TECHSUMMARY December 2021

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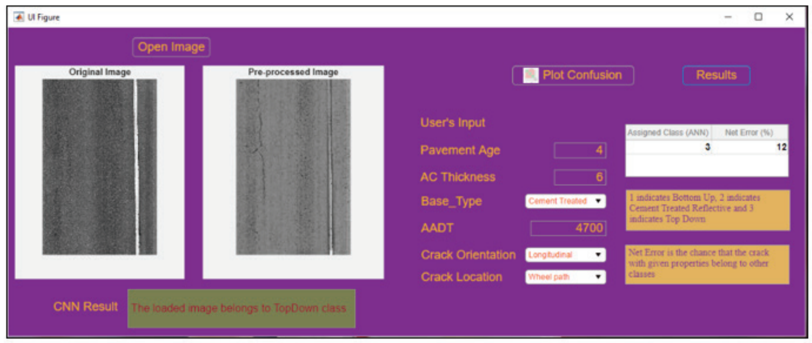
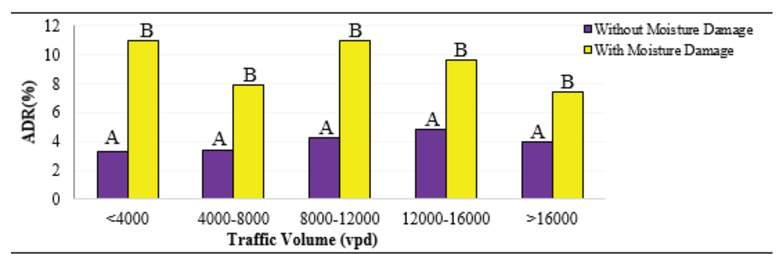
Cost-Effective Detection and Repair of Moisture Damage in Pavements

INTRODUCTION

Moisture damage is a significant distress that affects the field performance of asphalt pavements in Louisiana. The effect of moisture-induced damage on asphalt pavements is manifested in the roadway through stripping and poor durability of the mixes. Moisture-induced damage in pavements has detrimental consequences on the long-term performance, durability, and user safety. To ensure adequate long-term pavement performance against moisture damage, methods of early detection and repair are critically needed as moisture damage only appears at the surface after detrimental damage has already progressed in the underlying pavement layers. The conventional method to detect AC stripping and moisture damage is through core extraction, which is destructive, time-consuming, and is rarely conducted.



Windows-Based Application for Crack Identification and Classification Using ANN and CNN Models



Impact of moisture damage on the performance (Average Deterioration Rate [ADR]) of AC overlays

OBJECTIVES

The main objective of this study was to develop non-destructive field-testing methods to identify and detect moisture damage and to classify surface cracking in flexible pavements as top-down or bottom-up cracking. In addition, the effect of moisture damage on the performance and cost-effectiveness of asphalt concrete (AC) overlay and chip sealing was evaluated. The study also developed a deep-learning model to predict pavement roughness conditions based on the analysis of digital images of pavement surface.

SCOPE

Pavement performance, Ground Penetrating Radar (GPR), Rolling Wheel Deflectometer (RWD) measurements, and roadway cores were analyzed and evaluated to assess their use in detecting the presence, extent, and severity of stripping in in-service pavements. Furthermore, deflection measurements obtained from the RWD were evaluated to identify pavement sections that may suffer from AC stripping and moisture damage.

Machine learning models were developed to classify pavement cracks as top-down, bottom-up, and cement-treated reflective cracking based on pavement images and pavement and crack characteristics. Furthermore, machine learning models were developed in order to classify pavement sections into different roughness categories and to estimate the IRI values using pavement surface images.

METHODOLOGY

To achieve the study objectives, the research activities were divided into five main tasks. As part of these tasks, a Convolutional Neural Networks (CNN) model and a decision-making tool using Artificial Neural Networks (ANN) were developed to identify top-down, bottom-up, and cement treated (CT) reflective

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cracking in in-service flexible pavements. The CNN model was developed by modifying a pre-trained network, which was fitted, tested, and validated using 350 pavement images. Input variables for the ANN model were pavement age, asphalt concrete (AC) thickness, annual average daily traffic (AADT), type of base, crack orientation, and crack location.

