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UNIVERSITY OF WATERLOO

2013 GRADUATE STUDENT POSTER SYMPOSIUM

Hosted by the Centre for Pavement and Transportation Technology (CPATT) and the Norman W. McLeod Chair in Sustainable pavement engineering

Date: Friday October 4, 2013

Time: 12:30– 3:00pm

Location: Engineering 5 (E5) Student Design Centre

Doubra C. Ambaiowei

Student Profile

Thesis: Recycling and Testing of Recycled Asphalt Pavements

Supervisor: Dr. Susan L. Tighe

Current Study: PhD

Abstract

Thermal cracks develop in flexible pavements as a result of the pavement's tendency to contract at extremely low temperatures due to tensile stress induction. This study investigates 14 typical Ontario Superpave hot mix asphalt (HMA) mixtures, encompassing a variety of variables to characterize the low temperature cracking behaviour of dense and gap graded mixtures using the thermal stress restrained specimen test (TSRST) technique. The variables consist of 0, 15, 20 and 40% reclaimed asphalt pavement (RAP), 20% crumb rubber modifiers (CRM) incorporating the wet process (i.e. field and terminal blend), 9.5 mm—12.5 mm nominal maximum sized aggregates, and seven performance graded asphalt cement binders (PGAC). Results of the experimental program conducted on 250 mm x 50 mm x 50 mm asphalt concrete beams with7±1% air voids at 10˚C/hr after 6 hours of conditioning at 5˚C showed new insights on the effects of CRM and high RAP contents on fracture behaviour and low temperature thermal crack susceptibility. The findings supports the need to encourage higher percentages of CRM and RAP in typical Ontario HMA. The use of RAP and CRM in pavements is desirable since it offers economic benefits without compromising the performance of asphalt concrete. From a sustainability perspective, incorporating CRM in HMA will increase the percentage of scrap tires recycled; whereas RAP in HMA reuses the recycled aggregates and old binder, thus reducing the quantity of new materials, energy and cost required to produce asphalt concrete mixtures.

Cheng Zhang

Student Profile

Thesis: A Mechanistic-Empirical Aircraft Landing Distance Prediction Method

Supervisor: Dr. Susan L. Tighe

Current Study: MASc

Abstract

Landing overrun accidents have become a major concern over recent decades regarding airline and airport safety. This project is aimed to study aircraft landing and build on a mechanistic-empirical aircraft landing distance prediction model, which will help airport operators and airlines mitigate the risk of runway overrun. The landing distance prediction method established in this project incorporates a mechanistic-based analysis and an empirical real data calibration. The method includes two portions: deceleration equations and the landing distance model. Deceleration equations are built according to force and moment analysis and calibrated based on digital flight data and weather data. Then, based on the deceleration equations, a landing distance model is established. When building the landing distance model, the following characteristics are considered: pilot settings (TLA, spoiler position, and flap position configuration), aircraft operational characteristics (touchdown speed and weight), the runway friction condition, and aircraft braking system characteristics. A Boeing 737-700 real data case study is done and a comparison is made with the Boeing 737 Quick Reference Handbook reference landing distance. The results indicate the model offers an accurate prediction of aircraft landing distance. In addition, this mechanistic-empirical method has several advantages over previous methods and has the potential opportunity for routine airline safety management to enhance safety.

Colin van Niejenhuis

Student Profile

Thesis: The Behaviour of Corrosion Resistant Reinforcing Alloys in Cracked Concrete Exposed to Deicing Agents

Supervisor: Dr. Carolyn Hansson

Current Study: MASc

Abstract

Deicing-salt induced corrosion of reinforcing steel (rebar) severely limits the durability of highway infrastructure. In order to meet the highway bridge code requirement of service lives of 75-100 years, alternative, more-corrosion resistant alloys are being considered for reinforcement. It is acknowledged that all concrete contains cracks and that the cracks are locations of more rapid corrosion initiation. The American Society for Testing and Materials (ASTM) recognizes this fact in the recommended test procedures for stainless steel rebar (ASTM A955-10), which includes an artificial crack parallel to the bar. However, the "artificial crack" does not represent the "real" situation. In this project, eight corrosion resistant alloys are being evaluated in specimens with either transverse or longitudinal loading cracks. In addition, specimens with both longitudinal and transverse bars are being studied to determine the possibility of crevice corrosion at the intersection of the bars. The concrete mix design complies with the requirements of the Ministry of Transportation Ontario (MTO) for highway bridge decks, with 25% cement replacement by slag and a water to cementitious ratio of 0.4. The goal is to determine the corrosion initiation times in each of these conditions using the electrochemical galvanostatic pulse technique. Together with chloride threshold values determined in a parallel project by Tim Bandura, a life cycle cost analysis will be developed for each of the alloys.

