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Development of Void Prediction Models for Kansas Concrete Mixes Used in PCC Pavement

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Abstract

Permeability of the concrete material used in Portland Cement Concrete (PCC) pavement structures is a major factor for long-term durability assessment. To properly characterize the permeability response of a PCC pavement structure, the Kansas Department of Transportation (KDOT) generally runs the Boil Test (BT) to determine the % void response. The BT typically measures the volume of permeable pore space within the concrete samples over a period of five hours at a concrete age of 7, 28, and 56 days. In this study, backpropagation Artificial Neural Network-(ANN) and Regression-based % void response prediction models for the BT are developed by using the database provided by KDOT in order to reduce the duration of the testing period or ultimately eliminating the need to conduct the BT. The noted excellent prediction accuracy of the developed models proved that the ANN and the Regression models have efficiently characterized the BT response. Therefore, they can be considered as effective and applicable models to predict the permeability (% void response) response of concrete mixes used in PCC pavements.

Keywords: Boil Test; Artificial Neural Networks; Civil Engineering; Concrete Pavement; Modeling

1. Background

Permeability of the concrete in a PCC is a major factor for long-term durability. The permeability of concrete depends on its pore network, which comes primarily from the excess water used during mixing in the initial hardening process. The porosity of concrete consists of closed or logged pores in addition to a network of interconnected pores [6]. Pore size ranges from a few angstroms to about 100 A° for the so called ‘gel pores’, from 100 to 100000 A° in ‘capillary pores’, and a few millimeters in ‘air or large

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pores'. Inter connected pores endow the concrete permeability. All the hydrated cement products are subjected to attack by sulphates, chlorides, acids, and water. It is a common practice to evaluate the water permeability characteristics when assessing the concrete durability characteristics. Permeability can be measured by conducting standard test methods. In this study, % of water absorption, % of permeable voids and % of total voids have been determined as per ASTM C 642-97 [1]. This test was performed as per procedure given in ASTM C 642-97 [1] by the oven-drying method. The measurements as part of ASTM C 642-97 [1] such as Oven-dry mass (A), Saturated surface-dry weight (B) and Curing time (CT) were used to develop prediction models by ANN and Regression to predict Saturated surface-dry weight after boiling (C), and Weight in water after boiling (D). Therefore, two models are developed to predict C and D individually using the same database. A, B, C, D and CT are the only values used for model development. However, % volume of permeable pore space is the final value calculated out of A, C and D variables and thus was used for accuracy measure comparisons. In this study, both regression and ANN approaches were used to characterize the % volume of permeable voids of concrete.

2. ANN Model Development

Typically, the desired ANN model is developed by following four sequential development stages. In the first stage, the ANN architecture is determined based on problem characteristics and ANN knowledge. Therefore, input and output variables are chosen accordingly. This step also includes classifying the datasets as training, testing or validation sets. In the second stage, the network is trained and tested on the experimental data to obtain the optimum number of hidden nodes and iterations for the desired ANN architecture determined in stage one. In the third stage, the best performing network obtained from the second stage is validated on the validation database. If accuracy measures for training, testing and validation databases are very comparable, then the developed model may not need to be retrained on all data. In the fourth stage, if needed, the best performing network obtained in the second stage is retrained on all experimental data in order to allow the ANN model to better characterized the desired behavior by exposing it to the testing and validation datasets. Generally, retraining the network on all datasets is expected to provide more reliable model and better accuracy measures if the dataset classification task is done in an appropriate manner. However, it has been shown through several research studies by Najjar and Co-workers [[2], [3], [4] and [5]] that the stage four is recommended to arrive at a better performing network. In this chapter, the four sequential stages have been conducted twice to arrive at two desired prediction models for C and D. In order to develop boil test permeability prediction model, two models for predicting C and D have been proposed. The three best performing models for predicting C and D have been evaluated in order to select the most appropriate model to predict C and D. The networks developed for C and D have fully connected internal structure (i.e. any node in one layer connects to all the nodes in the next layer) with one hidden layer. ANN model development issues for C and D networks are explained in this section.

ANN Model Architecture

Based on the knowledge gained from experimental data analysis, ANN model architecture for C has been built by considering 3 inputs and 1 output, which respectively are:

Inputs:

1- (A) Mass of oven-dried sample in air (grams)
2- (B) Mass of surface-dry sample in air after immersion (grams)
3- (CT) Curing Time (days)

Output:

1- (C) Mass of surface-dry sample in air after immersion and boiling (grams)