2016 TRB Annual Meeting
Papers Related to Maintenance

Contents

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Repair and Rehabilitation Techniques

Pavement

Development of Performance-Based and Cost-Effective Rehabilitation Strategies for High-Traffic-Volume Flexible Pavement

Paper number 16-3018, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/742-1.2819911/16-3018-1.2817975/16-3018-1.2819913

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Abstract: A well-planned rehabilitation approach helps agencies to optimize the allocation of annual investment in pavement rehabilitation programs. A wide range of variables impacts the process of selecting the appropriate maintenance activities. Currently, many agencies are struggling with the selection of an optimal time-based and cost-effective rehabilitation strategy to address the long-term

needs of a pavement. The focus of this study is to conduct a comprehensive evaluation of a series of high traffic volume flexible pavements and develop a performance based rehabilitation strategy for selecting a long lasting and cost-effective solution. Therefore, a mechanistic-empirical methodology is employed to obtain an estimate of the performance of potential rehabilitation treatments and their extended service life. Three levels of rehabilitation activities including light, medium and heavy are considered for pavement family groups selected from eight field divisions in a state highway agency. For this purpose, a combination of local material properties, structural integrity and environmental condition are used for structural analysis and to develop an assessment output matrix for the seven pavement family groups identified in the highway system. The output matrix can be used as a supplemental tool to help the decision makers in the highway agency. At the end of this study a series of time-based renewal solutions are developed based on the results of pavement analysis for pavement family groups with similar existing condition. The results of this investigation are combined with the findings of life cycle cost analysis to determine the appropriate timing and cost effectiveness of the developed methodology.

Development of Performance-Based and Cost-Effective Rehabilitation Strategies for High-Traffic-Volume Flexible Pavement

Paper number 16-3018, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/742-1.2819911/16-3018-1.2817975/16-3018-1.2819913

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Accelerated Pavement Testing Evaluation of Interface Bond of Hot-Mix Asphalt Overlays

Paper number 16-4142, http://amonline.trb.org/trb60693-2016-1.2807374/t021-1.2817906/490-1.2818236/16-4142-1.2818240/16-4142-1.2818241

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Abstract: Construction of hot-mix asphalt overlay involves spraying tack coat onto the existing pavement surface in order to obtain a good bond between pavement layers and to ensure that they behave monolithically. Insufficient tack coat application has been linked to premature cracking failure of asphalt

pavement overlays. The Kansas Department of Transportation (KDOT) routinely uses SS-1hP tack for new construction and rehabilitation of pavements. However, KDOT also allows Emulsion Bonding Liquid (EBL) in spray pavers, thereby preventing truck and/or paver tires from picking up the tack material. In this study, accelerated pavement testing of asphalt overlay sections was conducted in order to compare the bond strength of tack materials. An existing asphalt pavement was milled, and six overlay test sections were paved for two tack materials (SS-1hP and EBL) with three tack rates for each material. Repetitive loads were applied using an 80-kN (18-kip) single-axle load until cracking. In addition, in-situ pull-off and laboratory pull off tests were conducted on cores from the test sections. Sections with EBL demonstrated higher interface bond strength than those with SS-1hP. The optimum tack rate for EBL was 0.362 l/m^2 (0.08 gallon/yd^2). SS-1hP sections failed to achieve minimum interface bond strength required by KDOT, and performed poorly in rutting. Cracks observed on the test sections were confirmed to be top-down cracking.

Laboratory Investigation on Performances of Basalt Fiber Reinforced Asphalt Chip Seal
Paper number 16-2657, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/621-1.2819997/16-2657-1.2818193/16-2657-1.2820001

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Abstract: This study aims to investigate performances and usability of basalt fiber additive used in asphalt chip seal, a wearing course applied as preventive maintenance strategy. The proportion ranges of basalt fiber and asphalt binder for the chip seal were first determined by empirical methods, and the specimens of basalt fiber asphalt chip seal (BFACS) at various contents of modified emulsified asphalt (EA) and basalt fiber (BF) were prepared. They were submitted for a series of tests, including plate impact test, sweeping test, pull-out test and direct shear test, to inspect the bond performances. The initial optimal contents of EA and BF were determined as 1.8 kg/m^2 and 70 g/m^2, respectively. This study then analyzed the performances of BFACS in terms of low temperature anti-cracking, interlayer bond and skid resistance. Specimens at different bitumen contents (1.4, 1.6, 1.8, 2.0, 2.2 kg/m^2), fiber contents (0[control], 50, 70, 90, 110 g/m^2) and fiber lengths (30, 70, 110 mm) were fabricated to quantify the individual impact. Results suggest the ultimate optimal BFACS design consists of 1.8 kg/m^2 EA and 70 g/m^2 BF at a length of 70 mm. The basalt fiber was demonstrated to enhance the performances of asphalt chip seal mixture compared to the control samples (0% BF), where the tensile strength, and the shear strength and the surface texture depth (the optimal content) were increased by 29.2%, 51.6%, 14.2%, respectively.

Field Study of Surface Characteristics of Chip Seal and Asphalt Concrete with Various Underlying Structures
Paper number 16-5868, http://amonline.trb.org/trb60693-2016-1.2807374/t004-1.2822737/641-1.2822828/16-5868-1.2818184/16-5868-1.2822829

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Abstract: The increased interest in pavement preservation and lower-cost rehabilitation alternatives has resulted in increased implementation of chip seal treatment. The pavement with a chip seal treatment has distinguished surface characteristics compared to asphalt concrete (AC) surface. Such differences can result in different road functional performances, such as friction, noise generation, tire wear, and fuel economy, which influence passengers' safety, level of comfort, and user costs. The surface characteristics of chip seals and bitumen surfaces have been studied extensively. However, little research has focused on the influences of the pavement structure and base treatment method on the surface layer functional

characteristics. This paper investigates the different surface behavior of chip seals and AC surfaces. The surface characteristics are evaluated using friction coefficient, mean texture depth (MTD), and international roughness index (IRI). A dynamic friction tester (DFT) was used to measure the friction coefficients; and the IRI was estimated with a smartphone-based roughness measurement system. The surface characterization tests were performed for ten test sections on a low-volume full-depth asphalt road in Iowa. The test sections include five chip seal sections and five AC surfaced sections with varying pavement structures. Some sections contain a recycled base layer treated with cold in-place recycling (CIR) or full-depth reclamation (FDR). This paper focuses on the influences of surface type, pavement structure, and traffic on road surface characteristics. The findings suggest pavement structure affects the influence of traffic on pavement surface behaviors of both chip seals and asphalt concrete. Chip seals showed comparable surface performance in terms of skid resistance and roughness. However, the chip seal layer applied directly on a full-depth reclamation base was found suffering from loss of the macro-texture.

