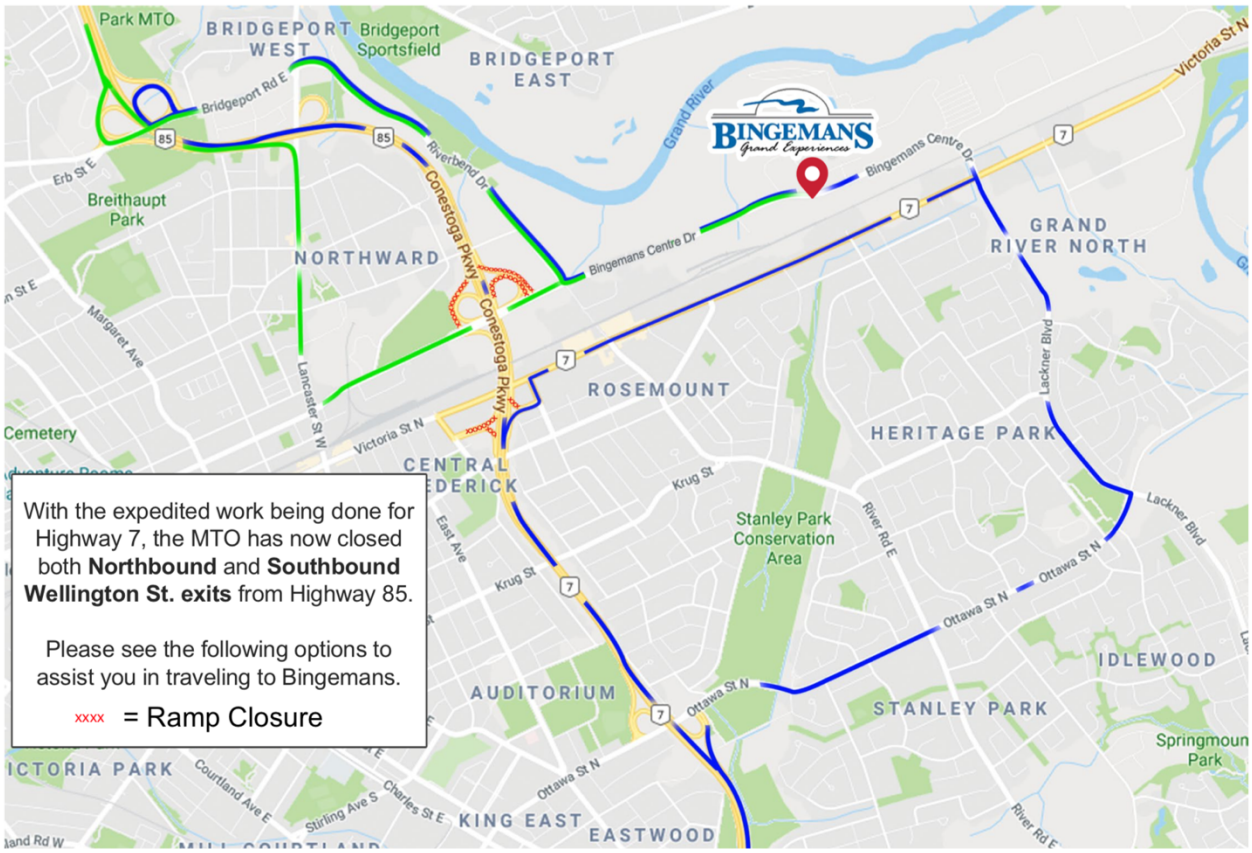
[1] The athletic activities are planned for the students and interested parties at the Columbia Icefield (CIF) of the Waterloo Warriors at the University of Waterloo. Two indoor soccer fields at Gym 1&2 are booked for this activity. The participants who are interested in playing are encouraged to come prepared with proper footwear and dresses. Below is the map of the CIF facility:



CIF Address is: 220 Columbia St W, Waterloo, ON N2L 0A1

[2] The dinner and social activities are planned to happen from 18:00 to 21:30 at the Bingemans. Aside from drinks and dinner, bowling lanes are booked to have some fun. The Bingemans is located at:

Address: 425 Bingemans Centre Drive, Kitchener, Ontario, Canada, N2B 3X7



GRINCH Seminar, Morning Program (Friday, April 26, 2019)

Time	Activity Description
8:00 – 8:15	Registration - Refreshments
8:15 – 8:30	Welcome Notes
8:30 – 10:00	**Session 1: Student Presentations**
8:30 – 8:40	**Xiangbing Kong (ULaval) :** *Development of design tools for convective mitigation techniques to stabilize embankments built on thaw sensitive permafrost*
8:40 – 8:50	**Simone Raschia (ÉST):** *Effect of RAP source and low production temperatures on mechanical properties of Cold Recycled Mixtures*
8:50 – 9:00	**Ali Al-Abbasi (UManitoba):** *Effect of asphalt overlays on load transfer efficiency at transverse joints*
9:00 – 9:10	**Yashar Azimi Alamdari (UW):** *Laboratory Simulation of the Impact of Solar Radiation and Moisture on Long-Term Age Conditioning of Asphalt Mixes*
9:10 – 9:20	**Erdrick Leandro Pérez-Gonzalez (ULaval) :** *Development of an analysis tool for the quantification of the effect of super heavy loads on pavements*
9:20 – 9:30	**Saeed Saliani (ÉST):** *Impact of the RAP particles size on HMA properties*
9:30 – 9:40	**Abimbola Grace Oyeyi (UW):** *Evaluating the Feasibility of Using Lightweight Cellular Concrete as a Subbase Alternative in Pavements* **Student Presentation (University of Waterloo)**
9:40 – 9:50	**Jean-Claude Carret (ÉTS)** *Cement Treated Granular Base Study*
10:00 – 10:20	**Coffee Break**
10:20 – 11:20	**Session 2: Faculty Members Presentations**
10:20 – 10:35	**Dr. Kamal Hossein:** *An Overview of Pavement Research Activities at Memorial University*
10:35 – 10:50	**Dr. Leila Hashemian:** Asphalt Concrete Modification for Improvement of Flexible Pavement Performance in Cold Regions
10:50 – 11:05	**Dr. Xiomara Sanchez:** *Experience with the use of waste and by-product materials in pavements*
11:20 – 11:50	**Session 3: Student Presentations**
11:05 – 11:15	**Amir Rahmanbeiki (ÉTS) :** *Effect of compaction method on cold recycled asphalt mixtures treated with foamed asphalt*
11:15 – 11:30	**Amin Mneina (UManitoba):** *Updating specifications for unbound granular materials for improved drainability and stiffness*
11:30 – 11:40	**Bahar Ahou Ghalandari (ULaval) :** *Experimental and numerical modeling of tire-soil interaction in off-road conditions*

11:40 – 11:50	**Eskedil Melese (UW):** *Mechanical Properties of Full-Depth Reclaimed Pavement Materials Treated with Hydraulic Road Binders*
11:50 – 12:00	**Nima Ghafari (ULaval) :** *Insulating Performance of Foam Glass Aggregate (FGA) in Cold Regions Roads and Highways*
12:00 – 12:10	**Haya Almutairi (UW) :***Investigating solutions for self-healing and crack mitigation of flexible pavements*
12:10 – 12:20 Closing	
12:20 – 13:00 Lunch Break & Networking	

GRINCH Seminar, Afternoon Program (Friday, April 26, 2019)

Time	Activity Description
13:00 – 15:00	Poster Presentation Session
15:00 – 15:20	Coffee Break
15:20 – 16:00 Awards and Closing Session	

Information about the presentations:

Given the time restrictions, 14 presentations will be made by students in the morning session. This will include three presentations from University of Waterloo, three from École de Technologie Supérieure, three from Laval University, and two from the University of Manitoba. The presentations will be 10-minute long each.
Three presentations will be made by professors from the Memorial University of Newfoundland, University of Alberta, and University of New Brunswick. The presentations will be 14-minute long each.

In order to facilitate switching from one speaker to the next one, please upload your presentations to the GRINCH 2019 Dropbox using the link below:

Access the Dropbox for GRINCH 2019 here!

Or copy and paste the following link to your browser:

https://www.dropbox.com/request/g1sAIzfsOqoFGyPgmUIm

The morning session will be by invitation only. The afternoon session will be open to everyone. All students and faculty members are welcome to present a poster in the afternoon. A jury composed of 3 to 4 industry members will select the best posters and presentations.