Tim Bandura

Student Profile

Thesis: Comparative Evaluation of the Chloride Threshold Values of Corrosion-Resistant Reinforcing Bars

Supervisor: Dr. Carolyn Hansson

Current Study: MASc

Abstract

Deicing-salt induced corrosion of reinforcing steel severely limits the durability of highway infrastructure. In order to meet the highway bridge code requirement of service lives of 75-100 years alternative, more-corrosion resistant alloys are being considered for reinforcement. In this project, electrochemical testing of the alloys is conducted in synthetic pore solution with incremental addition of magnesium chloride. $MgC1_2$ is selected because it is currently being used in Ontario and is the most aggressive of the deicing salts.

The objective is to evaluate the chloride tolerance of eight different corrosion resistant alloys in comparison to that of the common black steel reinforcement. The alloys consist of two austenitic and three duplex stainless steels, a low chromium micro-constituent alloy and galvanized steel. The advantages of using pore solution are a) that any corrosion activity on the specimen's surface can be seen and b) in contrast to steel embedded in concrete with chlorides diffusing into the concrete, the chloride of the solution in contact with the steel can be controlled and monitored. Hot rolling of stainless steel reinforcement to provide the ribbed surface and appropriate diameter is followed by quenching with water to rapidly cool the steel. If the cooling rate is insufficient, the chromium carbides can precipitate at the grain boundaries resulting in "sensitization". The consequence of sensitization is that the steel is susceptible to corrosion and stress corrosion cracking (SCC). Therefore, metallography and SCC tests have been carried out for all of the stainless steel alloys.

The data obtained will be used by Colin van Niejenhuis together with his measurements of corrosion initiation times of the same alloys embedded in concrete to develop a life cycle cost evaluation for each steel.

James Cameron

Student Profile

Thesis: Engineered Fibre-Reinforced Concrete for use in Bridge Deck Link Slabs

Supervisor: Drs. Jeffrey West and Carolyn Hansson

Current Study: MASc

Abstract

Traditionally when a bridge was constructed with simply supported spans, the installation of some type of expansion joint was required to allow for the expansion or contraction the bridge will undergo. After years of service, these expansion joints typically form a weak spot in the otherwise continuous bridge deck. When expansion joints fail, they allow road salts and other harmful contaminants to leak down from the deck surface onto the lower structure of the bridge and begin to deteriorate it. One solution to this problem is the installation of a fibre-reinforced concrete (FRC) link slab in place of a traditional expansion joint. When a link slab is installed, the bridge deck becomes continuous over the full length while keeping the girders simply supported. To accommodate the movement of the bridge with expansion and contraction as well as normal loading, the link slab needs to be designed to withstand high bending forces without forming large cracks. Engineered cementitious composite (ECC) concretes have recently been used for such link slabs. While these function well, they are costly and the suppliers often keep the materials and mixture design proprietary. In the present project, research was conducted to establish a less costly alternative FRC that could be used to the same effect with fibres commonly reserved for slab on grade and other nonstructural applications.

Ann Sychterz

Student Profile

Thesis: Vibration Characterization and Mitigation of Aluminium Pedestrian Bridges