Effectiveness of Crack Relief Techniques to Mitigate Reflective Cracking in Asphalt Overlaid Concrete Pavement

Paper number 16-1601, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/742-1.2819911/16-1609-1.2817976/16-1609-1.2819915

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Abstract: This study focused primarily on evaluating the effectiveness of five crack relief treatments to mitigate reflective cracking of asphalt overlaid concrete pavement including 0.5 inch Superpave 9.5 mm Nominal Maximum Aggregate Size (NMAS) structural course (SP-9.5), 1.5 inch SP-12.5, 2.5 inch SP-12.5, 1.0 inch Open-Graded Crack Relief (OGCR), and 0.5 inch Asphalt Rubber Membrane Interlayer (ARMI). Pavement performance was evaluated in terms of deflection, ride quality, rutting and cracking. Also, an evaluation of cracking performance based on the dissipated energy concept using Falling Weight Deflectometer (FWD) load-deflection time history data was presented. The results indicated that 0.5 inch SP-9.5, 1.5 inch SP-12.5, and 2.5 inch SP-12.5 treatments show relatively greater potential for reflective crack mitigation efficiency than the 1 inch OGCR or 0.5 inch ARMI. More reflective transverse cracks corresponding to the Portland Cement Concrete (PCC) base slab joints occurred in areas with thinner Asphalt Concrete (AC) overlay and were most predominant in the 0.5 inch ARMI section. Areas with more transverse cracks had relatively greater dissipated energy indicating a higher potential for pavement deterioration and/or damage rate. Therefore, the dissipated energy approach can be used as a reliable indicator of pavement cracking performance. Thinner AC overlay may reduce the reflective cracking mitigation potential of crack relief layers.

Bridges

Research on Cracking Mechanism and Repair Techniques of Epoxy Asphalt on Steel Bridge Deck Pavement

Paper number 16-3539, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/ahd40-1.2819863/16-3539-1.2817912/16-3539-1.2819866

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Abstract: Epoxy asphalt concrete has been one of the predominant paving materials for long-span steel bridge deck in China. Due to heavy traffic load and extreme climatic conditions, epoxy asphalt deck pavement tends to develop cracks, debonding and even potholes, and needs reconstructing typically after 5–10 years. In this study, the cracking mechanism is explored by considering both traffic load and thermal load. The performances of crack sealing materials including workability, mechanical property and durability are evaluated. Test methods such as simplified penetration ability test, bending fatigue test and so on are employed for rating the crack sealing materials. Experimental results reveal that the traditional crack sealing materials such as SBS modified bitumen, rubber bitumen, bitumen emulsion and solvent bitumen cannot meet the requirements for repairing epoxy asphalt on long-span bridge deck because of the low penetration ability and low adhesive strength. Results show that cracks can be well repaired using epoxy resin sealing materials, which showed great penetration ability, high bond strength, large deformation capacity and short curing time.

Field Investigation of In-Service Performance of Concrete Bridge Decks in Pennsylvania

Paper number 16-5581, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/811-1.2823032/16-5581-1.2812790/16-5581-1.2823033

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Abstract: The results of an expert survey and field investigation of early-age bridge deck cracking in the Commonwealth of Pennsylvania is summarized in this paper. The goal was to use field data to identify factors that contribute to, or reduce, early-age cracking in concrete bridge decks and to assess the effect of cracks on long-term durability performance of bridge decks. First, a survey of 71 PennDOT personnel was conducted to collect and document their experience with early-age cracking and its relation to longterm deck performance. Next, inspection data from 203 bridge decks were collected and analyzed to evaluate the effect of concrete mixture proportions and properties, construction methods, and rebar type on the propensity to experience early-age deck cracking. The inspections included 40 older bridge decks plus initial (post construction) inspection data for 163 new bridge decks that was received from PennDOT. The results suggest that limiting the total cementitious materials content (e.g., to 620 pcy) and the maximum compressive strength (e.g., to 5000 psi at 28 days) is advisable to reduce deck cracking. In addition, epoxy-coated rebar showed good corrosion resistance even in cracked concrete.

Introducing Two Sensing Schemes for Bridge Scour Monitoring
Paper number 16-2188, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/416-1.2823165/16-2188-1.2815504/16-2188-1.2823168

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Abstract: Scour monitoring, as part of bridge maintenance, can prevent scour-induced damage and failure of overwater bridges. Results from laboratory flume experiments aimed at evaluating two scour sensing schemes are presented. First, in-house piezoelectric sensing rods were driven into the soil surrounding a mock bridge pier. As the scour hole extended, the exposed length of the sensor changed, causing the flow-induced voltage signal to also vary. Scour depth at the sensor location was determined based on the fact that the natural frequency of the cantilevered sensing rod is inversely related to its length. The second sensing system utilized commercially available miniature dissolved oxygen (DO) probes. DO levels acquired from sensors installed at multiple depths along the buried length of the pier were used to obtain discrete measurements of the maximum scour depth. The measured DO increased to water DO levels once scour exposed the sensing tip of the probes to flowing water. The sensing concepts behind both scour monitoring schemes were confirmed through comparing the detected and observed scour depths. The PVDF-based sensors are designed to provide continuous scour depth measurements, as opposed to discrete ones offered by the DO sensing system. Following separate analyses of the results, future research was suggested for the two sensing techniques to gain a better understanding of their advantages, shortcomings, and potential applications.

Toward a 100 Year Bridge Coating System: Bridge Topcoats in Japan
Paper number 16-0712, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/416-1.2823165/16-0712-1.2813314/16-0712-1.2823169

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Abstract: Fluoropolymers have been used as topcoats for bridges in Japan for more than 30 years. Based on extensive laboratory testing and long term results from the field, these materials are now required as topcoats on all bridges in Japan. Properly applied, fluorinated topcoats can increase coating system life to more than 60 years, with a goal of 100 years of topcoat life. These fluoropolymer topcoats offer substantial reductions in life cycle costs compared to conventional coating systems. This paper will discuss test results from both field and laboratory studies demonstrating the long term durability of fluorinated topcoats. Surface preparation and coating application methods used in Japan will be reviewed. Finally, the life cycle cost advantages of fluorinated topcoats will be shown.