Recommended Poster Size

The spaces allocated for the poster presentation is equipped with boards of 4’ by 4’ (or 120 cm by 120 cm). Please make sure to use the proper dimensions for printing your posters.

Bio/Abstract of Oral Presentations by three of the Faculty Members

An Overview of Pavement Research Activities at Memorial University

Presenter: Dr. Kamal Hossain, Assistant Professor, Department of Civil Engineering, Memorial University, St. John's, NL

Biography:
The pavement research program at the Memorial University started in Fall 2017 under the leadership of Dr. Kamal Hossain. Since then the group has been working on several research projects that are supported by Memorial University and some local and federal organizations. Currently, the team is exploring several topics in the area of pavement materials, mechanistic design, pavement management, and road safety. The overall objectives of these research are 1) to better understand the characteristics of road materials, 2) to design a more durable pavement mixture and 3) to contribute in the development of an improved pavement design, construction, and management system. This presentation will give an overview of our efforts.

Asphalt Concrete Modification for Improvement of Flexible Pavement Performance in Cold Regions

Presenter: Dr. Leila Hashemian, Assistant Professor, Department of Civil Engineering, University of Alberta, Edmonton, AB

Biography:
Dr. Hashemian is an Assistant Professor at the Department of Civil & Environmental Engineering, University of Alberta. Her research focus centers primarily on asphalt material characterization and mix design. During her graduate studies, she conducted extensive research on warm mix asphalt (WMA) and cold mix asphalt (CMA) using advanced technologies. Her fourteen years of experience working in world leader companies in road and airport construction, provided her the opportunity to get involved in many successful pavement construction design and rehabilitation projects. These projects used innovative material and techniques, such as soil stabilization with cementitious material, asphalt hot and cold recycling, and advanced laboratory pavement material characterization.
During the past five years at the University of Alberta, Dr. Hashemian has been involved in the Integrated Road Research Facilities (IRRF) activities, including analysis of flexible pavement response to thermal-induced strains, falling weight deflectometer (FWD) tests, and controlled vehicle loading. She has also been involved in research studies on pavement material characterization for cold regions applications.

Experience with the Use of Waste and By-product Materials in Pavements

Presenter: Dr. Xiomara Sanchez-Castillo, Assistant Professor, Department of Civil Engineering, University of New Brunswick, Fredericton, NB

Biography:

Dr. Xiomara Sanchez is an Assistant Professor and the D.C. Campbell Chair for Highway Construction and Pavement Research at the University of New Brunswick (UNB), and a registered Professional Engineer in the province of New Brunswick. She has been working in the field of pavement engineering for over 15 years. In 2015 she completed her doctoral degree at the University of Waterloo under the supervision of Dr. Susan Tighe.

Dr. Sanchez's main research interests are the use and performance of recycled materials for road construction. At UNB she is developing a research program to study the effective use of waste and by-product materials in pavements. She has investigated the use of reclaimed asphalt pavement, recycled asphalt shingles, and recycled plastic. Additionally, in the past two years, she became interested in asphalt modification and exploring the use of biomaterials to enhance the performance of bitumen.

She is a member of the Canadian Society for Civil Engineers (CSCE), Academy of Pavement Science and Engineering (APSE) and Canadian Technical Asphalt Association (CTAA). Dr. Sanchez is also a board member of the New Brunswick Asphalt User-Producer Group (NBUPG).

Abstract of Oral Presentations by Students

MECHANICAL PROPERTIES OF FULL-DEPTH RECLAIMED PAVEMENT MATERIALS TREATED WITH HYDRAULIC ROAD BINDERS

Eskedil Melese, Ph.D. Candidate, University of Waterloo

ABSTRACT

Hydraulic road binders (HRB) are factory made blends which are composed of a substantial amount of supplementary cementitious materials and portland cement. Previous studies indicated that the use of chemical stabilizers containing supplementary cementious materials is a sustainable approach that can reduce carbon dioxide (CO_2) emission by 5% - 25%. Thus, the use of HRB in full-depth reclamation process could make the practice more sustainable if strength, stiffness, and durability of treated materials are not compromised. The primary objective of this study is to evaluate the mechanical properties of full-depth reclaimed pavement materials treated with hydraulic road binders. The study was conducted in the form of comparative assessment by using full-depth reclaimed pavement materials treated with General Use (GU) cement as a control mix. For this study, two types of full-depth reclaimed pavement materials and four types of cementitious binders, including GU cement, were used to make eight different types of mixes. Mechanical properties of the eight mixes were assessed using unconfined compressive strength, modulus of elasticity, and indirect tensile strength tests. The test results indicated that hydraulic road binders could provide equivalent strength and stiffness GU cement. The study also revealed that HRB could provide better tensile strength than GU cement. Based on the study findings, hydraulic road binders can be suitable sustainable alternative binders that can replace GU cement in full-depth reclamation process without compromising structural layer quality.

***Keywords*:** Hydraulic road binder, Full-depth reclamation, Mechanical properties, Soil stabilization, Chemically stabilized materials, Hydraulic binder

Laboratory Simulation of the Impact of Solar Radiation and Moisture on Long-Term Age Conditioning of Asphalt Mixes

Yashar Azimi Alamdary*, Sarbjot Singh, and Hassan Baaj
Civil and Environmental Engineering, University of Waterloo, Waterloo, Canada

ABSTRACT

Ageing is a renowned phenomenon for pavement engineers that can substantially affect the durability and long-term performance of flexible pavements. Several factors affect the mechanism of age-related changes, including asphalt cement's chemical composition, mix properties, and environmental conditions. Most of the laboratory accelerated age hardening procedures are trying to simplify conditioning by considering heat as the main affecting factor and neglecting the others, such as humidity, precipitation, and solar radiation. This research aims to examine the validity of such an assumption and evaluate the effect of photo-oxidation, moisture and precipitation on the chemical and rheological properties of the asphalt cement and mix.

In this research, a plant produced asphalt mix was selected and subjected to four different age conditioning procedures including Long-Term Oven Ageing procedure (AASHTO R30), Atlas® Whether-O-Meter™, and using a bespoke chamber by applying dry and wet cycles of solar radiation and water conditioning. After running the Complex Modulus test on unconditioned and conditioned asphalt mix samples, asphalt cement was recovered and subjected to chemical and rheological analysis. The 2S2P1D model was employed to develop Complex Modulus and Phase Angle master curves. Results of this research showed that concerning chemical changes, extended heating at excessively high temperatures would result in different chemical products of oxidation as compared to solar radiation technique in terms of Carbonyl and Sulfoxide Indices. Moreover, it was observed that the extended heating procedure resulted in less stiffening at the low-temperature range in comparison with solar radiation. From the results of this research, it can also be concluded that water plays a vital role in the age conditioning procedure using solar radiation.

Evaluating the Feasibility of Using Lightweight Cellular Concrete as a Subbase Alternative in Pavements

Abimbola Grace Oyeyi, Frank Mi-Way Ni, and Susan Tighe
Civil and Environmental Engineering, University of Waterloo, Waterloo, Canada

ABSTRACT

To mitigate the settlement issue in the road pavement structure and protect the subgrade soil from the damage caused by freeze-thaw cycling, several alternatives have been proposed. One of the options is to replace the conventional subbase granular material with the Lightweight Cellular Concrete (LCC). However, the actual performance of the LCC is yet to be verified. In this research, the goal is to evaluate the performance of the LCC through laboratory and field assessment. Laboratory evaluation involves assessing mechanical, durability and functional properties of 400, 475 and 600 kg/m3 LCC densities, while field evaluation encompasses the construction and instrumentation of a design incorporating the use these LCC densities and the traditional Granular B material used in Canada and assessing comparative performance throughout the life span. Currently, some laboratory testing has been performed and a trial section incorporating 475 kg/m3 and Granular B constructed and instrumented. Laboratory results show that LCC has adequate compressive strength for pavement application for the three densities considered. LCC also exhibits higher stiffness than typical granular B material. Field evaluation shows LCC has good insulation properties with higher temperatures observed within and below the LCC layers compared with the Granular B material in the winter months. In general, the results indicate that LCC has the potential to be considered as an alternative subbase material in road pavements.

Keywords: Lightweight cellular concrete, freeze-thaw, Pavements, Performance.

