Spearhead Network for Innovative, Clean and Safe Cement and Concrete Technologies

The Role of Infrared Thermography in Nondestructive Testing of Concrete Structures

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Zagreb SPIN Meeting, 7-12 May, 2012

Introduction

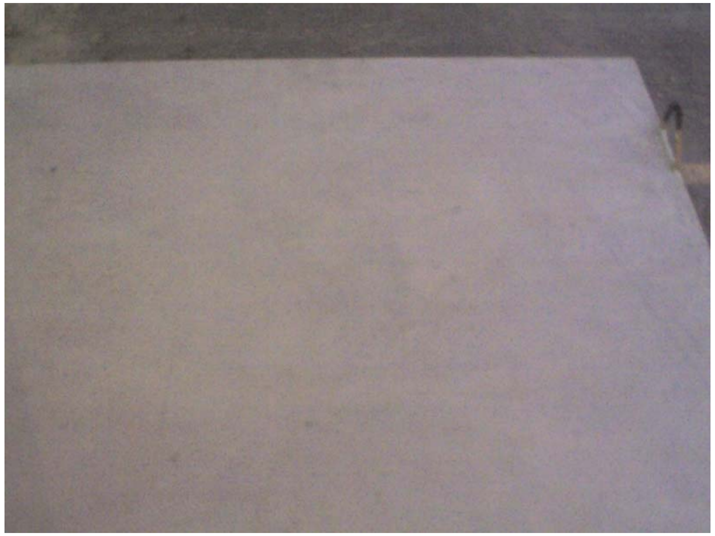
- Infrared thermography
  - one of the non-destructive thermal methods which is becoming ever more popular in non-destructive testing of materials and structures
  - completely noncontact and may be faster than many other techniques that are being used.

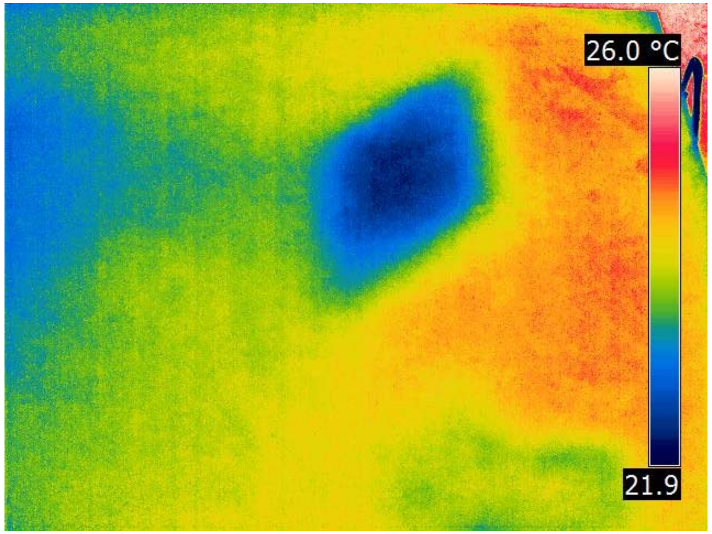
Introduction

- In Civil Engineering, the application of infrared thermography is not limited to passive investigations of the quality of thermal insulation of building envelopes.

Introduction

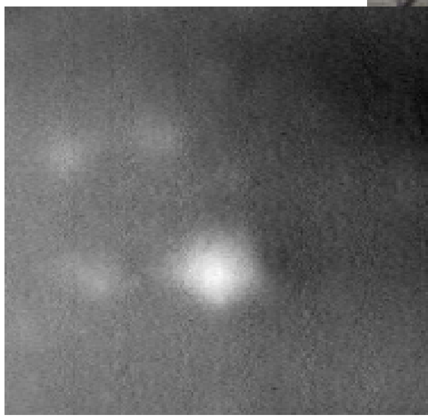
- Defects like voids in concrete or masonry, delaminations at interfaces of composites can be localized and characterized
  - different heat capacity and/or heat conductivity in comparison to the bulk material.





