Damage detection in a concrete slab using IR thermography and wavelet transform

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Abstract

The paper concerns one issue of class of problems dealing with the detection of material damage in structural components (elements) using non-destructive testing methods. The scope of research was limited to laboratory and numerical analysis of the reinforced concrete slab with dimensions of 60x60x10 cm with internal discontinuities imitating damages. Various external heat sources were used to induce non-stationary heat flow in the area of tested slab, wherefore the temperature distribution on its surface was recorded. Two-dimensional discrete wavelet transformations were used to improve the detection of disturbances (anomalies) in the temperature distribution caused by hidden damages.

Keywords: damage detection, discrete wavelet transform, infrared thermography

1. Introduction

Current and basic bridge inspections are obligatory. They differ from each other in terms of the range, accuracy and different used types of measurement and investigation techniques. Their main purpose is, among other things, to determine the current technical condition of structure, to provide conditions of safe operation and to specify the scope of the necessary works related to the current maintenance. In order to determine more accurately the real technical condition of elements of any bridge structure some special techniques and test methods should be used which are not normally applicable under typical inspections.

The most common signs of poor condition of reinforced concrete elements are cracks of big widths, concrete cover delaminations, internal voids or inclusions, rust-colored or white leaks on surfaces confirming the existence of corrosion of reinforcing bars or chemical corrosion of concrete. Considering the numerous advantages of NDT techniques, including IR thermography, its use for detection of delamination of the concrete cover, internal voids and corrosion of reinforcing bars in concrete elements, as part of routine inspections, seems to be very promising.

The above mentioned issues are the subject of many scientific and implementation works that are linked to bridge structures. One of the first applications of analyzing surface moisture of some small stone arched bridge was presented in [1]. The report [4] presented a performance evaluation and rating of commercially available 12 remote sensing technologies for infrastructure condition assessment, specifically bridges. Improvements in parameters of modern measuring infrared equipment (resolution and sensitivity) may improve the technical condition assessment of selected bridge elements. The use, comparison and combination of two NDT methods (impact-echo and IRT) for detection of simulated delaminations and cracking defects in full-scale reinforced concrete bridge deck model are described in [2].

This article is a continuation of the preciously presented research of Authors [3] and aims to examine the possibilities and limitations in detecting defects in concrete slabs using IR thermography and several signal processing techniques.

2. Problem formulation

The motivation of this research is to determine the optimal conditions of the experiment to detect internal discontinuities in the concrete slab imitating the deck of the bridge. The research was divided into two parts: experimental studies and numerical analysis.

We want to know how to:

- choose properly the parameters of the heat source
- determine the way of carrying out the experiments (heating and measurement time, limitations due to environmental conditions, etc.)
- use signal processing tools to enhance the detection of damage zones based on thermal images.

3. Experimental studies

The concrete slab of dimensions of 60x60x10 cm was made of concrete of strength class C35/45, used during execution of the real supports of one of the new-built viaduct in Poznan. Reinforcement mesh was made of steel bars type B500SP with a diameter of ∅10 and ∅12 mm in a spacing of 15.0 cm. The configuration and collocation of the bars grid in slab is shown in Figure 2a.

Inside the plate five discontinuities imitating damages were implemented. Internal voids were made in the form of plastic boxes with dimensions of 7.0x4.7x1.9 cm. They were placed in the plate (see Figures 1 and 2) so that they were about 1.5 to 3.0 cm below the top (measuring) surface. The fifth "damage" (marked as def_5) is a 6.5 cm section of ∅12 mm main bar with a diameter reduced to 7.0 mm, simulating the corrosion of this reinforcing bar. The above mentioned damages layout is shown in Figure 2.

