10.21611/qirt.2023.21

QIRT Asia 2023

4th Asian Quantitative InfraRed Thermography Conference

Exploring Ambient Influences on Infrared Thermography: A Study on Concrete Delamination Detection and Solar Loading

by Sreedhar Unnikrishnakurup*, Vinod Kumar*, Jonathan Zheng*, Carlos Manzano*, Andrew Ngo*

* *Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), 2 Fusionopolis Way, Innovis #08-03, Singapore 138634, Republic of Singapore*

1. Introduction

Infrared thermography (IRT) is a multifaceted non-destructive evaluation (NDE) technique employed across various industries [1]. IRT functions based on the concept of generating an image by detecting the thermal radiation that an object emits. When an external heat source is used to excite the object, it induces thermal transients. Any inconsistencies within the object, due to discontinuity, subsequently generate thermal contrast in the resulting thermal image. Features such as cracks, voids, and discontinuities within the concrete structure act as obstructions to heat conduction, resulting in pronounced temperature gradients and consequently, contrasts in the IRT image. While previous studies have delved into the inspection of delamination using solar-irradiated infrared thermography [2, 3], the influence of the inspection surface's orientation relative to solar irradiation remains an area that needs further exploration.

This study delves into the utilization of solar loading thermography for inspecting concrete structures, specifically focusing on delamination detection via active thermography algorithms. The model also assists in identifying the most relevant times for infrared data collection, depending on whether the delaminated surface is facing North, South, East, or West, taking into consideration the sun's positional influence. Experimental data is employed to verify the validity of the proposed model. Furthermore, the study investigates the correlation between the heat flux absorbed by the surface and the resultant thermal contrast created by internal delamination.

2. Material and Method

Polystyrene foam, varying in size as presented in Table 1, is strategically positioned within the concrete sample to simulate internal delamination, owing to its extremely low thermal conductivity, comparable to air. By choosing distinct depths and sizes for delamination, as detailed in Tables 1 and 2, the study examines how variations in these parameters may impact surface contrast. The plaster-concrete sample is 600×600×100 mm. A transient thermal finite element (FE) model has been developed to explore the thermal behavior within materials, utilizing Comsol Multiphysics for active thermography investigations. The model is designed to enhance the comprehension of active thermography's physical aspects, thereby informing the establishment of experimental protocols for diverse materials and components. The underpinning physics of the model derive from the basic heat transfer equation, with parameters like specific heat (C_p), density (ρ), and thermal conductivity (k) for each material incorporated as inputs.

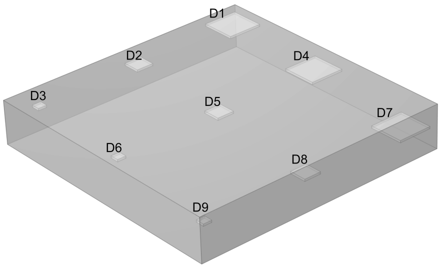


Fig. 1. *Sample with artificial subsurface delamination*

Defects	Dimensions (mm)
D1, D4, D7	80 × 80 × 5
D2, D5, D8	40 × 40 × 5
D3, D6, D9	200 × 20 × 5

Table 1. *Defect dimension*

Defects	Depth (mm)
D1, D2, D3	10
D4, D5, D6	20
D7, D8, D9	50

Table 2. *Defect depth*

3. Preliminary Results

Figure 2 displays the thermal images captured both experimentally and through simulation at three specific times - 8:00 AM to and 6:00 PM at an interval of 2:00 hr- as a result of heating induced by solar irradiation. The delaminations labeled as D1, D2, D3, D4, D5, and D7 are discernible in the images taken at 12:00 PM, a consistency observed in both the experimental and simulated images.