Effect of RAP source and low production temperatures on mechanical properties of Cold Recycled Mixtures

Simone Raschia, Ph.D. Student ÉTS, e-mail: simone.raschia.1@etsmtl.net
Director: Daniel Perraton (ÉTS), Codirector: Alan Carter (ÉTS) and Andrea Graziani (UNIVPM - Italy)

ABSTRACT

Cold Recycled Mixtures (CRM) 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 CRM 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 CRM material is still not known. Hence, it is reasonable to assume that different RAP aggregates could influence the mechanical properties of the CRM 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).

Impact of the RAP particles size on HMA properties

Saeed Saliani, PhD Student ÉTS, e-mail: saliani.saeed@gmail.com
Director: Alan Carter (ÉTS), Codirector: Hassan Baaj (U. of Waterloo)

ABSTRACT

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 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.

Effect of compaction method on cold recycled asphalt mixtures treated with foamed asphalt

Amir Rahmanbeiki, Master's Student ÉTS, e-mail: amir.rbeiki@gmail.com
Director: Alan Carter (ÉTS), Codirector: Daniel Perraton (ÉTS)

ABSTRACT

In this research, we try to address the main physical characteristics of cold in-place recycled material treated with foamed asphalt. More to the point, we aimed to define the material strength of the specimens of these mixes, which were made through different laboratory compaction and tested with different test methods. Firstly, a single mix design was followed, and also a single curing process (40°C and 55% of humidity for 14 days) during which the water loss was measured. Secondly, three different compaction method, including gyratory compaction, marshal hammer, and proctor rammer, were used. The tests include ITSM, at three different temperatures and 2 different angles for each specimen, and ITSwet and ITSdry. It's been clearly demonstrated that the stiffness is impacted by the temperature, and according to the different nature of the compaction methods, the strength of the specimens varies considerably. It is recommended to evaluate different foam percentage in the mix need to be investigated to cast a light on its' impact on differently compacted specimens.

Updating specifications for unbound granular materials for improved drainability and stiffness

Amin Mneina, University of Manitoba

Abstract

Providing adequate drainage performance to a pavement structure is an important design consideration to prevent premature failures resulting from presence of excess moisture. Recently, transportation agencies have been modifying their base/subbase specifications to provide better drainage performance while maintaining sufficient structural support to produce more sustainable pavement structures. Linking specifications to field performance of granular materials requires accurate characterization of the effect of physical and gradation parameters on drainage and mechanical performance of foundation materials. Constant head hydraulic conductivity, resilient modulus, permanent deformation, double ring infiltrometer, and falling weight deflectometer test methods were used in laboratory and field investigations which were conducted to characterize the drainage performance as well as the mechanical performance of ten UGM samples representing four different gradation bands. Test results show improvements in drainage quality and resilient modulus for samples in gradation bands with larger maximum aggregate size and limited fines. A statistical analysis showed that D_{10} larger than 0.2mm D_{60} larger than 8mm would guarantee high stiffness and drainage performance, (time-to drain<5days, and resilient modulus>200MPa).

Effect of asphalt overlays on load transfer efficiency at transverse joints

Ali Al-Abbasi, University of Manitoba

Abstract

This study reports the results of deflection testing aimed to evaluate the effect of asphalt concrete overlays (ACOs) on measured deflections and void detection. Rehabilitation planning can be improved through timely joint repairs and detecting voids more accurately. Deflection testing was performed on joints prior to and after ACO milling to evaluate its effect on measured deflections and void detection. Deflection correction factors for each load level are recommended to calibrate deflections to account for the presence of ACOs and to improve void detection analysis. Presented recommendations can improve rehabilitation planning by accounting for the contribution of ACOs on slab deflections and void detection analysis, without the need to mill ACOs prior to FWD testing.

Development of design tools for convective mitigation techniques to stabilize embankments built on thaw sensitive permafrost

By Xiangbing Kong, PhD candidate, Laval University

Abstract

About 24% of the exposed land area is underlain by permafrost in the northern hemisphere. Permafrost, as the support foundation of transportation infrastructure, is often ice-rich and designers need to take it into account due to the risk of excessive thaw settlements when permafrost thawing occurs. Both the construction of the transportation infrastructure and on-going climate change disturb the thermal equilibrium of the underlying soils, resulting in permafrost degradation and permafrost-related engineering problems. This affects road users and increase the maintenance cost. To keep the stability of embankment, different mitigation methods have been developed, and several techniques have been proved to be efficient in cooling permafrost underneath embankment. However, little can be found on specific design procedures or guidelines in permafrost conditions.

The goal of this research project is to develop improved engineering tools for the design of convective protection systems, including air convection embankment and heat drain. Thermal models have been built based on specific field sites and they are well calibrated to the measured temperature data. The engineering design charts have been validated using the additional data in Yukon and Nunavik, Canada to improve their robustness and their reliability. The charts have been developed for the conventional embankment, air convection embankment and heat drain.

Development of an analysis tool for the quantification of the effect of super heavy loads on pavements

Erdrick Leandro Pérez-Gonzalez, PhD candidate, *Université Laval*

Abstract

Transport of large shipments exceeding limitations of gross vehicle weight defined by current regulations, known as super-heavy loads (SHL), can benefit the economy and the environment by reducing the costs of road freight transport and allowing the transport of non-divisible cargo. However, the main concerns with the SHL is that there are potentially adverse effects on the performance and condition of road infrastructure. The high load rate at lower speeds, as well as the overlapping of stresses due to the special axles and wheels configuration, cause the validity of traditional models to be questioned. The objective of this project is to formulate an analytical framework to evaluate the effect of super heavy vehicles on flexible pavements. A method based on principles of mechanistic-empirical analysis is being developed as part of this comprehensive research project. Amongst other, the formulation of performance models for rutting and pavement fatigue under the conditions defined by super heavy vehicles is a fundamental part of this research. It is expected that the results of this research will improve the state of knowledge regarding the behaviour of pavements and embankments under special vehicle loads, as well as provide criteria and recommendations that allow better decision making in the analysis of super heavy loads.

Experimental and numerical modeling of tire-soil interaction in off-road conditions

Jesus David Cruz Sanchez, MSc candidate
Bahar Ahou Ghalandari, Postdoctoral fellow
Laval University

Abstract

In off-road conditions, the terrain underneath the operating vehicle undergoes deformations of various magnitude that may result in soil failure due to either a sudden collapse or accumulative permanent deformations. In order to better understand the tire-soil interaction in off-road conditions, sets of experimental simulator tests are performed to simulate the passage of a given wheel on a soil sample with given initial values of dry density and water content. Several sensors are installed in soil body to measure the values of stress and deformation developed in soil. The soil rutting conditions are also measured, using a laser-based system. The results of simulator tests are validated in ABAQUS numerical simulations, where the modified Drucker-Prager Cap model is used as the soil constitutive model. The parameters associated with Drucker-Prager model are obtained performing sets of triaxial tests on samples with the same values of initial dry density and water content as the simulator tests. Four types of soil samples are used in both experimental tests and numerical simulations. A successful numerical modeling of the soil under the passage of wheel will provide a tool for tire producers to evaluate the performance of their products interacting with soil.

Insulating Performance of Foam Glass Aggregate (FGA) in Cold Regions Roads and Highways

Nima Ghafari, Postdoctoral Fellow, Laval University

Abstract

Road construction is considered as one of the most expensive and time-consuming civil engineering projects. Hence, these kinds of infrastructures must be built with a long design life expectancy which requires innovative designs with advanced materials. In cold regions like Canada, some challenges of pavement design are related to the protection against frost action, as well as to mitigate excessive settlements and permafrost degradation. A cooperative research project introduced foam glass aggregate (FGA) as a novel lightweight insulating material to be used in Canadian road projects. Experimental studies including full-scale laboratory and field tests have been conducted to assess the physical, mechanical and thermal characteristics of FGA when used as a lightweight insulating layer. The same experiments have been carried out on the structures containing natural aggregates and extruded polystyrene (XPS) panels as the two reference tests. The results demonstrated that FGA can be considered as a suitable substitute for the XPS, which is the only standardized insulating material currently used in road construction projects in Québec. Moreover, in this study a conceptual design chart has been proposed for Québec region illustrating FGA thickness with respect to frost depth. To develop this design chart, the software "Chaussée2" was utilized to conduct the simulations. The simulation results have been then calibrated using the field data obtained from three consecutive winters between 2015 to 2018.

KEYWORDS: Foam glass aggregates, frost penetration, mechanical stiffness, thermal conductivity, thermal insulation.