IR thermography in civil engineering structures

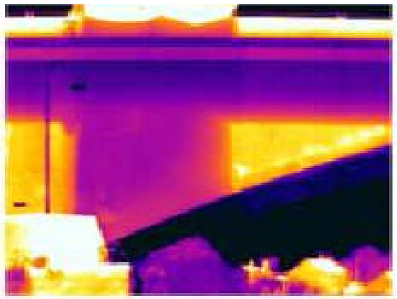
- Examples are inspections of bridge decks and of paving in general.
  - ASTM standard "Standard Test Method for Detecting Delaminations in Bridge Decks Using Infrared Thermography"



ASTM D 4788-03

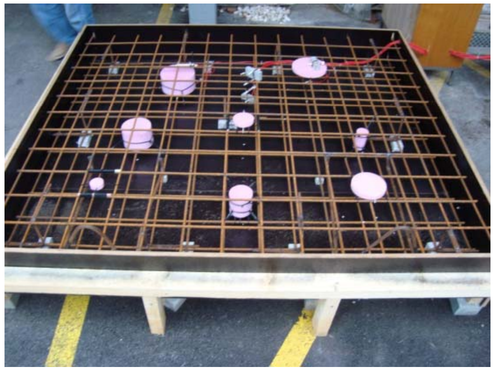
- Method intended for use on exposed and overlaid concrete bridge decks, asphalt or concrete overlays as thick as 100 mm
- The standard has no Precision and Bias statement and <u>*should not be used for acceptance or rejection of a material*</u> because comparative data is not available.
- Deck should be dry, minimum of 24h prior to the test
- The temperature difference must be at least 0.5 °C between the delaminated or deboned area and solid concrete.

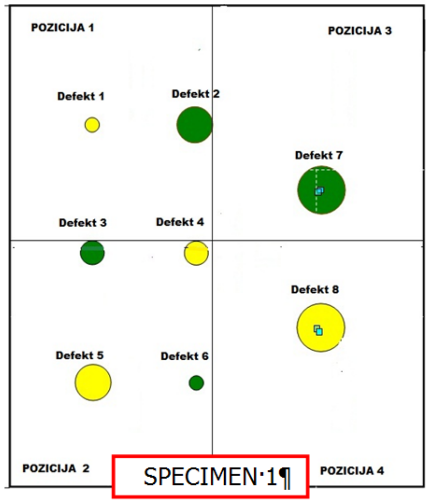


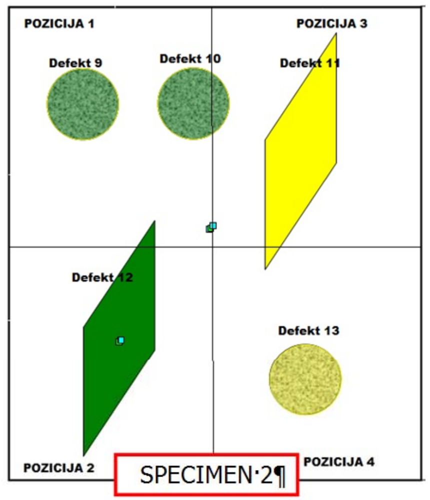


Location of voids in concrete

- To investigate the detectability of voids in concrete, two concrete test specimens were built, having a size of 1.8 x 2.0 x 0.25 m.
- Before concreting, voids, simulated by polystyrene cuboids with different sizes were positioned by polyamide threads in the wooden formwork.