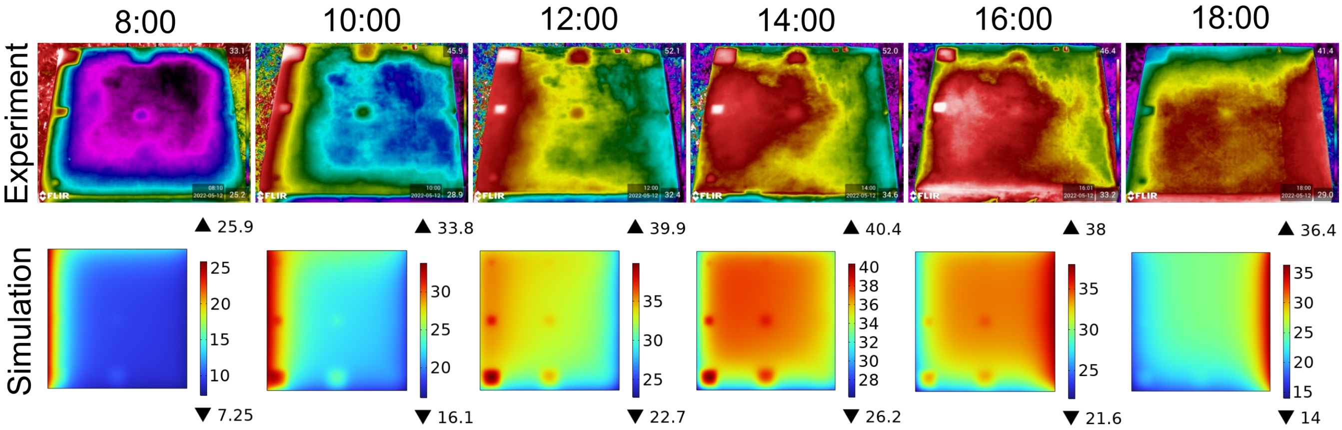


Fig. 2. *Solar heat loading simulation and experimental results*

Figure 3 (a), (b), (c), and (d) highlight the fluctuating thermal contrast corresponding to various depths and sizes of delamination, with the sample surface facing east (a, b) and west (c, d), respectively. Figures 3 (a) and (c) indicate that, given the same size, delaminations at deeper levels generate a reduced thermal contrast compared to their shallower counterparts. Figures 3 (b) and (d) demonstrate that larger delaminations typically result in correspondingly larger thermal contrasts. Furthermore, as seen in Figures 3 (a) and (c), the timing of the peak contrast occurrence also depends on the direction the defective surface is facing relative to the sun (East or West). Figure 4 showcases the simulated thermal images captured from 8:00 AM to 8:00 PM at four-hour intervals, with the sample surface oriented towards the East, West, North, and South. It is observable that the highest thermal contrast is achieved when the defective surface of the sample faces east, where it receives heating during the earlier part of the day.

4. Conclusion

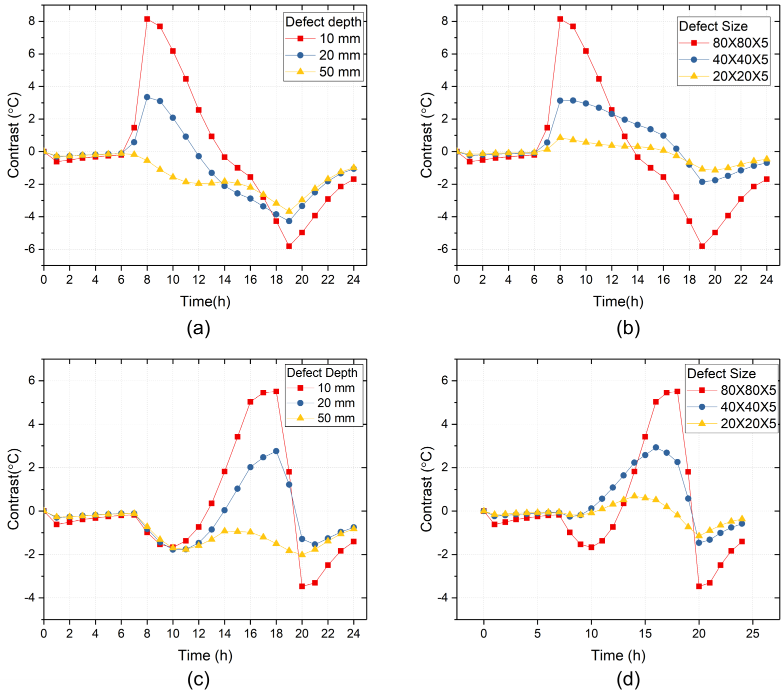
This work emphasizes the potential and limitations of Infrared Thermography (IRT) as a method for swiftly identifying subsurface defects in reinforced concrete. A Finite element model of concrete block with artificial delamination defects is developed. The results underline the significant sensitivity of IRT to various environmental factors. These conditions, including rain, wind velocity, radiant heat flux, and the sun's position relative to the defective surface, can considerably influence the effectiveness of defect detection. Through both experimental and numerical studies, this investigation elucidates the interplay between these environmental parameters and the performance of IRT, shedding light on its practical utility and paving the way for further optimizations in its application.