Abstract of Poster Presentations by Students

The Effects of Freeze-Thaw Cycles and Deicer Salt on the Durability of Recycled Asphalt Mixtures

Shahab Moeini, MSc., University of New Brunswick

Abstract

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, semicircular 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.

Insulating Performance of Foam Glass Aggregate (FGA) in Cold Regions Roads and Highways

Nima Ghafari, Postdoctoral Fellow, Laval University

Abstract

Road construction is considered as one of the most expensive and time-consuming civil engineering projects. Hence, these kinds of infrastructures must be built with a long design life expectancy which requires innovative designs with advanced materials. In cold regions like Canada, some challenges of pavement design are related to the protection against frost action, as well as to mitigate excessive settlements and permafrost degradation. A cooperative research project introduced foam glass aggregate (FGA) as a novel lightweight insulating material to be used in Canadian road projects. Experimental studies including full-scale laboratory and field tests have been conducted to assess the physical, mechanical and thermal characteristics of FGA when used as a lightweight insulating layer. The same experiments have been carried out on the structures containing natural aggregates and extruded polystyrene (XPS) panels as the two reference tests. The results demonstrated that FGA can be considered as a suitable substitute for the XPS, which is the only standardized insulating material currently used in road construction projects in Québec. Moreover, in this study a conceptual design chart has been proposed for Québec region illustrating FGA thickness with respect to frost depth. To develop this design chart, the software "Chaussée2" was utilized to conduct the simulations. The simulation results have been then calibrated using the field data obtained from three consecutive winters between 2015 to 2018.

KEYWORDS: Foam glass aggregates, frost penetration, mechanical stiffness, thermal conductivity, thermal insulation.

Assessment of the permanent deformation of pavement subgrades using the Light Weight Deflectometer

Mbayang Kandji, MSc candidate, Laval University

Abstract

The accumulation of the permanent deformation at the surface of subgrade soils is one of the main causes of rutting of flexible pavements. This type of deterioration often needs deep and expensive interventions. Permanent deformation of the subgrade soils is usually investigated with repeated loads triaxial tests. However, this test is quite expensive, time-consuming and requires a well-trained staff. Thus, it would be interesting to find a reliable alternative that allows determination of subgrade sensitivity to permanent deformation. The light weight deflectometer (LWD), which is an in-situ device for deflection measurements, could be a good alternative. It also gives the load and deflection history which can be used to define viscoelastic properties such as dissipated energy and phase angle. The objective of this project is the determination of the subgrade soils sensitivity to permanent deformation using the LWD. To that end, some deflection tests were performed on typical subgrade soils from Quebec at various frequencies, vertical stresses and conditions of saturation. The results have been interpreted according to approaches based on a viscoelastic behaviour of the materials. Permanent deformation tests were also performed at lower frequencies, and in the same physical conditions (saturation, applied stress and compaction). The permanent deformation behaviour was modelized using the Burger model. The characteristics of the model were correlated to the viscoelastic properties determined with the LWD.

Development of design tools for convective mitigation techniques to stabilize embankments built on thaw sensitive permafrost

By Xiangbing Kong, PhD candidate, Laval University

Abstract

About 24% of the exposed land area is underlain by permafrost in the northern hemisphere. Permafrost, as the support foundation of transportation infrastructure, is often ice-rich and designers need to take it into account due to the risk of excessive thaw settlements when permafrost thawing occurs. Both the construction of the transportation infrastructure and on-going climate change disturb the thermal equilibrium of the underlying soils, resulting in permafrost degradation and permafrost-related engineering problems. This affects road users and increase the maintenance cost. To keep the stability of embankment, different mitigation methods have been developed, and several techniques have been proved to be efficient in cooling permafrost underneath embankment. However, little can be found on specific design procedures or guidelines in permafrost conditions.

The goal of this research project is to develop improved engineering tools for the design of convective protection systems, including air convection embankment and heat drain. Thermal models have been built based on specific field sites and they are well calibrated to the measured temperature data. The engineering design charts have been validated using the additional data in Yukon and Nunavik, Canada to improve their robustness and their reliability. The charts have been developed for the conventional embankment, air convection embankment and heat drain.

Damage assessment of embankment dams' upper core and freeboard due to heavy vehicles loading upon crest

Charles-Antoine Bordeleau, MSc candidate, Laval University

Abstract

Hydro-Québec (HQ) is a state company responsible for electricity production, transport and distribution in the Quebec province. HQ has many hydro-electrical embankment dams. In the northern part of the province, these structures are often the only link to cross rivers and bodies of water. Because of this, HQ often receives requests from natural resources exploitation industries to allow transit of products and equipment on their earth dams.

These infrastructures were not specifically designed to sustain heavy load passes upon their crest and their effect on the embankment dam's performance needs to be assessed. To do so, strain and stress measurements are collected in the top part of the core and in the freeboard of chosen embankment dams. Resilient and permanent strain responses under load solicitations are recorded. The permanent deformation damage of the top of the core material is assessed and predictions can be made using laboratory triaxial tests. The outcome of the project is to provide HQ administrators with reliable decision tools to allow or decline passage and assess a corresponding damage which is function of the load applied and of the number of passes.

Foam glass aggregates: Thermal properties according to aggregate's general characteristics

Maxime Bradette, MSc candidate, Laval University

Abstract

The freezing and thawing cycles in cold regions create a lot of damages on the road network. Various solutions are available to mitigate this phenomenon, one of them being road insulation. In the meantime, the recycling industry faces challenges with the valorisation of glass, dumping and burying more than 90 000 tons of glass every year in Québec.

Foam glass aggregates, used in the road construction industry in Europe for nearly 50 years, are an insulating material produced by mixing glass residues with a foaming agent. When baked at high temperatures, the glass and the foaming agent react together resulting in a lightweight and insulating material having the potential to reduce the negative effects of frost action and contribute to glass recycling. This research project aims to optimise the foam glass aggregates thermal performance and to improve the understanding of full-scale test results.

In order to better understand the properties of this product for civil engineering applications, a one cubic meter insulated thermal box, filled with foam glass aggregates, is used to simulate different thermal gradients and create several types of heat flow driven by different heat transfer mechanisms, i.e. conduction, convection and radiation. Temperature and heat flux are measured by 48 thermistors and 4 flow meters installed in the box, and equivalent thermal conductivity (conduction and radiation) and intrinsic permeability (convection) are inferred. Varied grain-size distributions are used in the test setup to optimize material performance for seasonal frost or permafrost application.

Cracked asphalt pavement under cyclic loading – an experimental analysis

Youness Berraha, PhD candidate, Laval University

Abstract

Thermal cracking is one of the major modes of pavement degradation in cold regions and probably the most important behavioral problem for pavements built in Quebec. Thermal cracking is an irreversible phenomenon, vector of other localized degradations around the crack such as the loss of bearing capacity or the infiltration of water and de-icing salt.

Although the mechanism of cracking and the factors affecting the occurrence of thermal cracks are already well documented, the influence of this phenomenon on the structural capacity and the freezing behavior of the roadway near the cracks, as well as the consequence for the pavement of these localized effects is still poorly documented and poorly understood. The objective of the project is therefore to improve the state of knowledge regarding the effects of cracking and to develop effective approaches for the mitigation of this degradation.

A pavement structure was built in the experimental pit of Université Laval. The pavement is composed of a reference section and a section in which an idealized crack has been created. The mechanical response of the entire pavement structure has been monitored under different temperature and saturation conditions, with particular interest for the area around the crack. The results are derived from stress and deformation surveys around the crack and these data are compared with those obtained in the reference section.

Mitigation methods against melting permafrost for transportation infrastructure in Nunavik

Maria Fernanda Baron Hernandez, MSc candidate, Laval University

For several years now, climate change has had a major influence on the degradation of permafrost, which has a direct impact on infrastructure stability. To reduce the impact on transport infrastructure, several protection techniques have been developed. These different techniques are based on reducing heat induction under the infrastructure and increasing heat extraction from the embankment. The main objective of this project is to conduct long-term monitoring of the ground thermal behavior of three transportation infrastructure in Nunavik, which were adapted to limit the thawing of permafrost. At the Tasiujaq runway, three mitigation methods, which are the gentle slope, the air convection embankment and the heat drain, were installed in the embankment slope. On the access road to Salluit Airport, the permafrost mitigation method under study is the heat drain. At the Puvirnituq runway, an air convection embankment is monitored as part of this project. By monitoring the long-term thermal behavior of the ground, it can be determined whether the implementation of these methods has been sufficient to mitigate the thawing of permafrost.

