

DETECTION AND CHARACTERIZATION OF SUBSURFACE DEFECTS IN CONCRETE USING LOCK-IN AND STEP HEATING THERMOGRAPHY

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ABSTRACT

In this paper we discuss the application of Lock-in and Step heating techniques for defect detection in nuclear graded concrete structures. In case of Step Heating optimization of heating period is carried out by analyzing the Signal to Noise Ratio and defect detectability. Also Thermal Signal Reconstruction is carried out for noise reduction and the results are compared. In Lock-in Thermography depth probing is done by varying the frequency and the Signal to Noise Ratio and defect detectability limits are studied.

KEYWORDS: Concrete, Lock-in Thermography, Step Heating, Defect, Thermal Signal Reconstruction

1. INTRODUCTION

Concrete is one of the commonly used construction materials. In nuclear industries concretes are used as cost effective biological shield to prevent radiation hazard. The biological shield material and other concrete structures face extreme conditions like radiation and high temperature, which may induce damage in concrete structure. The induced damage may lead to defect creation which, if goes undetected, may lead to failure of the system. Non Destructive Evaluation (NDE) methods are suitable for such application since in NDE the material can be inspected without impairing its future usefulness. Since the concrete structure is situated in inaccessible area a non contact method is preferred. Infrared Thermography (IRT), being a non contact NDE method, is more suitable for in service inspection of concrete structures. In recent years IRT has gained more importance due to its ability to inspect non-invasively, fast inspection rates and provide a visual image which is easy to interpret [1]. Lock-in Thermography (LT) and Step Heating (SH) are two important techniques in active IRT which are widely used for material and defect characterization [2, 3]. In LT, a periodically modulated optical wave is used to excite the material surface and the corresponding temperature response is recorded using an IR camera. Then mathematical tools such as Fourier Transform or Four Point Method are used to derive phase and amplitude images which are further used for quantitative analysis. In SH a continuous optical stimulus is used to heat the material surface and the temperature response during heating as well as cooling period is recorded. The temperature response is later analyzed for quantitative information. IRT has been widely used in civil engineering applications such as bridge inspection, detection of corrosion in reinforced bar in concretes, evaluation thermal insulation of buildings etc. In the case of concrete evaluation using thermography most of studies carried out on the detection of corrosion in reinforcement in concrete and resulting delamination using active thermography and damage detection in concrete. Defect detection in concrete is challenging compared to metals and composite due to its heterogeneous nature. The present study focuses on the initial lab scale study carried out on nuclear grade concrete for defect characterization using LT and SH. In LT frequency is varied for depth probing and Signal to Noise Ratio (SNR) is evaluated. In case of SH the heating period is optimized by evaluating the defect detectability and SNR. For SH Thermal Signal Reconstruction (TSR) is also carried out for reducing the noise and better defect detectability.

2. MATERIAL AND EXPERIMENTAL SET UP

2.1 Material

The material chosen was nuclear grade concrete. Polystyrene cubes of different sizes were used to simulate the defects. While casting the concrete the polystyrene cubes were placed at desired depths. For the present study defects of size 10 cm x 10 cm, 5 cm x 5 cm and 3 cm x 3 cm at depth 1 cm, 2 cm and 3 cm respectively were created on concrete block of size 50 cm x 50 cm x 10 cm.

2.2 Experimental Setup

A focal plane array based IR camera with thermal sensitivity of 25 mK and maximum frame rate of 176 Hz was used for the experiment. The detector used was Indium Antimonide with spectral sensitivity in the range of 3 μm to 5 μm . For both LT and SH, 4 halogen lamps of power 1000 W each were used. In LT A function generator was used to modulate the heat source and Altair LI software was used for data analysis. In SH the images were acquired with frame rate of 10 Hz during heating and for 10 min during cooling. The camera to object distance was 1.5 m and lamp to object distance was kept at 2 m. Altair software was used for acquiring and analyzing the images.

3. RESULTS AND DISCUSSION

3.1 Lock-in Thermography

In LT, lower frequency was used since concrete has lower diffusivity. Frequencies ranging from 0.01 Hz to 0.0005 Hz were used to scan the depth. Figure 1 shows the phase images of concrete sample at frequencies 0.005 Hz and 0.001 Hz