Management of Bridges under Aging Mechanisms and Extreme Events: Risk-Based Approach
Paper number 16-5930, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/327-1.2823212/16-5930-1.2820100/16-5930-1.2823216

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Abstract: Current bridge management systems predict the condition state of bridge elements primarily based on the extent of continuous structural deterioration. While the existing systems deliver a range of capabilities for the management of bridges under normal operational conditions, they lack in taking into account the consequences of sudden extreme events in a systematic way. Considering the uncertainties involved in natural and manmade hazards further to the ones associated with environmental exposure conditions, there is a critical need to develop risk-based approaches that not only take into account the site-specific aging mechanisms and extreme events at the same time, but also accommodate the spatial and temporal randomness originated from them. Towards this goal, the current study introduces a risk-based life cycle cost analysis framework that can be properly implemented in the current bridge management systems used by the transportation agencies. To demonstrate the capabilities of this framework, a set of representative bridges exposed to environmental stressors and seismic hazard risk are

investigated. The condition states of the bridges are predicted based on Markovian transition matrices that are generated for both aging mechanisms and seismic events. The outcome of this study highlights how the developed framework can contribute to improve the life-cycle performance and cost predictions, especially when the adverse effects of extreme events cannot be neglected in the management of bridges.

Guardrails

Development of a Web-Based Program for Assessing Guardrail Damages and Determining if Repair is Warranted

Paper number 16-2707, http://amonline.trb.org/trb60693-2016-1.2807374/t006-1.2821566/561-1.2821694/16-2707-1.2815063/16-2707-1.2821695

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Abstract: A web application was developed for determining whether or not in-service w-beam guardrail with existing damage would still function as intended. Continuing the research presented in NCHRP Report 656, NCHRP Project 22-28 explored the effects of combinations of different types of damage on the performance of in-service strong-post guardrail systems and end anchorage. Free to use, this web application is a new tool available to the public for the purpose of determining if a damaged section is of high priority for repair. The web application automatically determines what components of a damaged system, if any, need to be replaced in order for the system to continue to function properly. It notifies the user on-screen at the end of the evaluation, as well as sends an email to a specified address and stores all results in a database. This software package can be used in its current online form, or the software package can be used directly on individual users' own internet site using HTML, PHP, and MySQL for user privacy. This paper is a description of what the user experiences, as well as an explanation of how the web application works.

Inspection and Condition Assessment

Pavement

Initial Classification Algorithm for Pavement Distress Images Using Features Fusion of Texture and Shape

Paper number 16-2518, http://amonline.trb.org/trb60693-2016-1.2807374/t005-1.2821934/443-1.2822367/16-2518-1.2818275/16-2518-1.2822377

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Abstract: After 40 years' development, Automated Pavement Condition Survey (APCS) system has made great improvement on image acquisition, but has encountered bottlenecks on automatic pavement image recognition algorithms. Low efficiency and poor robustness of the conventional algorithms hinder wide-spread applications of APCS. In this paper, a novel two-staged pavement image processing framework is presented. The pavement images are classified into four general categories in the first stage, so that the images can be processed using category-specific algorithms in the 2nd stage. The four categories include: 1) Distress-free pavement, 2) Pothole-type distress, 3) Cracking-type distress, and 4) Patching-type distress. The focus of this paper is on the initial classification algorithm. The proposed algorithm first fuses a local contrast enhanced image with a global grayscale corrected image to obtain an enhanced

distressed pavement image. The enhanced image is then decomposed with a three-layer wavelet transform to obtain three texture features of the entire image including High-Amplitude Wavelet Coefficient Percentage (HAWCP), the High-Frequency Energy Percentage (HFEP), and the Standard Deviation (STD). In the meantime, an improved P-tile method is used to obtain the binary image. From the binary image, three additional shape features are extracted including the Average Area of all Connected Components (AA), the Area of the Maximum Connected Component (AM), and the Equivalent Length of the longest Connected Component (EL). Finally, a BP neural network is used to fuse both the texture and shape features sequentially to achieve the initial classification. Experimental results show that for the four types of pavement images, the proposed algorithm achieves an effective classification of the pavement distress image with the accuracy rates of 96.5%, 91.4%, 95.2% and 98.1% respectively, which are higher than those of the classification algorithm with a single-type feature.

Comparison of Supervised Classification Techniques for Vision-Based Pavement Crack Detection
Paper number 16-6526, http://amonline.trb.org/trb60693-2016-1.2807374/t005-1.2821934/382-1.2822423/16-6526-1.2813367/16-6526-1.2822424

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Abstract: Application of four classification algorithms including Artificial Neural Network (ANN), Decision Tree (DT), k-Nearest Neighbours (kNN) and Adaptive Neuro-Fuzzy Inference System (ANFIS) for computer vision-based pavement crack detection systems is investigated in this study. Classification methods are evaluated for: 1) prediction performance, 2) computation time, 3) stability of results for highly imbalanced datasets, 4) stability of the classifiers performance for pavements in different deterioration stages, and 5) interpretability of results and clarity of the procedure. Based on the results, ANN and ANFIS methods not only provide superior performance but also are more flexible and compatible for the crack detection application. But ANFIS 'white-box' classifier and the inferred knowledge from its membership functions can be used to characterize the imagery properties of detected image components.

Seed Based Approach for Automated Crack Detection from Pavement Images
Paper number 16-4415, http://amonline.trb.org/trb60693-2016-1.2807374/t021-1.2817906/271-1.2818379/16-4415-1.2818380/16-4415-1.2818381

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Abstract: An accurate and reliable pavement crack detection system plays an important role in evaluating pavement condition and providing needed information for decision making for pavement maintenance and rehabilitation. Among the existing crack detection methods, the seed-based image segmentation method has been proven to be fast and efficient for automated crack detection. However, its performance is not stable under varying conditions. In this paper, we proposed an extended and optimized seed-based crack detection method after an extensive review of the current practices. The proposed method included two main steps. In the first step, pavement images were pre-processed. Lane-marking was masked to be non-crack area and non-uniform background of the images was corrected. In the second step, crack seeds were detected through Grid Cell Analysis, and then connected through a Euclidean Minimum Spanning Tree (EMST) construction. In addition, undesirable small objects, such as minimal branches and noises, were removed by a path length based removing method. The proposed algorithm was evaluated using 105 pavement images collected with the Texas DOT VCrack system. The experiment results showed that the proposed method could accurately and efficiently detect cracks in the images.