Supervisor: Drs. Sriram Narasimhan and Scott Walbridge

Current Study: MASc

Abstract

The key reasons motivating the use of aluminium pedestrian bridges are to compare there performance with respect to the CAN/CSA S6-06 Canadian Highway Bridge Design Code design specifications, and to learn more about their dynamic characteristics: natural frequencies, mode shapes, and damping. Aluminium presents as a material of interest due to its high strength to weight ratio and its resistance to corrosion. Current design codes are well characterized for the more conventional building materials, but the breadth is limited for aluminum. Two pedestrian bridges are presented as part of this study: the Daigneault Creek Bridge in Brossard, QC, and the Bota Bota Bridge in Montreal, QC. The first is 44 m long with welded connections and the second is a 14 m modular with bolt-connected extruded sections. A future, full-scale 23 m modular assembly lab specimen will allow for controlled environment and long-term testing. All of these structures are T6061 aluminium pony truss bridges. In order to develop an understanding of these structures, a finite element model was developed for each bridge in order to compare the experimental results to those for the manufacturer drawings. A comparison of the data collected from the accelerometers to the serviceability limits of S6-06 assessed whether the bridges performed within acceptable criteria and if these structures were capable of exceeding these criteria given another loading case. From the merging of these two analyses, a better understanding of the vibrational behaviour of aluminium pedestrian bridges and how this behaviour aligns with current design codes was gained. The results of these dynamic analyses will form the basis for the design of structural vibration control through damping devices.

Magdy Shaheen

Student Profile

Thesis: Predicting Hot Mix Asphalt Rutting using an Innovative Micromechanical Approach

Supervisor: Dr. Susan L. Tighe

Current Study: PhD

Abstract

The objective of this study is to develop a two dimensional (2D) micromechanical Finite Element (FE) model to predict the hot mix asphalt (HMA) rutting. This model was built to simulate the laboratory Hamburg Wheel Rut Tester (HWRT). A realistic geometry was obtained from a processed digital image in order to consider the asphalt heterogeneity and to obtain a relevant failure mechanism. A cylindrical rutting sample was sawn at the middle to capture a cross section image.

The HMA material characterization needed to run this model was obtained by simulating AASHTOWare Pavement ME Design (AASHTOWare). In the AASHTOWare, transfer functions use the dynamic modulus to predict the mix rutting performance, which can be obtained from experimental work in level 1 or predicted by several known models in level 2 and 3. The Witczak model and Hirsch model are among several methods which can be used to predict the HMA dynamic modulus. In this study, the dynamic modulus was obtained through the Hirsch predictive model.

The failure mechanism obtained from the developed model is more realistic and simulates the laboratory test. The FE model results were validated with the laboratory work results. The predicted FE results were in good agreement with the measured values. However, slight differences were observed.

Norman Fong

Student Profile

Thesis: Heat Straightening of Steel Girders

Supervisor: Drs. Scott Walbridge and Robert Gracie

Current Study: MASc

Abstract

Damage to overpassing bridges can commonly occur from corrosion, fatigue, and surprisingly impact. Unlike corrosion and fatigue where damage develops slowly due to environmental and cyclic loading, impact damage due to over-height vehicles is sudden and unpredictable. Remediation of a damaged bridge using heat straightening can be up to five times more cost-effective than a girder replacement.

Using techniques similar to curving steel girders, heat straightening repairs involves the application of cycles of heating and cooling in conjunction with external restraint forces. Heat straightening has been an acknowledged method to repairing impact-damaged steel structures for over 50 years. The application of heat straightening has been limited to technique and experience of technicians. In 1998, a comprehensive guide on heat straightening was established with a scientific basis outlining the procedure and its limitations. Recent research is focused on investigating American steel grades. Insufficient research has been completed for impact damage and heat straightening of Canadian structural steels commonly used in highway bridge construction. The main objective of this study is to investigate the effects of impact damage and heat straightening for girders of Canadian structural steels.

Using Finite Element (FE) models will be a practical approach to answering several questions concerning heat-straightening procedures on Canadian steel grades. Over the last 20 years, FE analysis has become routinely used in modelling forming and impact in the automotive industry; these concepts can be used in modelling impact and heat straightening. Research with respect to strain-rate and temperature dependence of Canadian structure steels is required in order to create relevant FE models.

This poster presents small-scale FE models where heat straightening is applied to a tee-section impacted with a spherical object. The residual stress, strain, and deformation of the FE models were studied before and after heat-straightening.

Marcelo Gonzalez

Student Profile

Thesis: Enhancing the Surface Characteristics of Canadian Concrete Pavements

Supervisor: Dr. Susan L. Tighe

Current Study: PhD

Abstract

Skid resistance or friction plays an important role in transportation safety. According to the National Cooperative Highway Research Program (NCHRP), there are many factors affecting friction of pavements, including microtexture, macrotexture, materials properties and environmental conditions such as temperature, water and snow.