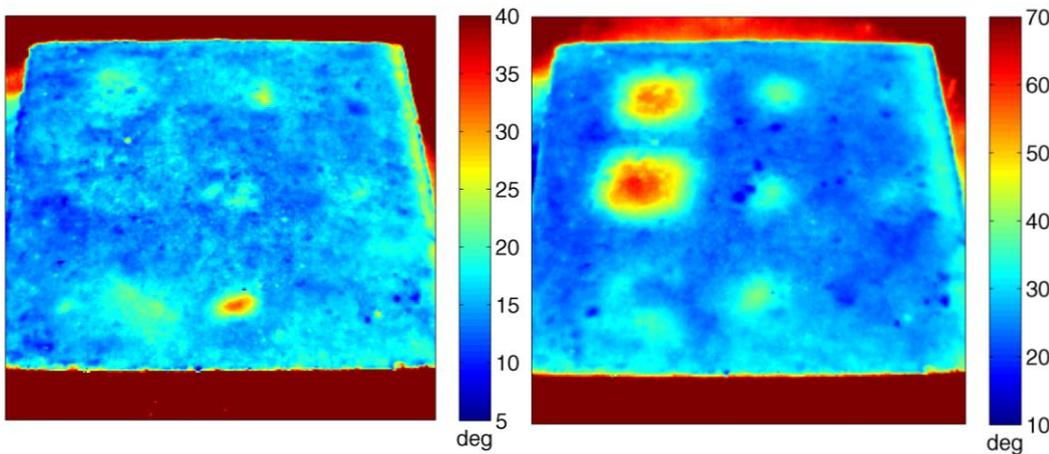


Fig. 1 Phase images of concrete sample at $f = 0.005$ Hz and 0.001 Hz.

3.2 Step Heating

In SH the heating period was varied from 10 sec to 250 sec and the analysis was carried out during the cooling period. Figure 2 shows thermal images of the sample at 100 sec after heating for different heating times. TSR was carried out for cooling period and the corresponding 1st and 2nd derivative images were derived. The SNR analysis was also carried out and figure 3 shows the SNR variation as a function of time for defect of size 10 cm x 10 cm at 1 cm depth.

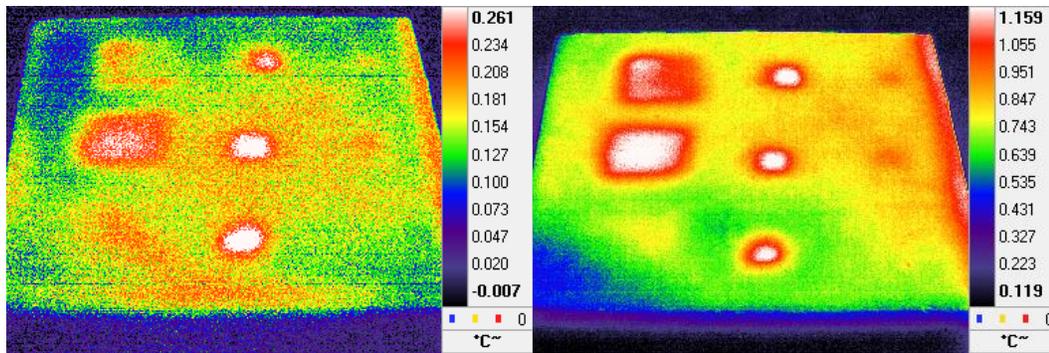


Fig. 2 Thermograms of the concrete sample at $t = 100$ sec for heating time of 25 sec and 100 sec.

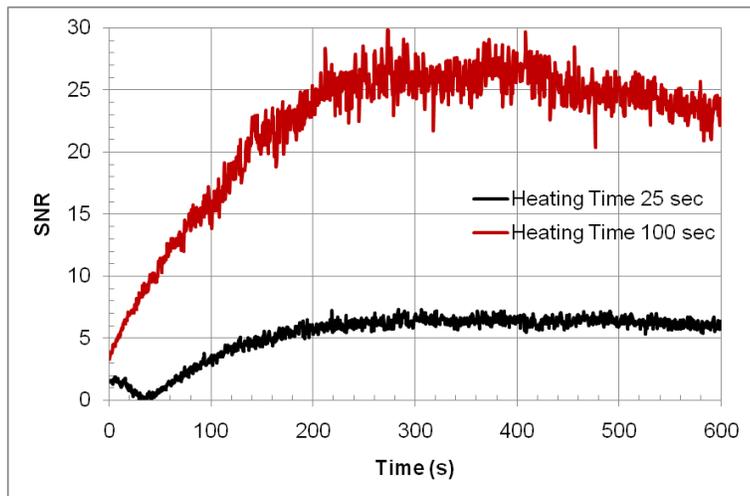


Fig. 3 SNR variation as a function of time for defect of size 10 cm x 10 cm at 1 cm depth.

4. CONCLUSION

Defect characterization in concrete was successfully carried out using LT and SH. Defect detectability and SNR in both techniques were analyzed and compared. Good SNR and defect detectability could be achieved by both the techniques. In SH the heating period is also optimized using SNR approach. It was observed that SH could detect finer defects than LT with the help of TSR.

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