Plagiarism Checker X Originality Report

Similarity Found: 11%

Date: Friday, April 28, 2023
Statistics: 262 words Plagiarized / 2358 Total words
Remarks: Low Plagiarism Detected - Your Document needs Optional Improvement.

The Effect of Material Present in the Void for Thermography Inspection in Concrete Rilya Rumbayan Abstract: In the previous study by the author, a numerical model to predict the thermal contrasts resulting from subsurface voids (i.e. delaminations) in concrete under a given set of environmental conditions was developed using the finite element method. The model was verified using the experimental test data, and the results indicated that the model could be an effective tool to support the thermography inspection of the concrete.

In this present study, the use of the verified model to evaluate the effects of materials present in the void created by the delamination expected to influence the detectability of the subsurface voids. The effect of this parameter on the thermal contrast developed on the surface above a subsurface delamination was assessed under a specific set of environmental conditions. The results indicated that air-filled void produced a significant thermal contrast compared to water-filled void, ice-filled void, and epoxy adhesive-filled void. Keywords : Delamination, thermal contrast, thermography, void materials. I.

INTRODUCTION Thermographic imaging technique provides a practical tool for the detection of subsurface delaminations from a distance without direct access to the surface; however, the effectiveness of the technique is highly dependent on environmental conditions at the time, and prior to, when a thermal image is captured. The thermal gradient in the concrete that results from certain environmental conditions, such as solar loading, drives conductive heat transfer in the concrete that is disrupted by subsurface delaminations, resulting in variations in surface temperature (i.e. thermal contrast) that are used to identify the location of subsurface damage in the thermal image. The previous study by the authors was proposed an analytical model of environmental effects on thermal detection of subsurface damage in concrete.

A 3 dimension (3D), nonlinear, numerical model of transient heat transfer was developed using finite element analysis to examine the environmental effects on thermal response of simulated subsurface voids in a large concrete block. The effects solar radiation, ambient temperature variation, and wind speed on the thermal images of a concrete block model with subsurface voids were presented. The model performance was evaluated by comparing the thermal contrast of the model results with those reported from a previous experiment study.

It was found that the model developed was sufficiently accurate to provide a useful tool for predicting the thermal contrasts in response to subsurface in the concrete, and provide a tool to support practical thermographic inspection [1]. Also, in the previous study, the authors was evaluated the effect of varying void depths and void thicknesses on thermal contrast, to develop a simplified estimation of void depth from the measured thermal contrast. The result shown that the maximum thermal contrast decreased exponential by a constant multiple of 0.98 as the void depth increased and the maximum thermal contrast increased nonlinearly with increasing thickness of the void [2].

The objective of this study was to evaluate the effect of another key parameter expected to influence the detectability of the subsurface voids, such as material in the void. The effect of different materials contained in the delamination void was evaluated. Modeling was completed for an air-filled void, a water-filled void, an ice-filled void and an epoxy-filled void on thermal contrast. The capabilities and limitations of thermography technique were evaluated based on the thermal contrast data results from the parametric studies.

Understanding how these various parameters affect the thermal contrast was the key to successful implementation of thermographic inspection. II. THEORY AND RESEARCH METHOD A. Basic Principles of Thermography Inspection in Concrete Thermography employs infrared sensors to detect thermal radiation emitted from objects and creates an image of surface temperatures based on the emitted radiation. The energy of emitted radiation is described by the Stefan Boltzmann Law, which stated that the power radiated by a body is directly proportional to the fourth power of its absolute temperature as (1).

???????? = ??????4 (1) in which ? is infrared emissivity of the object, ? is Stefan Boltzmann constant (5.67 x 10-8 W m-2 K-4), and T is the surface temperature of the object. In concrete, as shown in Fig. 1A, subsurface voids such as delaminations interrupt heat flow producing localized differences in the surface temperature [3]. These localized variations in surface temperature effect the total infrared radiation emitted from the surface. For example, as concrete warms in daytime, the surface temperature of a delamination is higher than the temperature of the sound concrete. The location of subsurface voids can be identified by analyzing the surface temperature variations [4]-[6].

These surface temperature variations were examined in terms of thermal contrast, as shown in Fig. 1B, to perform quantitative analysis of data in the study. Thermal contrast, ?T, was defined as (2). Fig. 1 (A) Schematic of the thermography technique to detect a void based on surface temperature differences (i.e. thermal contrast), and (B) Surface temperature and thermal contrast as a function of time [1] the epoxy is generally considered applying directly to the substrates for bonding concrete.

??? = ?????????? ? ???????????? ???????????????? (2) where Tvoid is the surface temperature above a void area and Tsound concrete is the surface temperature in the intact area of the concrete [6]. It can be seen that the thermal contrast curve has a maximum thermal contrast (?Tmax) at a distinct time (tmax). In this study, the maximum thermal contrast was only considered for evaluating the capabilities and limitations of the model for determining the subsurface voids under a variety of field test parameters based on given weather conditions.