References

[1] Xavier PV Maldague. *Nondestructive evaluation of materials by infrared thermography*. Springer Science & Business Media, 2012.

[2] Babar Nasim Khan Raja, Saeed Miramini, Colin Duffield, Massoud Sofi, Priyan Mendis, and Lihai Zhang. The influence of ambient environmental conditions in detecting bridge concrete deck delamination using infrared thermography (irt). *Structural Control and Health Monitoring*, 27(4):e2506, 2020.

[3] Van Ha Mac, Quang Huy Tran, Jungwon Huh, Nhu Son Doan, Choonghyun Kang, and Dongyeob Han. Detection of delamination with various width-to-depth ratios in concrete bridge deck using passive irt: Limits and applicability. *Materials*, 12(23):3996, 2019.



(a) (b)

(c) (d)

Fig. 3. *Thermal contrast due to solar heat loading throughout the day for different delamination defects (a) Thermal contrast for 80 × 80 × 5 defects at different depths when defect surface facing east direction (b) Thermal contrast for different size defects at depth 10 mm when the defect surface facing east direction (c) Thermal contrast for 80 × 80 × 5 defects at different depths when defect surface facing west direction(b) Thermal contrast for different size defects at depth 10 mm when the defect surface facing west direction*

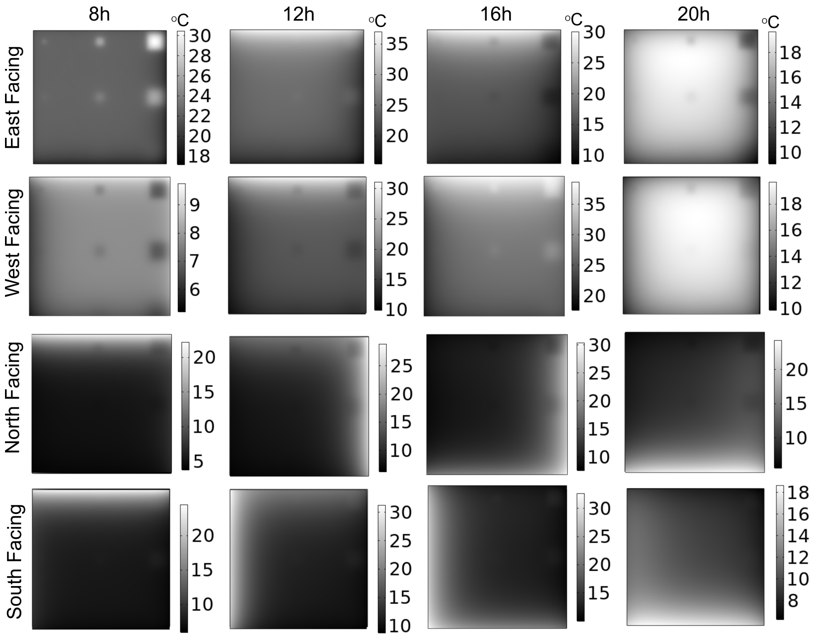


Fig. 4. *Thermal images captured at varying times throughout the day (8 AM, 12 PM, 4 PM, and 8 PM), illustrating the influence of the sun's position on the inspection surface facing East, West, North, and South*