Pavement friction is the result of two primary frictional force components; adhesion and hysteresis. Adhesion is dependent on the microtexture of the surface, while hysteresis depends on its macrotexture. Macrotexture also plays a significant role in preventing hydroplaning because of its impact on the surface drainage characteristic of pavements. Improvements in texture durability of concrete may provide important benefits in delivering long-term friction performance and safety enhancements in wet conditions.

Another concern for pavement engineers is traffic noise, as it has impacts on public health and the local economy. Under accelerating conditions, the tire-pavement noise is dominant at speeds greater than 35-45 km/h for cars and 45-55 km/h for trucks. Although this noise is generated though a variety of mechanisms at the tire-pavement contact patch, it has been recognized that pavement finishing can assist in reducing noise levels.

Previous research on friction and sound production of concrete pavement mostly emphasizes creating different surface textures through macrotexture modifications. In this research, the focus is on investigation of how friction and sound absorption can be improved by modifying the concrete microtexture through nanotechnology and varying surface characteristics through macrotexture modifications.

This poster presents an update of this research, where the results of the material characterization, abrasion response and nanoconcrete and the conceptual features of the next Canadian generation of concrete surface are included.

Xiomara Sanchez

Student Profile

Thesis: Low Temperature Performance of Recycled Hot Mixtures in Ontario

Supervisor: Dr. Susan Tighe

Current Study: PhD

Abstract

The addition of reclaimed asphalt pavement (RAP) in hot mix asphalt (HMA) is a regular practice in Ontario. Nonetheless, uncertainty and concerns about the behaviour of the recycled hot mix (RHM) persists.

Ontario's specification standards permits a maximum use of 20% RAP in surface courses, and recommends using a softer performance grade (PG) binder for HMA mixtures incorporating greater than 20% RAP.

The study examines the response of typical Ontario Superpave 12.5 RHM at a low temperature. Thermal stress restrained specimen tests (TSRST) were conducted on six laboratory prepared recycled hot mixtures with varying RAP contents and asphalt binder PG. The applicability of blending charts to predict the critical low temperature of the respective mixtures were evaluated and compared with results from the TSRST. The findings suggest that blending charts can reasonably predict the lower PG of the resulting blended binder.

Dina Saad

Student Profile

Thesis: Microeconomic Rationale for Infrastructure Spending

Supervisor: Dr. Tarek Hegazy

Current Study: PhD

Abstract

Renewing infrastructure assets has been a tremendous challenge under the prevailing budget constraints on municipalities and public agencies. While many research efforts have been directed towards supporting infrastructure renewal decisions, limited efforts have provided economic reasoning and interpretation behind the current budgeting and fund allocation approaches. Moreover, arriving at optimum decisions that maximize the return on renewal funds has been a huge challenge. This research, therefore, imports theories from microeconomics that explain how consumers optimally spend their limited budget on multiple goods, which is analogous to the situation of a government that has limited budget to spend on a large number of infrastructure rehabilitation needs. Testing microeconomic concepts on two real case studies of 800 building components and 1300 pavement sections proved the applicability of these concepts in the infrastructure problem. Accordingly, a new microeconomic-based decision support framework has been proposed, with two components: (1) a heuristic procedure to optimize infrastructure spending decisions; and (2) a visual approach to analyze the decision sensitivity under different budget levels. In essence, the proposed integration of microeconomics and asset management concepts provides a novel approach in which fair, equitable, and highest value allocation are the underlying rationale that can reach optimum spending decisions for public money.

Amin Hamdi

Student Profile

Thesis: Evaluation of Ontario's Pavement Design Methodology

Supervisor: Dr. Susan L. Tighe

Current Study: PhD

Abstract

Performance modules are a key component to effective pavement management. This paper presents performance models that have been developed using data from the Ministry of Transportation Ontario (MTO) Pavement Management System (PMS2). This study includes analysis of historical data from various sections in the MTO PMS2. The project involved analyzing 870 sections over 17,000 pavement treatment cycles for a 20 year cycle. The research involved development of a robust framework for sorting the extensive data and grouping them into categories that reflect typical pavement factors. Performance models were then calibrated, and validated. In the analysis of the historical data, the data was sorted, classified according to pavement type, traffic volume, and soil type. In the development of the performance curves, 75% of the data was used to calibrate the performance curves, which is described by the predicted pavement condition index (PCI) and as a function of pavement age. The remaining 25% of the data was used to validate the various performance models using various statistical tools.