Experimental and numerical modeling of tire-soil interaction in off-road conditions

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Abstract

In off-road conditions, the terrain underneath the operating vehicle undergoes deformations of various magnitude that may result in soil failure due to either a sudden collapse or accumulative permanent deformations. In order to better understand the tire-soil interaction in off-road conditions, sets of experimental simulator tests are performed to simulate the passage of a given wheel on a soil sample with given initial values of dry density and water content. Several sensors are installed in soil body to measure the values of stress and deformation developed in soil. The soil rutting conditions are also measured, using a laser-based system. The results of simulator tests are validated in ABAQUS numerical simulations, where the modified Drucker-Prager Cap model is used as the soil constitutive model. The parameters associated with Drucker-Prager model are obtained performing sets of triaxial tests on samples with the same values of initial dry density and water content as the simulator tests. Four types of soil samples are used in both experimental tests and numerical simulations. A successful numerical modeling of the soil under the passage of wheel will provide a tool for tire producers to evaluate the performance of their products interacting with soil.

Preliminary Investigation for Mechanical Degradation of Permafrost Embankment: Inuvik Tuktoyaktuk Highway case study

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Abstract

Roads and highways in cold regions are affected by the settlement of embankments leading to dangerous trafficability issues. There are uncertainties about the understanding of the mechanical behaviour of embankments built on permafrost. The objective of this project is to quantify the relative importance of consolidation, frost heave and long-term creep of the embankment material. Understanding the leading instability mechanism and the deformation of the embankment for different types of soil is helpful in order to develop efficient mitigation strategies, thus, contributing to performance improvement of transportation infrastructure for northern communities in permafrost regions.

In order to assess the influence of soil types on the mechanical degradation processes involved, three experimental sites are studied. The main site is located in continuous permafrost at kilometre 82 of the Inuvik Tuktoyaktuk Highway 10 (ITH) in the Northwest Territories, where vertical and horizontal inclinometers have been installed to monitor and collect data of the movements of the embankment. Investigation also includes temperature recording with thermistor strings to monitor the influence of the embankment on the thermal regime of the ground. Then, ITH data will be compared with data collected at Salluit airport access road (Nunavik, Quebec) and along the Provincial Road (PR) 373, 200 km southeast of Thompson, Manitoba.

Development of an analysis tool for the quantification of the effect of super heavy loads on pavements

Erdrick Leandro Pérez-Gonzalez, PhD candidate, *Université Laval*

Abstract

Transport of large shipments exceeding limitations of gross vehicle weight defined by current regulations, known as super-heavy loads (SHL), can benefit the economy and the environment by reducing the costs of road freight transport and allowing the transport of non-divisible cargo. However, the main concerns with the SHL is that there are potentially adverse effects on the performance and condition of road infrastructure. The high load rate at lower speeds, as well as the overlapping of stresses due to the special axles and wheels configuration, cause the validity of traditional models to be questioned. The objective of this project is to formulate an analytical framework to evaluate the effect of super heavy vehicles on flexible pavements. A method based on principles of mechanistic-empirical analysis is being developed as part of this comprehensive research project. Amongst other, the formulation of performance models for rutting and pavement fatigue under the conditions defined by super heavy vehicles is a fundamental part of this research. It is expected that the results of this research will improve the state of knowledge regarding the behaviour of pavements and embankments under special vehicle loads, as well as provide criteria and recommendations that allow better decision making in the analysis of super heavy loads.

Effect of RAP source and low production temperatures on mechanical properties of Cold Recycled Mixtures

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Abstract

Cold Recycled Mixtures (CRM) 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 CRM 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 CRM material is still not known. Hence, it is reasonable to assume that different RAP aggregates could influence the mechanical properties of the CRM 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).

Development a new method for laboratory evaluation of paving fabrics in asphalt layers

Ehsan Solatiyan**,** PhD Student ÉTS, Director: Alan Carter (ÉTS); Codirector: Nicolas Bueche (BFH - Switzerland)

Abstract

The road network is subjected to traffic loading and environmental incentives that make the surface crack and provide an accessible path for water to reach to the underlying layers. In the presence of water, these layers lose their stiffness which in turn, lead to the decline in structural capacity of the pavement. To ensure the integrity of the pavement, some interlayer materials have been introduced so far to waterproof the pavement system.

This study looks at the PAVEMAX system, which is positioned between a cracked layer and an asphalt overlay. In order to evaluate the waterproofing effect of the PAVEMAX system, it is essential that the permeability of the system after the appearance of cracking is measured and compared with an ordinary structure without PAVEMAX. In this regard, two laboratory tests will be carried out: crack generating tests, and permeability tests. These tests do not follow any standards. Instead they will be performed based on the innovative methods. The goal is a relative comparison of the two structures. Test specimens are fabricated in the laboratory in a standard manner. The result of the study shows that the PAVEMAX system is a very competitive material for reinforcing and waterproofing of the asphaltic layers in terms of delaying the propagation of cracks and keep the system impermeable for water for a long time.

Impact of the RAP particles size on HMA properties

Saeed Saliani. PhD Student ÉTS, Director: Alan Carter (ÉTS); Codirector: Hassan Baaj (U. of Waterloo

Abstract

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 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.

Effect of compaction method on cold recycled asphalt mixtures treated with foamed asphalt

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ABSTRACT

In this research, we try to address the main physical characteristics of cold in-place recycled material treated with foamed asphalt. More to the point, we aimed to define the material strength of the specimens of these mixes, which were made through different laboratory compaction and tested with different test methods. Firstly, a single mix design was followed, and also a single curing process (40°C and 55% of humidity for 14 days) during which the water loss was measured. Secondly, three different compaction method, including gyratory compaction, marshal hammer, and proctor rammer, were used. The tests include ITSM, at three different temperatures and 2 different angles for each specimen, and ITSwet and ITSdry. It's been clearly demonstrated that the stiffness is impacted by the temperature, and according to the different nature of the compaction methods, the strength of the specimens varies considerably. It is recommended to evaluate different foam percentage in the mix need to be investigated to cast a light on its' impact on differently compacted specimens.

Impact of asphalt and filler content on performance of HPAC designed for cold climate

Charles Neyret, Master's Student ÉTS; Director: Daniel Perraton (ÉTS); Codirector: Alan Carter (ÉTS)

Abstract

This research presents a sensibility study of high modulus asphalt concrete (HPAC) formula designed for cold climate. The main objective is to quantify the performance gap between HPAC laboratory formula (LF) and job mix formula (JMF). JMF are produced in the laboratory by changing two main parameters of the LF: the binder content (%b) and the filler content f%: <80 µm). This two-level factorial design of experiments (DOE) is realized to identify the main mix design parameters that influence the engineering proprieties of the mix. The performances of the mixes are evaluated under four different aspects: The rutting sensibility (with LCPC wheel tracker); The low temperature cracking susceptibility (AASHTO TP10-1993 standard); The stiffness of the materials and the fatigue resistance (both under uniaxial traction compression loading on cylindrical specimens). Results show the impact of the filler and binder content on low binder content HPAC the slightly reduce the fatigue resistance but don't seem to have a significant impact on the other parameters in terms of the road structure's lifetime. It also shows the impact of this change in the various biasing effects of the project's tests.

Formulation of a High Modulus Asphalt for Cold Climates and its Incorporation in Mechanistic Empirical Pavement Design Methods

Samuel Proteau-Gervais**,** Master's Student ÉTS; Director: Daniel Perraton (ÉTS)

Abstract

High Modulus Asphalts (EME [Enrobé à Module Élevé] in French) are currently used around the world to accommodate high traffic volume and long-lasting roads and other highly solicited pavements. Mainly inspired by the French knowledge and experience on EME, the goal is to design an EME mix that can be used in cold climates (Québec, Canada and northern USA). To do so, a highly modified bitumen, with a performance grade neighbouring PG88-28, is combined with an optimal aggregate packing (dense and continued). This bitumen and optimized aggregate packing assure that the EME has an excellent behaviour:

- High modulus over a wide range of temperatures (E*)
- Excellent resistance to rutting
- Excellent fatigue resistance (ε6; slope)
- Low fracture temperature for restrained specimens (TSRST)

To justify the plus-value of the EME, the EME needs to induce better performances in pavement structures than usual mixes. A preliminary solution to prove it is the use on mechanistic-empirical (ME) pavement design methods because they utilize the mechanistic properties of the mixes. The French Pavement Design (Alizé – LCPC) and the AASHTOWare Pavement ME Design methods are used to compare the EME to a reference mix. Based on the simulations, the EME is a promising solution to highly solicited pavements.