The research team also analyzed RWD-deflection and pavement performance data and evaluated their use in identifying pavement sections that may suffer from stripping and moisture damage. Statistical and Artificial Neural Network (ANN) models that use RWD measured deflections, pavement characteristics, and performance data as inputs were developed to predict the probability of stripping damage in in-service pavements. A moisture detection protocol was also developed based on GPR measurements as a noninvasive and continuous evaluation technique that can be used to detect AC stripping damage in flexible pavements. A Finite-Difference Time-Domain (FDTD) based simulation program was used to study the propagation of GPR signals in a stripped pavement. Based on this analysis, a novel GPR-based indicator, known as the Accumulating In-layer Peaks (AIP), was introduced to detect stripping damage in asphalt pavements.

The study also evaluated the effects of moisture damage on the performance and cost-effectiveness of chip seal and AC overlays in pavement maintenance and rehabilitation. Pavement sections were categorized according to traffic volume and pavement conditions prior to treatment (PCI-). The average deterioration rate (ADR), extension in pavement service life (ΔPSL), increase in average pavement condition (PI), and cost-effectiveness (CE) were compared for stripped and non-stripped sections.

The study employed Convolutional Neural Networks (CNNs) to classify pavement sections into different International Roughness Index (IRI) categories and to predict IRI values by analyzing the captured features in Three-Dimensional (3D) pavement images. In addition, the effectiveness of ANN-based pattern recognition and Multinomial Logistic (MNL) regression models to categorize the roughness conditions of pavement sections was investigated. A pre-existing CNN model was trained and was validated using 850 3D pavement surface images. In addition, 1,142 test observations including IRI measurements and distress data were used to develop an ANN-based pattern recognition and MNL models.

RESULTS

The developed CNN model for crack identification and classification was found to achieve an accuracy of 93.8% and 91.0% in the testing and validation phases, respectively. The ANN-based decision-making tool achieved an overall accuracy of 92% indicating its effectiveness in cross-checking the prediction from the CNN model in crack identification and classification. A windows-based application was developed based on validated CNN- and ANN-based models.

A regression-based classification tree was developed based on the available RWD deflection measurements; this tree can be used to interpret and detect AC stripping using TSDD measurements. The AIP predicted accuracies for stripped and non-stripped sections were 82% and 96%, respectively, indicating its effectiveness to detect AC stripping damage in flexible pavements. The analysis and developed methods developed in the study may be used for stripping damage detection and as an additional benefit of TSDD and GPR testing. Results showed that, for chip seal, moisture damage negatively affected the performance of the sections with PCI-<80 and low traffic volumes. For sections with PCI->80, similar deterioration rates were observed for stripped and non-stripped sections. For AC overlays, moisture-induced damage significantly affected the long-term pavement performance at all traffic levels. On average, moisture-induced damage decreased ΔPSL, PI, and CE of AC overlays by 4.6 years, 23%, and 0.5%, respectively.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this project, a windows-based application was developed based on validated CNN- and ANN-based models. This tool may be used to allow the PMS section in DOTD to classify surface cracks as top-down, bottom-up, and cement-treated reflective cracks. Furthermore, the developed GPR-based indicator, known as the Accumulating In-layer Peaks (AIP), may be used to detect AC stripping damage in asphalt pavements based on GPR measurements. An image-based CNN model was developed to predict the IRI value of the pavement section based on surface images. The developed model, which accurately predicted the IRI values, provides numerous implementation opportunities into PMS activities. The developed model may also be incorporated into predict pavement surface roughness using camera-captured pavement images during pavement evaluation and management.

Results of the study indicated that pavement-underlying conditions including AC stripping damage should be taken into consideration in PMS decision and treatment selection processes. Furthermore, moisture damage should be effectively corrected before the application of maintenance or rehabilitation strategies for more durable pavements and optimum use of available funds.