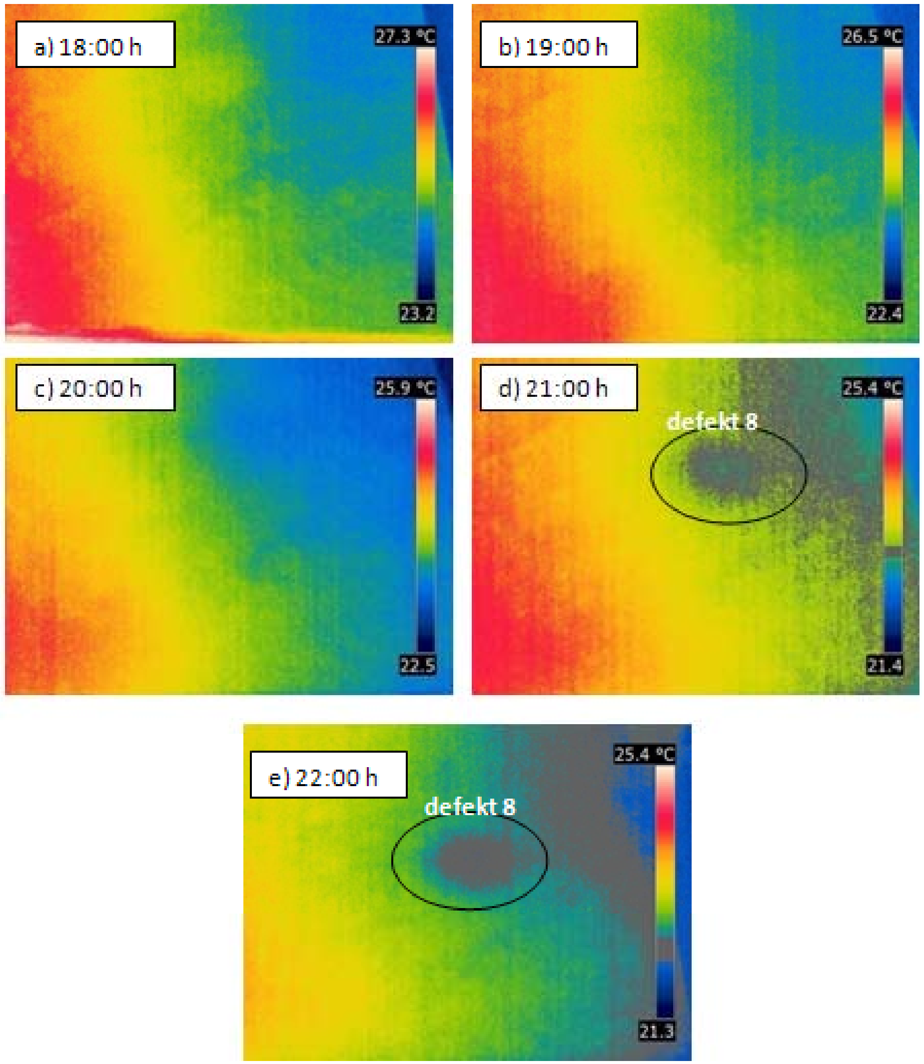




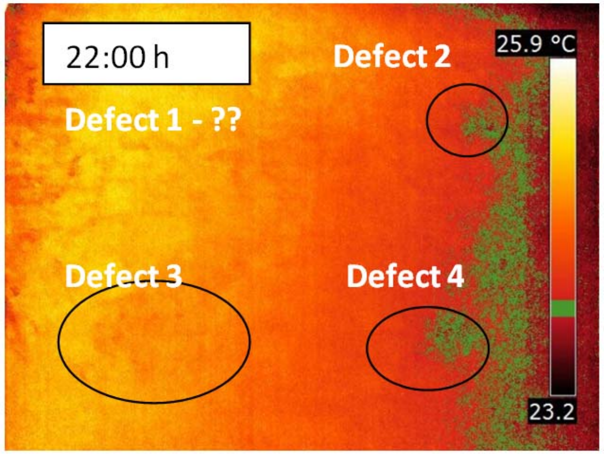


Location of voids in concrete

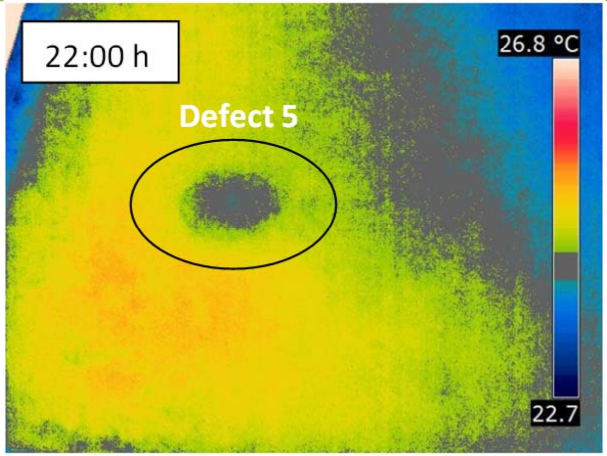
- Thermal imaging performed according to ASTM D 4788-03 in the summer period, between the 18.00 and 22.00 hours with the periodic imaging every hour.
- During the day both specimens were exposed to direct insolation while the shades moved over the specimens when the sun was setting.
- The day was sunny, and there was no rain for at least a week before the thermal imaging.