Finally, this research also provides a framework of evaluation of pavement thickness in Ontario and involves a comparison of the recommendations by other agencies in Canada. It also involves development of expected service lives for various typical pavement treatments under a series of varying conditions in Ontario. This research is important for MTO for validation of existing performance and incorporation for future design and construction strategies.

Yu (Tony) Hong

Student Profile

Thesis: Analysis and Design of Link Slabs in Jointless Bridges with Fibre-Reinforced Concrete

Supervisor: Drs. Jeffrey West and Carolyn Hansson

Current Study: MASc

Abstract

Many transportation agencies in Canada and the United States have explored alternatives to expansion joints in bridges due to high maintenance costs and poor joint durability. One of the alternatives is the use of link slabs in jointless bridges. The link slab is a section of the slab that replaces the expansion joint and connects the adjacent bridge deck slabs, forming a continuous slab across the bridge spans. While the link slab system can provide the benefits of a continuous bridge deck, refinement of the design and detailing of the link slab itself are needed to optimize this bridge deck system and ensure long-term performance. As well, materials with high tensile strain capacity, such as fibre reinforced concrete (FRC), can be explored for potential application in the link slab to improve the strength, durability and cracking characteristics of the link slab.

The focus of this research project funded by the Ministry of Transportation Ontario (MTO) is to investigate the behaviour of link slab bridges using computational structural models, and to explore how the use of FRC may affect the response bridges with link slabs. The research project also includes a parallel laboratory study to develop FRC to obtain the optimum mixture for link slab construction. The FRC material properties from the lab tests are incorporated into the structural model to assess the effect of the FRC properties on the behaviour of link slabs and to predict the forces and moments for link slab design.

The ongoing research will provide a better understanding of the link slab behaviour and allow development of guidelines for the design of link slab bridges, for both new bridges and rehabilitation of existing bridges. As well, this research will allow bridge engineers to confidently implement the link slab concept with FRC in new and existing bridges.

María-José Rodríguez

Student Profile

Thesis: NDT Condition Assessment of Distribution Lines

Supervisor: Drs. Giovanni Cascante and Mahesh Pandey

Current Study: PhD

Abstract

Wood poles are extensively used in North America to support electric transmission and distribution lines. Since wood is a natural material, its properties are affected by environmental conditions. Factors such as temperature, moisture, bacteria or fungi may induce internal decay in the wood; and the existence of decayed areas may result in a reduction of the strength of a pole. In order to avoid sudden failures and to ensure the reliability of the electrical network, it is needed to assess the internal condition of the wood poles. In this project, a new methodology is used based on ultrasonic waves to assess the internal condition of the wood poles. The new methodology relies on two statistical indices: the overall dissimilarity index (ODI) and the condition rating index (CRI). The ODI describes the overall condition of a wood pole in terms of ultrasonic measurements and estimates the deviation with respect to the expected values of a sound pole. CRI is correlated to the expected remaining strength ration and is used to determine the end-of-life (EOL) of an in-service wood pole. The new methodology provides quantitative measurements of the internal condition of wood poles and it allows detecting early decay. It also estimates the strength of the poles, which permits identifying the poles that need to be removed before the occurrence of failures and unexpected outages. Additionally, a simple, cost-effective, and efficient tool to perform the inspections is under development. The use of a reliable ultrasonic testing method for the condition assessment of wood poles presents several advantages. The method is non-invasive and non-destructive; therefore, the mechanical properties of the elements are not affected by the tests. The method also reduces the time required to performance the evaluations and provides a detailed and global assessment of the condition of wood poles.

Sonia Rahman

Student Profile

Thesis: Development of Acceptance Test Methods Related to Performance and Durability of Pervious Concrete

Supervisor: Dr. Susan L. Tighe

Current Study: MASc

Abstract

Pervious concrete is a promising technology which can help to overcome environmental imprints and to establish a "green" world. There are many benefits associated with pervious concrete such as water filtration, absorption of heavy metal, and reduction of pollution. But the most significant aspects which draws the attention of environmental agencies, is its ability to reduce the storm water runoff. Pervious concrete is documented as the paramount in storm water management by the United States Environmental Protection Agency. Though the practice of pervious concrete is recent in Northern cold climates, it has been used in the United States for years. Experience shows that there is no dedicated test method to assess pervious concrete, which is structurally substantially different from conventional concrete pavements. New standards need to be developed to make specifications that are usable in northern climates, where freeze thaw cycling and winter maintenance are major concerns.

