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The Concrete Industry in the Era of Artificial Intelligence

SP-350

Editors:
M.Z. Naser and Kevin Mueller

American Concrete Institute
Always advancing

The Concrete Industry in the Era of Artificial Intelligence

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PREFACE

The Concrete Industry in the Era of Artificial Intelligence

This special publication draws inspiration from the Technical Session entitled "The Concrete Industry in the Era of Artificial Intelligence," held during the ACI Virtual Concrete Convention in spring 2020. To parallel the Technical Session, this special publication is also tailored to showcase the unprecedented potential of leveraging artificial intelligence (AI) methods—including its derivatives of machine learning (ML) and deep learning (DL)—in the concrete industry as a whole.

The idea behind this effort started as a thought during an ACI Committee 216 meeting. From there, both ACI Committees 444 (Chair: Thomas Schumacher) and 554 (Chair: Liberato Ferrara) displayed interest in co-sponsoring this special publication. This special publication comprises fifteen papers (five from our panelists and ten received from authors representing academia and the concrete industry). This collection of papers covers the use of various AI techniques at the material level (i.e., concrete performance and mass-scale testing, property predictions, and optimization, etc.), elemental level (e.g., behavioral and capacity prediction of slabs, walls, beams, and anchorages, etc.), as well as system level (viz. damage and crack detection of concrete bridges and concrete composite structures).

We are very thankful to ACI, the ACI Technical Activities Committee, as well as all three technical committees. Your kind support and commitment have not only allowed us to explore a new realm of possibilities but have also enabled us to set the stage towards a new and modern future to our industry. Special thanks go to our panelists and contributors who were very kind to share their most recent research and unique ideas pertaining to infusing AI solutions to various problems within our domain. In addition, we send our warm regards to our reviewers, ACI staff, and Ms. Barbara A. Coleman for her help in setting up and editing this effort.

TABLE OF CONTENTS

Damage Detection in Concrete Bridge T girders using 3D Finite Element Simulations Trained by Artificial Neural Network

AlaaEldin Abouelleil, Hayder A. Rasheed, and Eric Fletcher

Synopsis: The structural deterioration of aging infrastructure systems is becoming an increasingly important issue worldwide. To compound the problem, economic strains limit the resources available for repair or replacement of such systems. Over the past several decades, structural health monitoring (SHM) has proven to be a cost-effective method for the detection and evaluation of damage in structures. Visual inspection and condition rating is one of the most commonly applied SHM techniques, but the effectiveness of SHM varies depending on the availability and experience of qualified personnel and largely qualitative damage evaluations. Simply supported three-dimensional reinforced concrete T-beams with varying geometric, material, and cracking properties were modeled using Abaqus finite element (FE) analysis software. Up to five cracks were considered in each beam, and the ratios of stiffness between cracked and healthy beams with the same geometric and material parameters were measured at nine equidistant nodes along the beam. A feedforward ANN utilizing backpropagation learning algorithms was then trained on the FE model database with beam properties and nodal stiffness ratios serving as inputs for the neural network model. The outputs consisted of the predicted parameters of location, depth and width of up to five cracks. This inverse problem is very difficult or impossible to solve with the training done by the Artificial Neural Network. One ANN was trained to predict the parameters of the cracks using the full database of FE simulations. The damage prediction ANN achieved fair prediction accuracies with coefficients of determination (R^2) equal to 0.42. This result was the outcome of the no uniqueness in the prediction of this inverse analysis. Nevertheless, this ANN model provides a rough estimate of the cracking type and damage content in bridge girders once the nodal stiffness ratios are measured by applying a field vehicle loading and measuring the deflection using a theodolite. A touch-enabled user interface was developed to allow the ANN model to predict the crack configurations. The application was given the acronym DRY BEAM, for Damage Recognition Yielding Bridge Evaluation After Monitoring.

Keywords: artificial neural network, finite element, damage detection, girders