Evaluation of rehabilitated pavement performance to cracking propagation

Amel Ferjani, PhD Student ÉTS, Director: Alan Carter (ÉTS); Codirector: Michel Vaillancourt (ÉTS)

Abstract

The repetitive loading from traffic and the extreme weather conditions cause the pavement structure failure which requires 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. First, 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. Afterwards, 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 test were used to simulate 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.

Characterization of Cold In-Place Recycled materials at young age using shear wave velocity

Quentin Lecuru, PhD Student ÉTS; Director: Alan Carter (ÉTS); Codirector: Yannic Éthier (ÉTS)

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 behaviour of such materials especially at very early age.

Cold in Place Recycled (CIR) materials treated with emulsion contains a large 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 highlighting 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. aims 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.

Study of the shear stiffness of bituminous mastics incorporating post-consumer glass fillers

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Abstract

This project studies the effect of glass post-consumer (GPC) filler on the shear stiffness of mastic (mixture of bitumen and filler) in the linear viscoelastic domain (LVE). The research project was carried out at the Laboratory of Roads and Bituminous Materials (LCMB) of the École de technologie supérieure (ÉTS) using a new experimental device called annular shear rheometer (ASR). The complex shear modulus G* of bitumen and mastic were measured under various temperature and frequency conditions (from -25 °C to 45 °C and from, 0.3 Hz to 10 Hz). Two glass type fillers (crushed glass and micronized glass) and a reference limestone filler were used to manufacture the PG70-28 based mastics. The complex reinforcing coefficient RM* was used to compare the shear stiffness of GPC mastics with a limestone-based reference mastic. Results indicate that the glass filler effect is important at high temperature and/or low frequency where no significant effects were observed at low temperature and/or high frequency. Moreover, the filler gradation (size and spread of particles size values) and the filler nature seem to have little influence on the viscoelastic properties of mastics. Overall, it was shown that post-consumer glass fillers are suitable for improving mastic shear stiffness in a pavement structure.

DEVELOPMENT OF HIGH MODULUS ASPHALT CONCRETE MIX DESIGN TECHNOLOGY FOR USE ON ONTARIO'S HIGHWAYS

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Abstract

"Enrobé à Module Élevé- (EME)" or High-Modulus Asphalt is a type of asphalt concrete that represents high modulus/stiffness, high durability, superior rutting performance and good fatigue resistance. This type of mix was developed in France in the 1980's. EME is a very good option to be used in lower and upper binder courses in the pavement structure which are subject to the highest levels of tensile and compressive stresses. EME offers several advantages including: reducing the pavement construction cost; improving pavement's structural life; increasing in axle loading capacity without increasing the layer thickness; and environmental benefits (by saving in raw materials).

Despite the excellent performance at higher and intermediate temperatures, traditional EME mixes would be very susceptible to low-temperature cracking which is associated to using very hard grade asphalt binder. This study, funded by the Highway Infrastructure Innovation Funding Program (HIIFP-2015), aims to introduce a new approach to EME mix design that contributes to good performance at high, medium and low temperatures. This could be achieved by using premium aggregate particles with dense structure (high packing density), along with utilizing high quality asphalt binder with precise content in the mix. A performance-based mix design approach is developed for EME mix design in Ontario which is a modified version of Superpave mix design procedure. Compressible Packing Model (CPM) was used for the first time to optimize the packing density of aggregate particles for two categories of mixes (12.5 mm and 19 mm Nominal Maximum Aggregate Size (NMAS)). Three types of modified asphalt binders were also considered: PG 88-28, PG 82-28 and PG 58-28 + modifiers (Elastomer additives). In addition to measuring the compaction ability (compactibility) of the developed mixes, several thermo-mechanical testing methods were designated to be used in this study to evaluate the performance of asphalt mixes at different levels. Results of this study showed that the CPM-obtained gradation limits were within the grading control points of EME mixes recommended by French specification. The asphalt mixes had higher compactibility than the conventional mix, and, EME 19 was more compactible than EME 12.5 although it had less binder content than EME 12.5. Complex modulus test results illustrated that the mixes had high modulus values, and that the values of EME 19 were generally higher than those of EME 12.5. Hamburg wheel track rutting test results showed that both mix types had superior rutting performance. Fatigue performance of developed mixes was assessed using four-point bending beam fatigue test at different strain levels to develop fatigue curves. The test results showed that the minimum strain level to meet 1,000,000 cycles of fatigue life (ε_6) was more than 300 μm/m for all the mixes. Additionally, Thermal Stress Restrained Specimen Test (TSRST) results showed that the cracking temperatures of the developed mixes were less than -25˚C; and that EME 12.5 performed slightly better than EME 19.

High Temperature Properties of Asphalt Binders Modified with Different MWCNTs

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Abstract

Asphalt binder modified with carbon nanotubes has drawn great attention in pavement material design for their ability to enhance the anti-rutting performance, fatigue property and anti-aging capacity of asphalt. However, few studies have focused on the size of these nanotubes on asphalt modification. In this study, three types of multi-walled caborn nanotubes (MWCNTs) with different aspect ratios were used as nanomodifiers. High temperature properties, including high temperature stability and compatibility, viscosity, permanent deformation resistance and rheological properties were investigated for both the neat asphalt and MWCNTs-asphalt. Separation mechanism varies by the length of MWCNTs, the result of this research showed MWCNTs with smaller aspect ratio had lower separation index in separation test, which leads to higher mixing and compaction temperatures for MWCNTs-asphalt binders. Dynamic shear modulus (G^*) and phase angle (δ) were measured by temperature sweep test, MWCNTs-asphalt showed higher G^* value and smaller phase angle, hence larger rutting potential index was obtained, resulting in higher failure temperature. Improvement of permanent deformation resistance and elastic recovery were observed in Multiple Stress Creep Recovery (MSCR) test, MWCNTs are expected to amplify the non-linear viscoelastic behavior of asphalt binder, and this phenomenon is more apparent with the increasing dosage of MWCNTs and larger aspect ratio of MWCNTs.

MECHANICAL PROPERTIES OF FULL-DEPTH RECLAIMED PAVEMENT MATERIALS TREATED WITH HYDRAULIC ROAD BINDERS

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ABSTRACT

Hydraulic road binders (HRB) are factory made blends which are composed of a substantial amount of supplementary cementitious materials and portland cement. Previous studies indicated that the use of chemical stabilizers containing supplementary cementious materials is a sustainable approach that can reduce carbon dioxide (CO_2) emission by 5% - 25%. Thus, the use of HRB in full-depth reclamation process could make the practice more sustainable if strength, stiffness, and durability of treated materials are not compromised. The primary objective of this study is to evaluate the mechanical properties of full-depth reclaimed pavement materials treated with hydraulic road binders. The study was conducted in the form of comparative assessment by using full-depth reclaimed pavement materials treated with General Use (GU) cement as a control mix. For this study, two types of full-depth reclaimed pavement materials and four types of cementitious binders, including GU cement, were used to make eight different types of mixes. Mechanical properties of the eight mixes were assessed using unconfined compressive strength, modulus of elasticity, and indirect tensile strength tests. The test results indicated that hydraulic road binders could provide equivalent strength and stiffness GU cement. The study also revealed that HRB could provide better tensile strength than GU cement. Based on the study findings, hydraulic road binders can be suitable sustainable alternative binders that can replace GU cement in full-depth reclamation process without compromising structural layer quality.

***Keywords*:** Hydraulic road binder, Full-depth reclamation, Mechanical properties, Soil stabilization, Chemically stabilized materials, Hydraulic binder

Laboratory Simulation of the Impact of Solar Radiation and Moisture on Long-Term Age Conditioning of Asphalt Mixes

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ABSTRACT

Ageing is a renowned phenomenon for pavement engineers that can substantially affect the durability and long-term performance of flexible pavements. Several factors affect the mechanism of age-related changes, including asphalt cement's chemical composition, mix properties, and environmental conditions. Most of the laboratory accelerated age hardening procedures are trying to simplify conditioning by considering heat as the main affecting factor and neglecting the others, such as humidity, precipitation, and solar radiation. This research aims to examine the validity of such an assumption and evaluate the effect of photo-oxidation, moisture and precipitation on the chemical and rheological properties of the asphalt cement and mix.

