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Durability of Concrete Structures Incorporating Conventional and Advanced Materials

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Editors:
Yail J. Kim, Isamu Yoshitake,
and Mark F. Green

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Preface

Durability of Concrete Structures Incorporating Conventional and Advanced Materials

Sustainability is one of the salient requirements in modern society. Structures frequently deteriorate because of aggressive service environments; consequently, federal and state agencies expend significant endeavors to maintain the quality of the structures. Among many factors, durability plays a major role in accomplishing the concept of sustainability. Extensive research has been conducted to understand the deterioration mechanisms of concrete and to extend the longevity of concrete members. Over the past decades, the advancement of technologies has resulted in durable construction materials such as advanced composites. This Special Publication (SP) contains nine papers selected from two technical sessions held in the ACI Spring Convention at Detroit, MI, in March 2017. All manuscripts were reviewed by at least two experts in accordance with the ACI publication policy. The Editors wish to thank all contributing authors and anonymous reviewers for their rigorous efforts. The Editors also gratefully acknowledge Ms. Barbara Coleman at ACI for her knowledgeable guidance.

Yail J. Kim, Isamu, Yoshitake, and Mark F. Green
Editors
University of Colorado Denver, USA
Yamaguchi University, Japan
Queen's University, Canada

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Thermal Detection of Subsurface Delaminations in Reinforced Concrete Bridge Decks Using Unmanned Aerial Vehicle

Tarek Omar and Moncef L. Nehdi

Synopsis: Bridge deck condition assessment is commonly conducted through visual inspection by bridge inspectors. Considering the colossal backlog of aging bridge structures, there is a need to develop cost-effective and innovative solutions to evaluate bridge deck conditions on regular time intervals, without interrupting traffic. This makes remote sensing technologies viable options in the field of bridge inspection. This paper explores the potential for applying infrared thermography (IRT) using unmanned aerial vehicle (UAV) to detect and quantify subsurface delaminations in concrete bridge decks. The UAV-borne thermal sensing system focuses on acquiring thermal imagery using a UAV and extracting information from the image data. Two in-service concrete bridge decks were inspected using a high resolution thermal camera mounted on a UAV. The captured images were then enhanced and stitched together using a tailored procedure to produce a mosaic view of the entire bridge deck, indicating the size and geometry of the detected delaminated areas. The results were validated by conducting hammer sounding and half-cell potential testing on the same bridge decks. The findings reveal the capability of the technology to provide measurements comparable to those derived from traditional hands-on inspection methods. Thus, it can be an excellent aid in efficient bridge maintenance and repair decision-making.

Keywords: bridge deck, condition assessment, delamination, infrared, thermal image, unmanned aerial vehicle

Thermal Detection of Subsurface Delaminations in Reinforced Concrete Bridge Decks Using Unmanned Aerial Vehicle

Tarek Omar is a PhD Candidate, Department of Civil and Environmental Engineering, Western University, London, Ontario, Canada. His research interests include concrete durability, bridge condition assessment and non-destructive testing technologies. He has substantial industrial experience in the management of roads and infrastructure utilities.

ACI member **Moncef Nehdi** is a Professor in the Department of Civil and Environmental Engineering, Western University, London, Ontario, Canada. His research interests are in the area of cement and concrete technology, durability and repair of concrete infrastructure, structural behavior of special concretes, modeling the behavior of cement-based materials, and recycling industrial and mining by-products in construction applications. He is a licensed Professional Engineer in Ontario, Canada.

INTRODUCTION

Concrete is the most used construction material in civil infrastructures. Its service life is considered synonymous to its mechanical strength, durability and serviceability. Durability of concrete can be defined as its ability to resist weathering action, chemical attack, abrasion, or any other processes of deterioration to retain its original shape, dimensions, quality and serviceability. However, concrete structures are vulnerable to a number of factors that can cause deterioration and result in loss of strength and unsafe or failure conditions. Existing concrete bridges represent strategic components of infrastructural networks. Bridge failures can be catastrophic, both in terms of human life and economic loss, rendering the task of managing this important infrastructure asset a complex endeavour that attracts growing attention. Among all reinforced concrete (RC) bridge components, bridge decks are rapidly deteriorating and have been the leading contributor to most deficient bridges in the United States [1]. A major challenge associated with inspecting RC bridge decks is that defects are often concealed subsurface mechanisms which increase in severity until the damage becomes too severe for cost-effective repair. Therefore, condition assessment tools capable of detecting subsurface anomalies, such as voids, delaminations and cracks are required to ensure bridge safety and define maintenance and repair needs. Current bridge deck inspection practices rely on visual inspection, which heavily depend on the experience and engineering judgment of bridge inspectors. A number of hand tools, including hammers, steel rods and chains, have been widely used to detect subsurface delaminations and voids in RC bridge decks. Hammer sounding involves tapping the surface of a concrete member with a hammer at multiple locations, while chain dragging involves dragging a chain over the bridge deck surface. In both cases, the user listens to and interprets the distinctive sounds produced. A dull or hollow sound indicates delaminated concrete, and a distinct ringing sound designates non-delaminated concrete. The advantages of these methods include simplicity, portability and low operating cost. However, such techniques require hands-on access and can be labor-intensive and time-consuming for large areas of concrete, while being ineffective for detecting subsurface anomalies in decks having overlays. Traffic control must also be in place so that inspectors can safely access the concrete element. In addition, the interpretation of the sound produced is subject to the operator's judgment and experience, typically yielding primarily qualitative and subjective decisions.

These limitations have motivated the pursuit of advanced non-destructive testing (NDT) techniques for more effective and reliable bridge inspection. NDT methods used to assess subsurface defects in RC bridge decks vary in complexity and reliability and often applied only when severe defects and deficiencies are observed. Infrared thermography (IRT) is a NDT technology that has gradually gained wider acceptance as a condition evaluation tool to detect subsurface delaminations in RC bridge decks without physical contact. Such subsurface anomalies can be detected on the basis of variable concrete properties, such as density, thermal conductivity and specific heat capacity. Rapid data collection using remote sensing technology with thermal IR imagery can reduce traffic disruption and lane closures on and underneath bridge decks, thus, it is less costly than other NDT methods. Generally, IRT testing collects radiant temperature and visualizes the data in the form of real-time thermal infrared images. With the advent of newer generations of infrared cameras, IRT is evolving as an accurate, reliable and cost-effective technique that can yield both qualitative and quantitative indicators of a RC bridge deck condition. Conducting ground IRT testing in-situ on full-scale bridge decks requires mounting the IR camera on a vehicle. Collecting thermal IR images is highly dependent on the camera's field of view (FOV) and lens. The ideal option for data collection is to scan one traffic lane on each pass. However, obtaining such horizontal FOV is not always achievable in the field as it may require to mount the camera at a high level. Thus a number of survey passes should be adopted to cover the entire bridge deck area, which requires the arrangement of traffic control.