The effective use of quantitative infrared (IR) thermography for subsurface void detection and void characterization in concrete requires the study of the transient heat transfer phenomenon. Theoretically, this phenomenon could be solved using direct computation of the theory of diffusion or using numerical analysis. The theory of diffusion in isotropic homogeneous material is governed by the Fourier equation as (3). ???? = ?? ? ?2 ?? (3) These materials contained in the void have different thermal conductivity, heat capacity, and density in comparison to the sound concrete.

Among these properties, thermal conductivity is a main property affecting temperature contrast between the void area and the sound area. Since the thermal conductivity of air is considerably lower than that of concrete, the significant temperature differences between a thin delaminated area and the thicker sound concrete can be expected when the material contained in the void is air. In another hand, since the thermal conductivity of water is not significantly lower than that of concrete, clear thermal differences at water filled voids would not be expected for steady state.

However, for transient case, the thermal contrast can be produced because of the differing heat capacity of water and sound concrete [8]. C. Method Similar to the previous study by the author [1], in this study, finite element method (FEM) was used to perform 3D transient heat transfer analysis of a concrete block with a subsurface void under the actual weather conditions (solar ???? ??,??,?? radiation, ambient temperature and wind speed).

The in which ?=k/?Cp is the thermal diffusivity which indicates how fast a material changes temperature; k is the thermal conductivity; ? is the density; Cp is the specific heat; T is the temperature; t is time and ?2 is the Laplacian operator. This equation shows that the temperature at any point in the material changes with time during transient heat flow [7]. B. Material Contained in the Delamination Air-filled void is the most commonly postulated model as a material contained in subsurface delamination. However, in the field application, the material which fills a delamination is not necessarily air.

Other possible void-filling materials are water, ice, and epoxy used to repair concrete. Water filled voids would be expected under saturated concrete surface. The water turns ice in the delamination when temperature drop below freezing [8]. In the case of deteriorated concrete, parametric studies were conducted using the FEM to evaluate the effect of key parameters expected to influence the detectability of the subsurface voids, for the purpose of providing an analytical tool to study potential testing procedures of thermography in the field.

The FEM was the selected analytical tool for predicting the thermal response of the model in a variety of different key parameters, including materials contained in the delamination void, which may be encountered in the field. All analyses were simulated using COMSOL Multiphysics software. A model of a concrete block with a variety of materials contained in the delamination void was proposed. Five different materials present in the void including air, water, ice, epoxy and Styrofoam were analyzed.

The Styrofoam filled void was included in this case such that the resulting thermal contrasts from the model and the experimental data could be compared. Table 1 shows the material properties for each material Table 1. Material Properties Involving Different plus the material properties of the sound concrete that was used for simulation in this case. The thickness of the void was 13 mm for all simulations. Materials Contained in the Void and the Sound Concrete Material k Cp ? [W/(m °C)] [J/(kg °C)] [kg/m3] Void (air) 0.024 700 1.2 Void (styrofoam) 0.027 1300 35 Void (water) 0.6 4200 1000 Void (ice) 2.2 2050 915 Void (epoxy) 1.24 1200 1530 The sound concrete 1.8 1000 2300 Three days of weather data, that were obtained from the previous experimental study, were simulated as boundary conditions [1]. Solar radiation was simulated only at the front surface of the concrete block.

Convective cooling was simulated at the front surface and the bottom surface of the concrete. The four other surfaces were treated as adiabatic. All simulations were run using 10 minutes time step over a period of three consecutive days. The purpose was to allow the concrete block reaching its thermal inertia for transient heat flow. In the further analysis, data results of the final 24 hours in the last day were only used. The initial temperature of the concrete block was taken as same as the initial surface temperature obtained from thermocouple measurement in the experimental test. The model was meshed using tetrahedral meshing feature from the COMSOL Multiphysics software.

The “extra fine” element size was selected as a balance between computational economy and accuracy in the solution [1]. III. RESULTS AND DISCUSSION Fig. 2 shows the time varying thermal contrast as a function of materials present in the void for 51 mm deep void. The results showed that when the void was air filled, the substantial difference in thermal conductivity (k) between air and concrete (Table 1) supported expectations of significant thermal contrasts between a void area and the sound concrete.

Since the thermal conductivity of water, ice, and epoxy adhesive was not substantially different than that of concrete, the thermal contrasts of these materials in the void were not more pronounced. In addition, the results showed that the differing specific heat (Cp) of air and styrofoam would be expected to produce a small difference in the thermal contrast. There was a small difference in thermal contrast among water, ice, and epoxy. However, it can be noted that the thermal conductivity of the material in void dominated the thermal contrast behavior. Fig.

2 The Time Varying Thermal Contrast as a Function of the Materials Present in the Void A characteristic maximum of thermal contrast for different materials contained in the void could be summarized in Fig. 3 for 25 mm, 51 mm, 76 mm and 127 mm deep void. It can be seen clearly that the maximum thermal contrasts for air filled void and styrofoam filled void were detected easily than the others filled materials. Fig. 3 Effect of Void Material On The Maximum Thermal Contrast IV. CONCLUSSION This paper focused on the evaluation of the effect of key parameters expected to influence the detectability of the subsurface voids, such as material in the void.