Analysis of Pavement Raveling Using a Smart Phone

Paper number 16-6155, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/213-1.2820140/16-6155-1.2818427/16-6155-1.2820141

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Abstract: Raveling is a common mode of failure in open graded asphalt mixtures. The Florida Department of Transportation (FDOT) Districts 4 and 6, located in southeastern Florida, have experienced a disproportionate amount of premature raveling with Open Graded Friction Course mixes (OGFC) compared to the other districts in Florida. To determine why this amount of raveling is occurring, the research team devised a data collection tool for smart phone and developed software to measure the raveling area and its location and severity in the video images by using smart phone GPS capability. The data used in this study was extracted from different FDOT database systems, such as the Laboratory Information Management System (LIMS) and the Electronic Data Management System (EDMS), as well as from the National Oceanic and Atmospheric Administration (NOAA). Some projects were surveyed by the research team, and numerical raveling statistics were developed and compared with qualitative raveling ratings provided by FDOT. Good correlation was found between the two, and the comparison was used to establish thresholds of good performance. Such thresholds can be used to develop performance specifications or warranty benchmarks. The relative effects of mix design, construction, and environmental factors were also studied. Project level of analysis was conducted. Several hypotheses were evaluated to determine the cause of premature raveling. Data analysis results indicate significant correlations between raveling and ambient temperature, mix temperature, mix spread rate, and gradation. In light of this study, recommendations were made to enhance the longevity of the FC-5 mixtures.

Pothole Detection Based on the Features of Intensity and Motion

Paper number 16-4615, http://amonline.trb.org/trb60693-2016-1.2807374/t005-1.2821934/443-1.2822367/16-4615-1.2813751/16-4615-1.2822369

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Abstract: Damage to road surfaces in the form of cracks and potholes increases over time, and is compounded by poor maintenance systems. Potholes in particular can cause serious problems, such as flat tires, damaged wheels, and car accidents. In our previous study, we developed a pothole detection algorithm that used features of two-dimensional images to accurately detect potholes. However, it yielded wrong detection in the case of similar objects, such as patches, stains, and shades. In particular, complicated shapes and random variations of similar objects led to misdetection. In this study, we propose a pothole detection algorithm that uses motion and intensity of features to accurately distinguish potholes from similar objects. The motion feature is the source of primary information in the proposed algorithm, and provides clear and noise-tolerant data for the extraction of potholes from the background region. The proposed algorithm consists of two steps of segmentation and decision, and is much simpler than our previous method. Experimental results show that our algorithm outperforms prevalent pothole detection algorithms as well as our previous one.

Bridges

Critical Review of the Current Inspection and Maintenance Practices for Concrete Bridges
Paper number 16-2488, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/326-1.2823225/16-2488-1.2820105/16-2488-1.2823230

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Abstract: A concrete bridge would cost less to maintain and safely serves its full design service life, if not longer, when deterioration mechanisms are prevented or controlled. The current inspection practice gives a good assessment of the condition rating of the bridge elements based on their physical conditions. If followed by proper maintenance measures, it is likely that the bridge would serve its full design service life. However, preventive maintenance actions could be used more efficiently before the formation of any physical deterioration, which could only be determined through proper assessment of the chemical condition of the bridge elements. Therefore, chemical Nondestructive Evaluation should be utilized more widely as bases for inspection and assessment of bridge condition. A chemical Nondestructive Evaluation followed by an active preventive maintenance scheme may prevent deterioration mechanism from starting, or at least slows it down at a very early stage. This paper presents a critical constructive review of the current inspection and maintenance manuals by various transportation agencies. As a result, more active chemical Nondestructive Tests (NDT) are recommended for routine inspections to evaluate the chemical conditions of the concrete bridge elements, based on which a more precise numerical deterioration model could be derived. The NDT results could also be used to evaluate the effectiveness of maintenance measures, and guides the future maintenance work. Cost-effective preventive maintenance measures could be selected and scheduled systematically which may leads to an optimal life-cycle cost throughout the service life of the concrete bridge.

Quality Function Deployment Based Method for Condition Assessment of Concrete Bridges
Paper number 16-4431, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/501-1.2823135/16-4431-1.2820059/16-4431-1.2823139

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Abstract: Bridge condition assessment is essential step in bridge management. To ensure safety and serviceability of bridge infrastructure, accurate condition rating methods are needed to provide basis for bridge Maintenance, Repair and Replacement (MR&R) decisions. In Canada and the United States, visual inspection and close-up observation are the common practice to detect surface defects and external flaws. Non-Destructive Testing (NDT) and evaluation technologies are used during visual inspection to reveal subsurface defects. It is paramount to develop systematic methods to capture inspection data and to produce robust condition rating and MR&R decisions. The current research reviews current practice in bridge condition assessment and discusses the main deteriorations and defects identified during visual inspection and NDT and evaluation. Further, the research discusses limitations of available bridge condition assessment models and introduces the Quality Function Deployment (QFD) theory as a novel approach to the area of bridge management. The principles of the QFD theory are demonstrated with a real case study and the potential of using the approach in the area of bridge condition assessment is discussed. Different defects correlations are measured based on an expert's opinion and are included in the developed QFD method. Wasserman's normalization technique is embedded in the method to take into account interdependency between the different defects. The QFD method recommendations are compared to other condition assessment methods and validated against twenty bridge projects which were assessed by bridge inspection teams. The validation showed consistent results between inspection teams' assessments and the QFD method recommendations.

Migration of Element-Level Inspection Data for Bridge Management System
Paper number 16-2050, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/327-1.2823212/16-2050-1.2820102/16-2050-1.2823224

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Abstract: In the United States, the Pontis software system, developed by the American Association of State Highway and Transportation Officials (AASHTO), has been the primary system used by State Departments of Transportation (DOTs) for bridge management. The system facilitates collection of element-level condition data and management of bridge inventories. The newly released AASHTOWare Bridge Management Software (BrM) system will replace the Pontis system and will have improved capabilities. Along with the new system, AASHTO has revised the element-level inspection guidelines to improve bridge management by providing greater inspection detail. To facilitate the adoption of the new BrM system, AASHTO provides a program, termed the "Migrator", to convert inspection data from the Pontis elements to the new AASHTO BrM elements and definitions. The Migrator is a general rules-based program developed to convert condition state quantities and element coding. This research investigates the Migrator rules for element data by comparing the Pontis definitions to the new AASHTOWare BrM definitions for select elements in the State of Virginia. Data migration was performed for elements in each major bridge component; superstructure, substructure and deck. Modified migration rules were developed to improve agreement of condition state definitions. Additionally, deterioration models for these elements were developed with the migrated data and were compared to deterioration models developed using current Pontis data as well as migrated data using the AASHTO Migrator. This research found the Migrator is adequate for concrete elements but modifications to the migration rules produced more useful results and more consistent deterioration models for deck and other elements.