In this research, a plant produced asphalt mix was selected and subjected to four different age conditioning procedures including Long-Term Oven Ageing procedure (AASHTO R30), Atlas® Whether-O-Meter™, and using a bespoke chamber by applying dry and wet cycles of solar radiation and water conditioning. After running the Complex Modulus test on unconditioned and conditioned asphalt mix samples, asphalt cement was recovered and subjected to chemical and rheological analysis. The 2S2P1D model was employed to develop Complex Modulus and Phase Angle master curves. Results of this research showed that concerning chemical changes, extended heating at excessively high temperatures would result in different chemical products of oxidation as compared to solar radiation technique in terms of Carbonyl and Sulfoxide Indices. Moreover, it was observed that the extended heating procedure resulted in less stiffening at the low-temperature range in comparison with solar radiation. From the results of this research, it can also be concluded that water plays a vital role in the age conditioning procedure using solar radiation.

Evaluating the Feasibility of Using Lightweight Cellular Concrete as a Subbase Alternative in Pavements

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ABSTRACT

To mitigate the settlement issue in the road pavement structure and protect the subgrade soil from the damage caused by freeze-thaw cycling, several alternatives have been proposed. One of the options is to replace the conventional subbase granular material with the Lightweight Cellular Concrete (LCC). However, the actual performance of the LCC is yet to be verified. In this research, the goal is to evaluate the performance of the LCC through laboratory and field assessment. Laboratory evaluation involves assessing mechanical, durability and functional properties of 400, 475 and 600 kg/m3 LCC densities, while field evaluation encompasses the construction and instrumentation of a design incorporating the use these LCC densities and the traditional Granular B material used in Canada and assessing comparative performance throughout the life span. Currently, some laboratory testing has been performed and a trial section incorporating 475 kg/m3 and Granular B constructed and instrumented. Laboratory results show that LCC has adequate compressive strength for pavement application for the three densities considered. LCC also exhibits higher stiffness than typical granular B material. Field evaluation shows LCC has good insulation properties with higher temperatures observed within and below the LCC layers compared with the Granular B material in the winter months. In general, the results indicate that LCC has the potential to be considered as an alternative subbase material in road pavements.

Keywords: Lightweight cellular concrete, freeze-thaw, Pavements, Performance.

Hydraulic Road Binder (HRB) and Its Application for Subgrade Stabilization

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Abstract

Chemical stabilizers such as Portland cement and lime have been widely used to improve the engineering performance of road subgrade. The mining and manufacturing of cement clinker contribute to 5–8% of the global man made CO2 emissions. Therefore it is crucial to reduce the use of cement clinker in construction materials. HRB (hydraulic road binder) usually contains high contents of supplementary cementitious materials (SCMs) and by-products and is specialized for the stabilization of road base, subbase, and subgrade layers. HRB has the potential of reducing the amount of cement clinker thereby making it more cost effective and environmentally friendly. HRBs has the potential to reduce the drying shrinkage, sulfate content, the hydration rate in blended systems. Moreover, by replacing clinker by different percentages of SCMs (such as limestone, slag, fly ash, and cement kiln dust), the properties of HRBs vary significantly. Formulated HRBs then have various strength grades meeting different engineering purposes. Some of the HRB mortars have comparable or exceeded strength than OPC mortars after 28 days of curing. When HRBs are mixed with local organic and clayey soils, the strength, stiffness of soils have been significantly increased. Soil's chemical environment has been changed from acidic to alkaline, preventing the organics from growing and enable the sustained progress of hydration and pozzolanic reactions. Consequently, HRB stabilized weak subgrade soils have a continuous increase of strength and stiffness. The HRB improved soils are observed to have higher strength and stiffness than cement treated ones in the same adding ratio, however their actual contents of cement clinker are lower. Stabilizers also change the particle size and microstructure of subgrade soils, such effects can be visualized from the Scanning Electron Microscope (SEM) images. This research contributes to a development of HRB and the application of using HRB for subgrade soil improvement. It also proposes an economic, sustainable and environmentally friendly solution to the construction and maintenance of pavements.

Impact of Cementitious Material Type and Complex Mineralizer on the Compressive Strength of Hempcrete

Rob Aurilio and Michelle Liu, University of Waterloo

Abstract

Hemp hurds possess numerous desirable properties as a building material, including its low density, moderate tensile strength, renewable source, and ability to sequester carbon throughout its cultivation and service life. Previous experiments explored the complete substitution of coarse aggregates with hemp hurds in general-use Portland cement concrete mixes, but extremely low compressive strengths were recorded. In this paper, the substitution of coarse aggregates with hemp hurds is paired with the use of a complex mineralizer and various combinations of general-use Portland cement, general-use Portland-limestone cement, and blast furnace slag. Results indicated that compressive strength values after 28 days of curing are three times higher with the addition of complex mineralizer than without. Of the mixes with complex mineralizer, the combination of general-use Portland cement and blast furnace slag yielded the highest strength at 28 days. Density for the specimen with Portland cement and complex mineralizer was also calculated and compared to a typical Portland cement concrete specimen with coarse aggregates. From this, it was found that the substitution of all coarse aggregates with hemp hurds reduces the density of the concrete by up to 30%.

Investigating solutions for self-healing and crack mitigation of flexible pavements

Haya Almutairi; Supervisor: Professor Hassan Baaj, University of Waterloo

Abstract

Transportation systems have the same importance for society that arteries, veins and nerves for the human body. Canada has a well-developed transportation system consisting of road, rail, water and air networks. However, the road network remains the most important as 90% of all goods are transported using this system. Nationwide, Canada has over one million kilometers of road including over 30,000 km of highway (TAC, 2013). The modern road appeared with the advent of the automobile and has evolved over the years with the evolution of humanity. In recent decades, the road industry has positively changed to meet the needs of sustainable development and cost reduction. Meanwhile, the technological evolution in other transportation-related industries, such as the automotive industry and traffic control systems, has also accelerated. In this context, several international experts have started working on defining the road of the future. This road would be sustainable, resilient, connected, adaptable, self-healing, a source of energy, smart and versatile. The ideas proposed for this research aim to advance our ability to build this road of the future.

In Canada, cracking is one of the most prevalent deterioration modes of pavements. It is caused by traffic loading, low temperature and can be accelerated by oxidation of the asphalt or when the asphalt material performs poorly. Four breakthrough ideas will be investigated in this research program to advance new solutions that will effectively extend the service life of pavements. Some of these innovations are inspired by the human body, specifically its capacity to adapt, evolve and heal itself. Biomimetic research has opened up new avenues of innovation for many industries, namely architecture, transportation, communication and adhesives to name but a few. The proposed research will leverage nature-inspired strategies to create a range of High Performance Asphalt Mixes (HPAM). The use of Self-Healing Materials, Phase-Change Materials and nanotube fibers will be explored to reduce the risk of pavement cracking and help tomorrow's roads heal themselves.

Ultimately, this research aims to contribute to the construction of highly durable, long-lasting pavements in Canada and in the world.

Title: Improving Durability of Asphalt Mixes Produced With Reclaimed Asphalt Pavement (Rap) By Enhancing Binder Blending

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Abstract

In this study, the kinematics of blending of aged and virgin binders were examined by considering the time-temperature effect during mixing and silo-storage, and assess the thermo-mechanical behaviour of Hot Mix Asphalt (HMA) containing RAP at different blending states. The asphalt mixes used in this research were produced and collected at two plants (Plant 1) and (Plant 2) located in Ontario, Canada. These mixes had different percentage of RAP (15%, 20%, 30%, and 40%). To investigate the impact of storage time on the blending progress and achieving a cohesive final binder, the mix samples were collected as a function of storage time in the silo. The first sampling was done immediately after production (t = 0-hour), and then at several time intervals of silo-storage; i.e., at 1, 4, 8, 12, and 24 hours.

The microstructure of the blending zones were examined under The Environmental Scanning Electron Microscope (ESEM). In addition the effect of the silo-storage time on the rheology of the binders was investigated. The results indicate that increasing the interaction time and temperature between the aged and virgin binder significantly results in a better blending.