The analysis was performed using finite element analysis to evaluate the effect of different materials contained in the void. The results from the study of the effect of different materials contained in subsurface void (i.e. delamination) demonstrated that air-filled void produced a significant thermal contrast compared to water-filled void, ice-filled void, and epoxy adhesive-filled void. The differences of the thermal contrast for each material in void arose from different thermal behavior due to different properties of heat conduction and/or specific heat compared to the thermal properties of the sound concrete.

Based on the results of these studies, it was concluded that the model developed provided valuable information on the expected responses and possible limitations of using thermographic technique to detect subsurface voids in concrete bridge.

REFERENCES 1. R. Rumbayan and G.A. Washer, "Modeling of Environmental Effects on Thermal Detection of Subsurface Damage in Concrete", Research in Nondestructive Evaluation, Vol. 25, Issue 4, pp. 235-252, 2014. 2. R. Rumbayan and G.A. Washer, "Numerical Parametric Studies For Thermographic Inspection In Concrete", ISEC 2017 - 9th International Structural Engineering and Construction Conference: Resilient Structures and Sustainable Construction, Vol. 4, Issue 1, July 2017. 3. K.R.

Maser and W.M.K. Roddis, "Principles of thermography and radar for bridge deck assessment", Journal of Transportation Engineering, 116(5), pp. 583-601, 1990. 4. G.G. Clemena and W.T. McKeel Jr., "Detection of delamination in bridge deck with infrared thermography", Transportation Research Record, Vol. 664, pp. 180-182, 1978. 5. D.G. Manning and F.B. Holt, "Detecting delaminations in concrete bridge decks", Concrete International, Vol. 2(11), pp. 34-41, 1980. 6. G.A. Washer, R. Fenwick, N. Bolleni, and J.

Harper, "Effects of Environmental Variables on Infrared Imaging of Subsurface Features of Concrete Bridges", Transportation Research Record: Journal of the Transportation Research Board, Vol. 2108, pp. 107-114, 2009. 7. J.H. Lienhard, A heat transfer textbook, Mineola, N.Y., Dover Publications, 2011. 8. W.M.K. Roddis, "Concrete bridge deck assessment using thermography and radar", Theses in Department of Civil Engineering, Massachusetts Institute of Technology, 1987. AUTHORS PROFILE Rilya Rumbayan specializes in Structural Engineering, with a focus on non-destructive evaluation for concrete structures.

She studied in Department of Civil Engineering at The University of Tokyo, Japan for her Master degree and completed her Ph.D in 2013 in Department of Civil Engineering at University of Missouri, USA. Since 2002 until now, she works as Researcher and Lecturer at Civil Engineering Department, Manado State Polytechnic, Indonesia. Since March 2019, she holds a position as Secretary of Civil Engineering Department at Manado State Polytechnic. She actively participates in community service in the field of civil engineering.

INTERNET SOURCES:

<1% - sinta.kemdikbud.go.id › authors › profile
<1% - mospace.umsystem.edu › xmlui › bitstream
<1% - acsess.onlinelibrary.wiley.com › doi › pdf
<1% - www.powermag.com › making-the-most-of-thermal
<1% - www.chegg.com › homework-help › questions-and
<1% - www.isec-society.org › ISEC_PRESS › ISEC_09
<1% - www.collinsdictionary.com › evaluate-the-effect
<1% - www.researchgate.net › publication › 329634069
2% - www.sciencedirect.com › science › article
<1% - quizlet.com › 623204366 › stefan-boltzmann-flash-cards
<1% - apollo.lsc.vsc.edu › classes › met130
<1% - www.tandfonline.com › doi › full
<1% - www.sciencedirect.com › topics › engineering
<1% - www.sciencedirect.com › topics › materials-science
<1% - www.researchgate.net › post › Is-there-a-correlation
<1% - pubmed.ncbi.nlm.nih.gov › 33055376
<1% - www.thermal-engineering.org › what-is-thermal
<1% - resources.system-analysis.cadence.com › blog › msa
<1% - byjus.com › physics › thermal-diffusivity
<1% - www.semanticscholar.org › paper › A-Mathematical
<1% - www.researchgate.net › publication › 352057927_The
<1% - www.linkedin.com › pulse › selection-appropriate
1% - spexternal.modot.mo.gov › sites › cm
<1% - www.engineeringtoolbox.com › water-liquid-gas
<1% - courses.ansys.com › wp-content › uploads
<1% - www.researchgate.net › publication › 348744462_Study
<1% - ui.adsabs.harvard.edu › abs › 2014ReNEv
1% - research.unsw.edu.au › people › professor-stephen
<1% - www.semanticscholar.org › paper › Principles-of
<1% - www.semanticscholar.org › paper › Development-of
1% - ndtlibrary.asnt.org › 2017 › ThermalImagingfor
<1% - www.amazon.com › Heat-Transfer-Textbook-Fifth
<1% - https://www.tandfonline.com/journals/tsei20
<1% - www.researchgate.net › profile › Takeshi-Ishihara-2