Automating Visual Image Analysis of GPR Profiles for Reinforced Concrete Bridges
Paper number 16-5898, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/327-1.2823212/16-5898-1.2814302/16-5898-1.2823218

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Abstract: Inspection and repair maintenance or replacement of bridges at regular intervals of time is essential for long term safety and sustainability of bridge infrastructure. Visual Inspection method has been commonly used by transportation agencies for condition assessment of bridges but it has not proved to be totally reliable because of its inability to detect internal defects. Various Nondestructive Evaluation (NDE) Techniques for different types of bridges have been proposed but Ground Penetrating Radar (GPR) method has been extensively used and is preferred due to its distinct advantages of identifying major subsurface detects in a short interval of time with few limitations. However, interpretation of data obtained from the GPR profiles have been ambiguous due to lack of correlation of its results with the actual bridge condition. The commonly utilized numerical analysis approach of evaluating data yield inconclusive results as it does not encompass several factors like reinforcing bar depth, surface anomalies, reinforcement bar spacing and others into consideration. A novel approach based on visual image analysis identified in the literature involves an experienced analyst reading through GPR profiles and marking attenuated areas all along the GPR profile while considering structural anomalies and other several parameters, which are generally ignored in numerical analysis. Thus, such a holistic method can prove to be very efficient in decision making regarding replacement or repair of bridge elements. The shortcomings of the visual image analysis of GPR profiles include: subjectivity of analyst interpretation leading to differing results obtained by different experts; and to manually profile through all data profiles by the analyst is time consuming and prone to error. This research aims to overcome these limitations by automating the visual image approach using MATLAB® image processing tools. A condition rating algorithm of GPR profiles is developed in a sequential step-by-step procedure to incorporate defects and

anomalies like corrosion, expansion joints, concrete cut & repair and presence of structural member. An 'X-ray' type image is developed based on texture segmentation and is found to be most useful in identifying corrosion through scaling it into color zones according to the severity of condition. The algorithm is further modified to incorporate other anomalies. A corrosion map can be generated for the complete bridge element by systematically combining all GPR data pro-files. However, the authors wish to further improve this algorithm by considering all remaining major defects and anomalies. The results obtained will be unique and more reliable in nature, and can be efficient in making informed decisions regarding repair and rehabilitation of concrete bridges.

Performance Assessment of Corroded Highway Bridge Piers under Cyclic Loading
Paper number 16-5904, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/416-1.2823165/16-5904-1.2820080/16-5904-1.2823166

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Abstract: The corrosion of reinforcement in reinforced concrete (RC) bridge piers adversely affects the capacity and serviceability of bridges, causing increasing vulnerability to failure due to multiple hazards. This paper evaluates the performance of RC piers with different levels of corrosion under cyclic loading using a finite element model. The model is capable of taking into account all the degrading effects of corrosion, such as reduction of cross sectional area of steel, reduction of strength and ductility of steel, degradation of material property of concrete, as well as bond deterioration. First the finite element model results are compared to and validated by a precious set of experimental results. Then two RC columns with different corrosion levels have been simulated and their response under cyclic loading similar to those in the experimental tests have been studied. The details of the hysteretic loops, as well as concrete crushing and cover cracking of the corroded columns are provided. The results indicate the proposed model is capable of simulating the cyclic behavior of corroded RC bridge piers with accuracy, efficiency and full details.

Signals and Signs

Field Study of Ohio's Structural Support Inspection Program for Overhead Signs, Traffic Signals and High Mast Lights
Paper number 16-1245, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/357-1.2823185/16-1245-1.2813405/16-1245-1.2823192

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Abstract: The Ohio Department of Transportation (ODOT) undertook a field study to evaluate their overall structural inspection programs for overhead sign supports (including those mounted on bridges), high mast light supports and traffic signal supports. This paper describes ODOT's current support inspection program, the field study performed and the recommendations that resulted from the field study. This research evaluated the adequacy and frequency of the current structural support inspection program for the studied supports. To assess the current program, a detailed, hands-on inspection was conducted on 202 supports. These results were then compared to the current ODOT ground based, visual inspection process. The hands-on inspection process found almost 87% more deficiencies; some deficiencies detected during the hands-on inspections could not have been observed from the ground. Additionally, it was noted that the different inspection procedures used by each district often produced inspection reports that varied in the amount of information and level of details collected during inspection.

Recommendations were made to address the inventory process and inspection procedures for each type of support; a long-term goal should be to establish the current structural adequacy of every support in the ODOT inventory at the time of inspection.

Program Management

Asset Management

Integrated Optimization Framework for Road Asset Management Decision Making Considering Travel Delay

Paper number 16-0196, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/299-1.2823262/16-0196-1.2819350/16-0196-1.2823263

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Abstract: This paper examines the limitations of current asset management practice, such as monitoring assets and undertaking maintenance treatments at a slower pace than intervention needs are being created. Furthermore, approaches for overcoming the use of inflexible protocol based techniques that yield inefficient solutions are analysed and the potential for utilizing traffic monitoring and management at a network level is assessed. An integrated analysis framework is proposed that connects asset deterioration to traffic assignment, incorporating the impact of user disruptions. The framework integrates the two models and associates asset management performance with traffic and asset monitoring, asset maintenance planning and traffic management. A linear optimisation model is developed based on the integrated approach and is applied to a simple network case study to quantitatively illustrate the network level assessment of maintenance and travel delay costs. The comparative analysis stresses the benefits of the integrated approach over maintenance cost minimisation techniques.