The aim of this project is to recommend specification and performance criteria for pervious concrete based on the results of experimental investigation and field experience. Also, this study will suggest practical acceptance test procedures for evaluation of pervious concrete for municipal and provincial applications.

Gulfam Jannat

Student Profile

Thesis: Developing Optimized Pavement (Rigid and Flexible) Maintenance Schedule: Application of Pavement Deterioration Models over the Service Life of Pavements

Supervisor: Dr. Susan L. Tighe

Current Study: PhD

Abstract

Pavement maintenance and rehabilitation are the most critical and expensive components of infrastructure asset management. Rapidly increasing heavy traffic, climate change, and limited resources for maintenance accelerate pavement deterioration and increase the need for more maintenance than in the past. As a result, pavement management programs are turning progressively more complex. For this reason, highway agencies are currently facing major challenges in implementing conventional pavement management programs.

The complexities are attributed to sketching the realistic time based distress prediction and predicting optimized maintenance schedules. Efficient road maintenance programmes can be developed by accurate predictions of pavement deterioration and service life. So, the main objective of this study is to develop methods for accurate predictions of pavement deterioration and service life. The study will focus on how deterioration differs for pavements that receive regular maintenance over the service life versus those that do not receive maintenance. This will help with identifying optimum maintenance schedules and accurate service life.

Andrew Northmore

Student Profile

Thesis: Sustainability of Solar Road Panels as Transportation Infrastructure

Supervisor: Dr. Susan L. Tighe

Current Study: MASc

Abstract

With sustainability becoming the leading goal of infrastructure design practice, innovative technologies such as solar road panels are being considered as replacements to modern infrastructure. Solar road panels are solar modules that have been designed to also act as transportation infrastructure; making use of the available solar energy on concrete and asphalt surfaces to generate electricity. While these panels are currently proof-of-concepts, this paper evaluates their sustainability benefits through economic, environmental, and societal analysis to determine their feasibility.

Thorough analysis finds that while the near-term sustainability of solar road panels is hampered by lifecycle economics, they have the potential in the medium– to long-term to become a sustainable aspect of pavement infrastructure. The high greenhouse gas emissions from initially building the panels are easily offset in most regions from generating cleaner electricity, making them lower emitters than conventional pavements. The social acceptance is promising as governments and society are both open to innovative and sustainable ideas, though community level acceptance will require careful panel design.

To make solar road panels a sustainable part of transportation infrastructure, the cost of the panels need to be competitive to conventional materials. This can be achieved through innovative material selection, panel design, and manufacturing processes. Further work should involve testing different prototype panels to understand long-term maintenance and installation requirements.

Dan Pickel

Student Profile

Thesis: Assessing Internal Curing Benefits of Pre-Soaked Recycled Concrete Aggregate on Variably Cured Concrete

Supervisor: Drs. Susan L. Tighe and Jeffrey West

Current Study: MASc

Abstract

Coarse recycled concrete aggregate (RCA) is a variable material, and that variability can often make it less desirable for usage in concrete infrastructure. One consistent characteristic of RCA; however, is a higher absorptive capacity when compared with natural aggregate. Due to this higher absorptivity, there is potential for the RCA to provide some internal curing-like benefits when it is properly prepared prior to batching into concrete. Internal curing involves the entrainment of water in reservoirs within the concrete which is drawn from the reservoirs at the beneficial point of the cement hydration process. Internal curing in concrete has been found to have many benefits including reducing the negative effects of poor external curing.

In this research, two types of saturated coarse RCA have been used to study the effects of varying RCA saturation levels on the performance of the concrete. The RCA saturation levels considered include 0%, 60%, and 100%, while the effective water-cement ratio of the mixtures are kept constant. The two RCA types include a low and a high quality type, as specified by a classification framework previously developed at the University of Waterloo.

Within the research, particular emphasis has been placed on studying the effects on those concrete properties that are critical for concrete pavement design, such as compressive and tensile strength, modulus of elasticity, thermal expansion, and permeable porosity. Two curing regimes are also studied in order to better understand the impact of different curing practices on saturated RCA concretes.