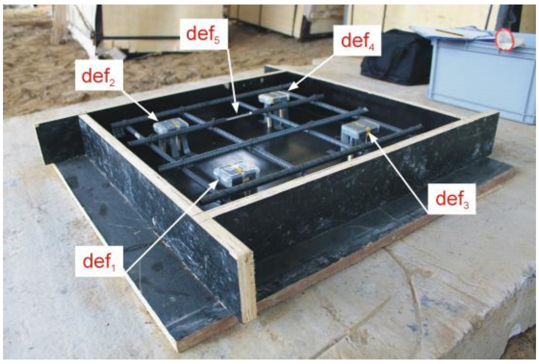

Figure 1: View of formwork, reinforcement mesh layout and "defects" before concreting the plate

Thermograph type FLIR X6540SC (FPA 640x480; thermal resolution NETD - 0.025°K) for acquisition and processing of thermal imaging was used in laboratory to carry out the measurements. For the analysis of thermal images sequences (real-time) program IrNDT (AT-Automation Technology GmbH) was used, which has been specially designed for non-destructive testing with active thermography. The FLIR T620 (thermal resolution NETD - 0.05°K) IR-camera was also tested because of ease of its use outsider the lab.

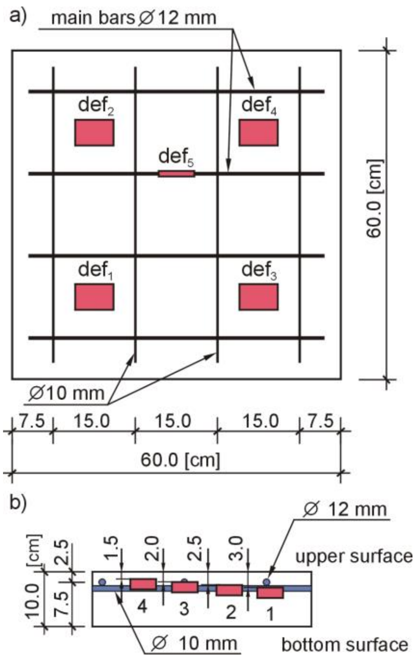

Figure 2: Geometry of the reinforced concrete (RC) plate: a) reinforcing bars and "defects" layout, b) schematic position of voids in plate

4. Numerical analysis

Numerical analyzes are used to verify the FE model of plate, damage models, types and methods of thermal excitations and to properly take into account the influence of environmental conditions. For these purposes, numerical model of concrete slab with a grid (mesh) of steel bars in Abaqus/Standard was prepared. It almost exactly corresponds to the geometry of the experimental plate. The numerical model consists of 16 layers of elements of different thickness. The total number of 8-nodes continuum diffusive heat transfer elements DC3D8 is 90000.

An example of solving the problem of non-stationary heat flow through the plate at time t = 500 s is shown in Fig. 3. Visible differences in the temperature distribution on the surface, caused by the "defects", are in fact very small. Only the decomposition of the signal (temperature fields) performed by means of 2D discrete wavelet transformation, thanks to its properties, allows to locate places of temperature anomalies in a reliable way.

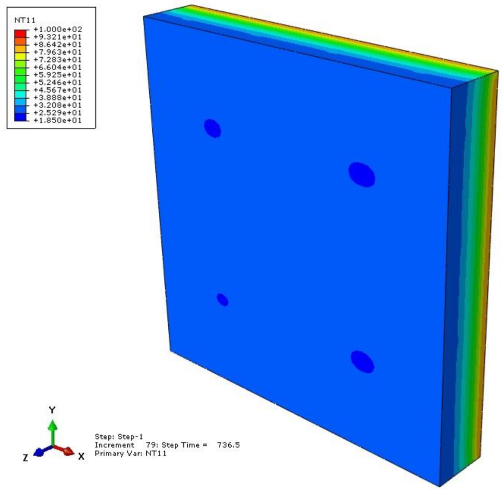

Figure 3: FEM model of RC plate with temperature distribution NT11 at time t=500s

5. Concluding remarks

The objectives and tasks defined above are currently under investigation. The preliminary results of the numerical analyzes seems to be very promising. It is expected that tests of reinforced concrete slab in laboratory will allow to answer many questions and especially the most important question about the possibility of using presented method in detection of damages in real structures.

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