Using Data Envelopment Analysis Method to Identify Characteristics of Parameters in Maintenance of Transportation Infrastructure Assets

Paper number 16-6793, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/561-1.2820036/16-6793-1.2820037/16-6793-1.2820038

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Abstract: An essential part in performance-based maintenance for transportation infrastructure assets is well-informed resource allocation process and sound investment strategy in prioritizing maintenance activities and operations. Periodical maintenance cycle commonly used by state transportation agencies includes resource allocation and distribution, actual maintenance work, and condition assessment at the end of the cycle that affects how subsequent maintenance cycle is planned. Maintenance efficiency is defined as a representation of the technical efficiency of this maintenance cycle. Data Envelopment Analysis (DEA) method is often used in a wide variety of fields to compare work efficiency of multiple decision-making units. In transportation infrastructure maintenance, this method is mostly used to compare efficiency of decision-making units within a specific jurisdictional area. This study used DEA in a decentralized fashion and focuses on a single decision-making unit, and compares its own efficiencies each year throughout a seven-year period. This decentralized analysis allows us to understand more about individual decision-making units and to uncover tendencies and identify characteristics of the maintenance parameters, which are helpful in planning for subsequent maintenance cycle. Case studies were performed using sensitivity analysis technique. This was done by gradually varying the values of known maintenance parameters and run them as DEA models. Findings from the case studies are a wealth of information regarding maintenance parameters of a particular decision-making unit. These will help

maintenance administrators evaluate the efficiencies of prior work, plan subsequent maintenance period, and possibly establish efficiency guideline to prepare for future, specific situations.

Personnel and Training

Development of a Regional Workforce Needs Profile: Results and Guidance from the Northeast and Southwest Regional Transportation Workforce Centers

Paper number 16-1456, http://amonline.trb.org/trb60693-2016-1.2807374/t008-1.2821210/543-1.2821241/16-1456-1.2816372/16-1456-1.2821249

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Abstract: Workforce issues in the Transportation Industry seldom take center stage in front of the many crises stemming from failed infrastructure and unsustainable financing mechanisms. The recent establishment, by FHWA, of five regional surface transportation workforce centers has provided the impetus to facilitate a deep and comprehensive look at the workforce picture and needs related to attracting, retaining, and upskilling the workforce that is needed to design, build, maintain, and operate the nation's transportation systems. The purpose of this paper is to describe the three-phase method employed by two of those Centers (NE and SW) and to compare and contrast initial workforce demand findings. The paper concludes with lessons learned and provides practical guidance for the other entities seeking to conduct similar research projects, such as professional associations, State DOTs, and transit, air, rail, or maritime systems.

Systemwide Data Collection and Performance Measurement

A Hybrid Modeling Approach for Quantifying Maintenance and Rehabilitation Treatment Effectiveness of Asphalt Pavements

Paper number 16-2868, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/807-1.2819889/16-2868-1.2817944/16-2868-1.2819893

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Abstract: Analysis tools in pavement management systems are critical to assist transportation agencies in developing the most adequate maintenance and rehabilitation program. A key aspect in the treatment selection process is to evaluate the effectiveness of maintenance and rehabilitation alternative treatments. Treatment effectiveness is related to the time of the application and should be measured in the short and long-term. Short-term treatment effectiveness measures include condition improvement and reduction of the deterioration rate; while long-term treatment effectiveness is related to its ability to extend the pavement remaining life. In this paper, a hybrid modelling approach is presented to integrate expert knowledge with pavement performance data for quantifying short-term and long-term treatment effectiveness. Optimal times to apply asphalt treatments were obtained as a result of the hybrid modeling approach. The Texas Department of Transportation (TxDOT) has successfully incorporated these results to enhance its Pavement Management Information System (PMIS). PMIS is used as a tool to assist TxDOT decision-makers to formulate maintenance and rehabilitation programs.

Using Data Envelopment Analysis Method to Identify Characteristics of Parameters in Maintenance of Transportation Infrastructure Assets

Paper number 16-6793, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/561-1.2820036/16-6793-1.2820037/16-6793-1.2820038

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Abstract: An essential part in performance-based maintenance for transportation infrastructure assets is well-informed resource allocation process and sound investment strategy in prioritizing maintenance activities and operations. Periodical maintenance cycle commonly used by state transportation agencies includes resource allocation and distribution, actual maintenance work, and condition assessment at the end of the cycle that affects how subsequent maintenance cycle is planned. Maintenance efficiency is defined as a representation of the technical efficiency of this maintenance cycle. Data Envelopment Analysis (DEA) method is often used in a wide variety of fields to compare work efficiency of multiple decision-making units. In transportation infrastructure maintenance, this method is mostly used to compare efficiency of decision-making units within a specific jurisdictional area. This study used DEA in a decentralized fashion and focuses on a single decision-making unit, and compares its own efficiencies each year throughout a seven-year period. This decentralized analysis allows us to understand more about individual decision-making units and to uncover tendencies and identify characteristics of the maintenance parameters, which are helpful in planning for subsequent maintenance cycle. Case studies were performed using sensitivity analysis technique. This was done by gradually varying the values of known maintenance parameters and run them as DEA models. Findings from the case studies are a wealth of information regarding maintenance parameters of a particular decision-making unit. These will help maintenance administrators evaluate the efficiencies of prior work, plan subsequent maintenance period, and possibly establish efficiency guideline to prepare for future, specific situations.

Pavement Management Systems: Opportunities to Improve the Current Frameworks

Paper number 16-2940, http://amonline.trb.org/trb60693-2016-1.2807374/t006-1.2821566/afd10-1.2821578/16-2940-1.2817918/16-2940-1.2821579

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Abstract: Pavement management systems have emerged as an effective tool for allocating resources for the maintenance and rehabilitation of pavement networks. The goal of this paper is to benchmark the existing literature in order to facilitate a better understanding of the opportunities to augment the current frameworks while remaining consistent with the aims of the Moving Ahead for Progress in the 21st Century (MAP-21) Act. Key themes that emerge include the need to (a) consider sources of uncertainty beyond pavement deterioration (b) preserve and utilize multi-attribute condition information in a more efficient manner and (c) reach a consensus on the objective functions of relevance. Addressing these three areas, in the opinion of the authors, will place the pavement management community in a better position to maintain existing assets in the face of limited resources and an uncertain future. The authors demonstrate the need to incorporate uncertainty for a larger range of inputs than currently implemented by developing a case study that evaluates the implications of uncertainty in future costs. Two methodologies are used; the first transforms stochastic uncertainty into a deterministic constraint, while the second is a locally optimal algorithm that makes the best decision at each time step as uncertainty evolves. Results suggest that (a) cost uncertainty has implications on the optimal maintenance strategy and (b) allowing decisions to evolve over time can lead to improved performance compared to finding the globally optimal decision at once.