The performance of RAP-HMA with respect to the silo-storage time was examined using Dynamic Modules Test, Thermal Stress Restrained Specimen Test (TSRST), Rutting Test, and Flexural Beam Fatigue Test. The experimental data indicates that samples collected after 12-hour of silo storage exhibited a reduction in the stiffness due to better blending of aged and virgin binder. In addition, the 12-hour samples showed enhancement in their fracture temperature, rutting depth, and fatigue life, accompanied with a better blending between their aged and virgin binder. Moreover, the MEPDG AASHTOWare was utilized to examine the effect of the 12-hour silo-storage time on the long term performance of the pavements.

The impact of Climate Change on Canadian Airport Pavements

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Abstract

Due to the meaningful quantity of greenhouse gasses (GHG) emitted by the burn of fossil fuels and supplementary anthropogenic activities, the world is becoming congested of these gases which have caused notable changes in the climate and has also been the beginning of what is now a reality called global warming. The whole world is been affected by this situation and Canadian airports are no exception. This research aims to present the changes of climate in different territories and provinces of Canada such as the changes in wind direction and strength, the increment of precipitation, the risk of flooding, the higher temperatures in summer, and the variation of freeze-thaw cycles. In addition, analyze the impact of these changes on the operation and/or performance of the runway, taxi-lane, taxiway, and apron of the airports that belong to the category of national airport systems (NAS); and provide recommended mitigation and adaptation strategies. The methodology of this research consists of first evaluating how is the climate changing for which data obtained from Environment Canada and Meteoblue will be used. Once these evaluations are obtained, they will be used as climate inputs to measure the impact of these on the Canadian Airport Pavement's operation and/or performance. The changes in winds will be measured, and accordingly, adaptation strategies will be proposed. The precipitation analysis will consist of developing moisture susceptibility tests on different airside asphalt mixtures and apron concrete mixtures. In regard to flooding, the main purpose is to use Geographic Information Systems (GIS) software to develop maps of possible future flooding near-airside areas to help decision makers to take mitigation actions. Concerning the temperature, the objective is to describe how these changes impact the different airside pavement structures and which mitigation and adaptation strategies can be implemented considering the changes presented in the first part of the methodology.

Analysis of Double Edge Notched Tension Test and Multiple Stress Creep Recovery Test Ability to Predict HMA Fatigue Performance

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ABSTRACT

The addition of polymers to asphalt binder has allowed for the enhancement of hot mix asphalt (HMA) rutting and fatigue performance. In Ontario, the performance of polymer modified asphalts (PMA) is evaluated by using the Double Edge Notched Tension (DENT) test and Multiple Stress Creep Recovery (MSCR) test. In order to understand whether these performance characteristics correspond to asphalt mixture properties, this paper examined the relationship between HMA fatigue performance, percent recovery and two DENT test properties. Four-point Bending Beam Fatigue (4PB) testing on HMA samples showed that there is a poor correlation between the CTOD and the 4PB properties. Several other DENT test properties have also shown an inability to differentiate various levels of polymer modification. The results have shown that there is a positive correlation between the percent recovery of the asphalt cement and the fatigue properties. The addition of polymer increased the 4PB fatigue life of asphalt mixture, but the magnitude of the increase also depended on the nature of the source binder. This testing has added evidence to the notion that the DENT test may not effectively evaluate the performance of PMAs.

KEYWORDS: Double Edge Notched Tension, Multiple Stress Creep Recovery, Fatigue Performance, Polymer Modified Asphalt

High Performance Asphalt Mixture Applied on Airside Pavement

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Abstract

Flexible pavements are predominantly chosen for runways and taxiways in North American airports. Shear distress, a typical load-induced asphalt pavement failure, has been frequently observed in many airports' runways and taxiways. Pavement maintenance and airline delay cause tremendous economic loss for airport agencies every year. This study intends to evaluate shear resistance of asphalt mixes applied in airport by using Uniaxial Shear Tester, which was proved well correlated with Superpave Shear Test by previous studies. The volumetric parameters of asphalt mix design such as asphalt binder performance grade, gradation, and coarse aggregate angularity will be identified and evaluated in terms of its contribution for shear resistance through laboratory tests and statistical analysis. A high shear strength asphalt mixture applied for airport pavement will be provided at the end of this research.

RESEARCH ON UNIFORMITY DETECTION METHOD OF ASPHALT MIXTURE DURING PAVING PROCESS BASED ON DIGITAL IMAGE TECHNOLOGY

Wei Yu, University of Waterloo

Abstract

Focus on the problem of continuous real-time monitoring of aggregate distribution uniformity during asphalt pavement paving process, an asphalt mixture identification and segmentation method based on image processing technology and a uniformity evaluation method based on static moment theory were proposed. Firstly, the original true color images were converted to binary images. And then the watershed segmentation method based on extended-maxima transform was developed, which could significantly eliminate the over-segmentation of particles. Seventy images of particles were tested, and experimental results showed that the segmentation is satisfactory by the improved algorithm; the accuracy of segmentation is as high as 98%. Considering the influence of aggregate size and distribution position on the uniformity, the computational model based on four-side static moment theory is established, and then the uniformity judging criteria were determined by analyzing 1,000 randomly on-site collected images. The remaining 85 images were used to verify the plausibility of the uniformity judging criterion. The remaining 85 images were used to verify the plausibility of the criterion. The results indicated that when the value of UA is greater than or equal to 0.91, the loose asphalt mixtures can be considered as uniform, vice versa.

Deep Learning based Innovations for Pixelwise Pavement Surface Crack Detection

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Abstract

Automatic crack detection is challenging yet important issue for effective pavement management. Deep Learning techniques can achieve intelligent object detections through learning the hierarchical features of the training images, which have witnessed successful applications recently. Current pavement crack detection methods are less satisfactory regarding efficiency and robustness. Explicit gaps exist between the advanced deep learning technologies and the less satisfied crack detection algorithms. With this consideration, this research sought to bridge this gap via outlining deep neural network model for pixel prefect pavement crack detection. Two state-of-the-art deep neural network models are constructed for semantic segmentation of crack images. The first architecture, VGGCrackU-net is composed of 10 3×3 convolutional layers, 4 max-pooling layers, 4 up-sampling layers and 4 concatenate operations. Another architecture, ResCrackU-net is composed of 7-level residual unites with totally 22 convolutional layers. Pavement crack images are collected by smartphones, action camera and automatic pavement monitoring system from diverse functional classes of pavements. The crack images are manually labeled and double checked by trained operators for quality insurance. After that, 500 crack images are randomly divided into training, validating and test datasets with the ratio of 3:1:1. Both architectures are trained on GPU facilitated Keras platform with Python version of 3.5, which demonstrated fast convergence. Results show that the proposed models exhibit significant advantage for pixelwise crack detection when comparing with the widely used FCN net and PSPnet. Meanwhile, ResCrackU-net slightly outperform VGGCrackU-net, which, however, can provide acceptable results as well. Meanwhile, significant false negative and false positive errors are observed in both methodologies. All in all, the contributions of this research are noticeable, which can provide guidance for other researchers and the authors' future work in figuring out solutions for the problems observed in this research.

Finite Element Modelling of Precast Concrete Inlay Panels (PCIP)

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Abstract

Precast concrete pavement is constructed from prefabricated panels, which are transported to site and placed contiguously. Precast concrete inlay panels (PCIPs) are a unique type of precast pavement, developed to rehabilitate high-volume asphalt highways exhibiting structural rutting issues. The panels are installed by partially milling the existing asphalt, preparing a panel support layer, then inlaying panels into the roadway, and grouting. The PCIPs are expected to be long-lasting, and the panels can be rapidly installed during overnight highway lane closures to minimize construction-related delays.

Precast concrete pavement used for pavement repairs has an expected service life of 20 years or more. To achieve this long-term performance, it is essential to provide a stable and uniform support underneath the panels. Inadequate support can induce stresses in the panels, leading to cracking and premature failure. In 2016, a PCIP trial section was installed on Highway 400 in Ontario, Canada. Three different types of panel support conditions were constructed to evaluate alternatives for providing panel support; they are referred to as asphalt-supported, grade-supported, and grout-supported. The support condition is prepared at the asphalt-panel interface and each type varies in the materials, design, and construction method.

Finite element modelling of the PCIPs is being performed to compare and evaluate the performance of the pavement for the three support conditions. Three-dimensional models of the PCIPs were created using the finite-element program ABAQUS. Axle loading and linear temperature gradients were applied to the pavement, and parametric studies were performed to evaluate the critical stresses in the loaded panel under various conditions. The finite element analysis results can provide insight into the optimal support condition for PCIP and potential improvements for future PCIP installations.