Use of Pavement Management System Data to Enhance Pavement Performance Specifications in Canada

Paper number 16-4816, http://amonline.trb.org/trb60693-2016-1.2807374/t004-1.2822737/248-1.2822932/16-4816-1.2813554/16-4816-1.2822933

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Abstract: Presently, most agency materials and construction specifications for pavement rehabilitation and construction activities provide little or no linkage between quality assurance methods and the in-service performance of the treatment. The Ministry of Transportation of Ontario (MTO) is moving to develop and implement performance specifications to bridge this gap. MTO defines performance specifications as specifications that describe how the finished product should perform over time. This paper will describe how MTO used historical pavement management system (PMS) data to assess performance sensitivity, create historical performance distributions, and use these distributions to set acceptance criteria including payment adjustment for performance.

RoadLab: Revamping Road Condition and Road Safety Monitoring by Crowdsourcing with Smartphone App

Paper number 16-2116, http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/213-1.2823623/16-2116-1.2818428/16-2116-1.2823624

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Abstract: Road agencies constantly face the challenge of developing cost-effective asset management strategies with limited resources and only a modest understanding of road infrastructure conditions from road users' perspective. This paper described a pilot project that allows the determination of user-focused road condition indicators and road safety concerns by developing a road user oriented smartphone based app - RoadLab and extracting information from big data collected through drivers and other road users. This crowdsourcing-based approach provides wider coverage of road networks at frequent intervals and collects uniform data to support strategic and network level asset management decision making. This approach also promotes citizen engagement in decision making and enhances government accountability by enabling road agencies to promptly respond to collectively identified problems. This initiative is undertaken in conjunction with the expansion and development of the Traffic and Road Safety Coordination Center in Belarus, which the World Bank is providing technical assistance under the Transit Corridor Improvement Project. As one of the first that develops a mobile app in collaboration with a national road management agency and integrates their direct inputs into the product development, the RoadLab app and data management server developed through this pilot project is practical for practitioners - the innovative approach of applying empirical Bayes methods to update existing road roughness values presented in this paper demonstrated that big data collected from this smartphone app prove to be valuable inputs for road asset management.

Road Anomaly Detection and Classification Using Smartphones and Artificial Neural Networks

Paper number 16-3384, http://amonline.trb.org/trb60693-2016-1.2807374/t005-1.2821934/443-1.2822367/16-3384-1.2818271/16-3384-1.2822372

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Abstract: The study presented herein explores the use of data, collected by sensors from smartphones and from automobiles' on-board diagnostic (OBD-II) devices while vehicles are in movement, for the detection of roadway anomalies. The smartphone-based data collection is complimented with artificial neural network techniques for classifying detected roadway anomalies. Thirty-one factors are used for the detection (subsequently reduced to eleven, without loss of accuracy). The proposed method and system

architecture are checked against three types of roadway anomalies, and validated against hundreds of roadway runs (relating to several thousands of data points) with above 90% accuracy rate. The study's results confirm the value of smartphone sensors in the low-cost (and eventually crow-sourced) detection of roadway anomalies.

Quantitative Risk Assessment for Performance-Based Pavement Management Systems
Paper number 16-3890, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/713-1.2819961/16-3890-1.2816930/16-3890-1.2819964

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Abstract: Inaccuracies in pavement management system (PMS) input data can pose significant risks to the outputs of network-level PMSs. This paper quantitatively assesses these risks on two modern PMSs: Quebec and Virginia Departments of Transportation. This study shows that errors in key performance indexes and unit costs, and also bias in performance models can significantly distort network-level PMS outputs. This study also shows that this distortion persists during the planning period. This study provides insights into the consequences of different magnitudes and types of error in PMS input data. The results can be used to identify data categories and error types and magnitudes that pose the greatest risk on PMS outputs accuracy. Additionally, the results can help pavement management agencies to establish quality acceptance criteria for PMS input data based on an agency's risk tolerance.

Contracting and Outsourcing

Effective Risk Management Strategies in Construction and Maintenance Indefinite Delivery/Indefinite Quantity Contracts
Paper number 16-6287, http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/555-1.2823502/16-6287-1.2822842/16-6287-1.2823503

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Abstract: Indefinite Delivery/Indefinite Quantity (IDIQ) contracting has been used by state departments of transportation for decades under a wide variety of names: job order contracts, push-button contracts, on-call contracts, master contracts, stand-by contracts, and the list goes on. The common factor that makes each of these procurement methods to be generically classified as IDIQ agreements is their use of a single procurement transaction to advertise, evaluate, and award a contract that provides the capacity to execute multiple projects for a quantity of services or products that is not known at the time the contract is signed. The higher level of uncertainty resulting from the "indefinite" nature of this contracting methodology brings the need for a set of risk management practices that are somewhat different than those used in traditional procurement approaches because of the multiple, repetitive nature of IDIQ. This paper presents a two-part framework for IDIQ contract risk analysis. The framework suggests the use of several risk management strategies during the planning phase (first part) and monitoring/control phase (second part) of the risk analysis process. This study is the result of a formal content analysis of IDIQ procurement documents, policy and procedure manuals from public agencies and the careful examination of survey responses from different types of contract participants.

Performance-Based Maintenance Contract: Woodrow Wilson Bridge Case Study
Paper number 16-2151, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/500-1.2823142/16-2151-1.2820062/16-2151-1.2823143

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Abstract: Woodrow Wilson Bridge Turnkey Asset Maintenance Services contract is perceived as an example of outstanding maintenance outcomes and positive collaboration between two transportation

agencies. Virginia Department of Transportation Central Office Maintenance Division wishes to conduct a case study to learn more about the project in order to identify best practices and lessons learned applicable to other maintenance contracts. The study team has proposed a case study research approach to collect evidence from multiple sources in order to understand the variables and events present in the project. Additionally, the study team has conducted a peer review to identify common denominators among other successful performance-based maintenance projects in the United States. The following report presents the evidence and the conclusions of the case study.

Maintenance Planning and Prioritization

Enhancement of Integrated Prioritization Method Using Urgency Scale

Paper number 16-6154, http://amonline.trb.org/trb60693-2016-1.2807374/t003-1.2822982/327-1.2823212/16-6154-1.2820099/16-6154-1.2823214

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Abstract: An accurate prioritization method is necessary to maximize the effects of rehabilitation within a limited budget. Bridge facilities generally have different functional, economic, social, and environmental impacts. Therefore, the prioritization methods to plan bridge management needs have evolved into the consideration of multiple attributes from the worst-condition-first approach. The prioritization methods addressing the multiple attributes of a network of facilities generally develop an integrated prioritization scale. However, the integrated prioritization scale measures the physical condition of an individual bridge facility as a part of multiple attributes. It is possible for the prioritization methods to delay an individual bridge in physically urgent condition to later fiscal years, at which time its further deteriorated condition may exceed the parameters for rehabilitation. Therefore, there is a need to handle the undesirable circumstance in a decision-making process for bridge management. This paper proposes an enhanced integrated prioritization approach to minimize the potential problems in the existing prioritization methods using an urgency scale of rehabilitation projects while pursuing the current study trends. The urgency scale is the severity level of the physical condition of an individual facility for rehabilitation. It is calculated by estimating the acceptable time frame within which a rehabilitation project can be delayed until the physical condition of the facility goes beyond the minimum threshold for rehabilitation. The proposed prioritization method is applied to a concrete bridge deck network as a case study. The proposed method's results are discussed in comparison with the results of other commonly used prioritization methods.

Prioritization of Georgia State Highway System

Paper number 16-3019, http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/500-1.2823534/16-3019-1.2814174/16-3019-1.2823535

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Abstract: The Georgia Department of Transportation's (GDOT) State Highway System consists of a diverse mixture of roadways including multi-lane Interstates, business spurs, and two-lane, rural roads. The State Highway System should ensure a well-connected network of high quality roads that comply with Georgia State Code and Federal law requirements. GDOT undertook an assessment of the State's 18,000 centerline miles using Geospatial Information System (GIS) technology to determine criteria to evaluate State Routes and prioritize the State Routes. Prioritization criteria were determined in an internal workshop with additional input from members of GDOT management. Four categories of State Routes were established: *Critical, High, Medium,* and *Low*. GDOT implemented the results of this GIS research to effectively allocate maintenance funding, and ensure a high level of service and quality on Critical and High Priority routes. GDOT will focus its resources on the components of the transportation system that are most important to Georgia's economy, specifically, those that serve a significant role in freight

movement, intrastate travel, tourism, and business travel.

Resilience

The Arizona DOT Resilience Pilot Program—Framework Identification, Partnerships, Climate Data Downscaling, and Drone Capabilities

Paper number 16-5436, http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/744-1.2823455/16-5436-1.2820173/16-5436-1.2823456

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Abstract: The Arizona Department of Transportation (ADOT) manages 30,000 maintenance lane miles, 4,750 bridges, and one international border, all spread over 114,000 square miles. The agency and its assets need to function from sea level to 6,000 feet and withstand temperatures from below 0°F to over 120°F. ADOT's mission to provide a safe, efficient, cost effective transportation system can be compromised from the effects of heat extremes, dust storms, wildfires, flooding, landslides, rockfall incidents, and slope failures. In order to cope with the ever-growing cost of these threats, ADOT set out to develop a pilot resilience program that could incorporate existing planning, design, construction, operations, and maintenance criteria, identify a strategic and systematic framework, take advantage of available technologies, tools, and partnerships, build upon their 2014 *Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona* and the 2015 *Extreme Weather Vulnerability Assessment Final Report*, and contribute to the national conversation surrounding these topics. Since ADOT has had a long history considering the balance between predictable asset deterioration curves and the unknown, erratic, and abrupt incidents of flood, overtopping, system hotspots, hydraulic-related failure, and extreme weather impacts, these topics were identified to make up the core of the pilot program. The following paper discusses three framework components of ADOT's Resilience Pilot Program - stormwater, extreme weather, and handling scientifically-informed climate data downscaling as it relates to transportation systems. Moreover, the paper represents the partnerships undertaken to further evidence-based decision making, the opportunities from next generation ground based LiDAR (Light Detection and Ranging) and drone-based photogrammetry services, and data collection platforms that can advance magnitude of peak flow engineering efforts.

Case Study for Integrating FHWA's Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) Throughout the Illinois Tollway's System Planning and Operations and Maintenance Programs

Paper number 16-3431, http://amonline.trb.org/trb60693-2016-1.2807374/t017-1.2819856/532-1.2820050/16-3431-1.2814138/16-3431-1.2820051

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Abstract: The project lifecycle includes three phases: System Planning, Project Development and Operations and Maintenance. Thoughtfully and programmatically incorporating sustainable practices throughout each of these phases allows an agency to take advantage of complementary sustainable benefits that improve the overall sustainability of an agency's transportation program, in essence, the total sustainability benefit equals more than the sum of its parts. The Illinois Tollway (Tollway) is an industry leader in sustainability and is one of the first agencies to implement a sustainability tool to promote sustainability throughout all of these phases on their 286-mile system of toll roads and bridges throughout Northern Illinois. The Tollway selected FHWA's Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) and moved forward integrating its use throughout each of these phases in order to measure and drive the continual sustainable performance to which they are committed. This paper focuses on the implementation of the System Planning and Operations and Maintenance Programs. The Tollway

developed an implementation plan for INVEST and has completed the first year of the plan including coordination with the local metropolitan planning organization, the execution of baseline and current year evaluations, and identification of opportunities to improve. Results show remarkable improvements in the sustainability of projects over time and provide key information to program managers to improve specific areas of sustainability. These results provide: 1) specific areas for improvement, 2) target goals for sustainability achievement, 3) key information to educate program teams, and 3) data for stakeholders to demonstrate advances being made in sustainability.

Operationalizing Sustainable Transportation: Arizona Department of Transportation Approach
Paper number 16-2945, http://amonline.trb.org/trb60693-2016-1.2807374/t001-1.2823436/532-1.2823519/16-2945-1.2816384/16-2945-1.2823521

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Abstract: Though many states and local public agencies are encouraging and implementing sustainability plans or efforts, integration of an entire sustainable transportation program inside a state Department of Transportation (DOT) can be a particularly complex undertaking. Traditional planning, design, and construction dynamics, where any given discipline is focused solely on their respective area of expertise, is not always conducive to adopting and/or integrating a collaborative sustainability process. Amongst these challenges, developing a state DOT sustainable transportation program from the ground up, that encompasses an agency wide approach including administration, project planning, design, construction, and systems operations and maintenance, is a particularly daunting effort. Developing a process to operationalize such a far reaching sustainable transportation program that properly reflects these new and novel economic, social, and environmental considerations and maintains executive management buy-in, was experimental at the state DOT level. The Arizona Department of Transportation (ADOT) presented their initial experience with sustainability tools and process identification at the 2015 Transportation Research Board Annual Meeting. Since that time, ADOT has made measurable inroads in understanding the sustainability playing field as it encompasses transportation systems, has begun completing the initial program framework, and initiated subsequent operationalization of these activities. This paper presents how ADOT piloted this process.