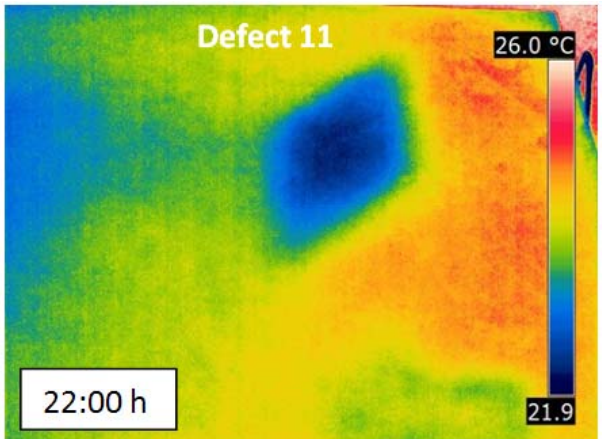
Location of voids in concrete



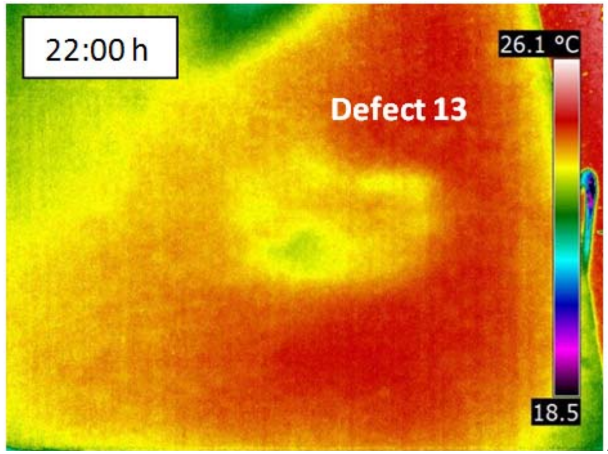
Thermogram of specimen 1, defects 1 to 4, at 22.00 hours



Thermogram of specimen 1, defect 5, at 22.00 hours



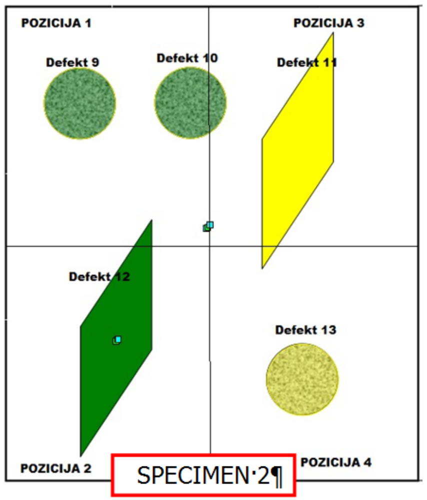
Thermogram of specimen 2, defect 11, at 22.00 hours

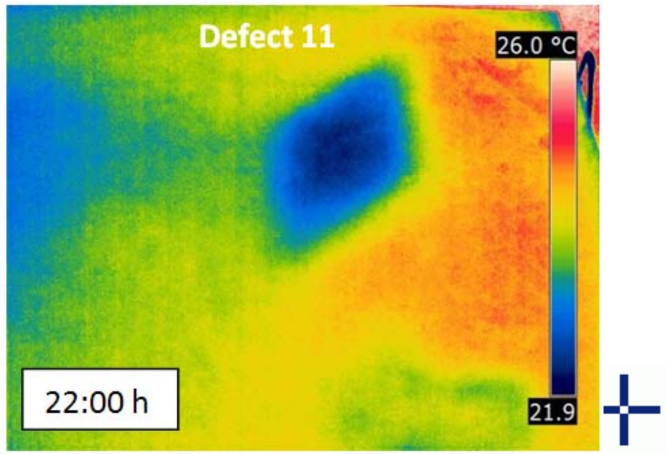


Thermogram of specimen 2, defect 13, at 22.00 hours

Location of voids in concrete

- It can be seen that the small voids (Defect No. 1 to 4) are not visible or just barely visible.
- Defects which are covered by 3 - 4.5 cm of concrete as well as the shallow larger voids (Defects No. 5, 11 and 13) are visible with maximum contrast at the end of thermal imaging process, 3 hours after the time shade has covered the sample and 2 hours after the sunset.



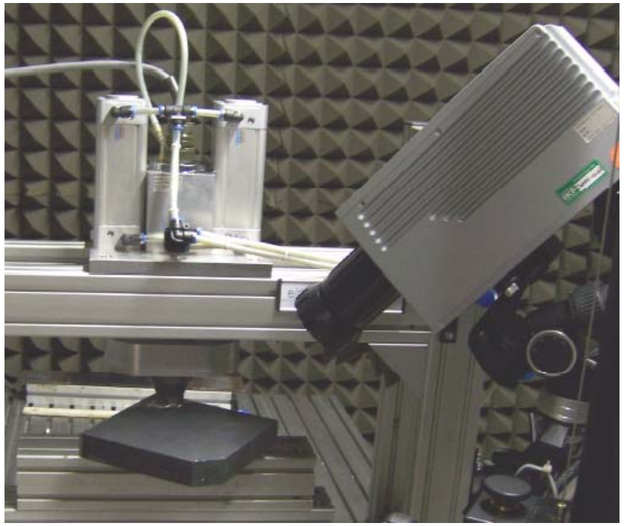


ASTM D 4788-03 - problems identified

- Relatively low thermal conductivities of materials and large dimensions of civil engineering structures contribute to difficulties in achieving homogenous cooling of the monitored surface.
- By using the passive thermography, defects in the construction elements that are not exposed to direct sunlight cannot be located.

ASTM D 4788-03 - problems identified

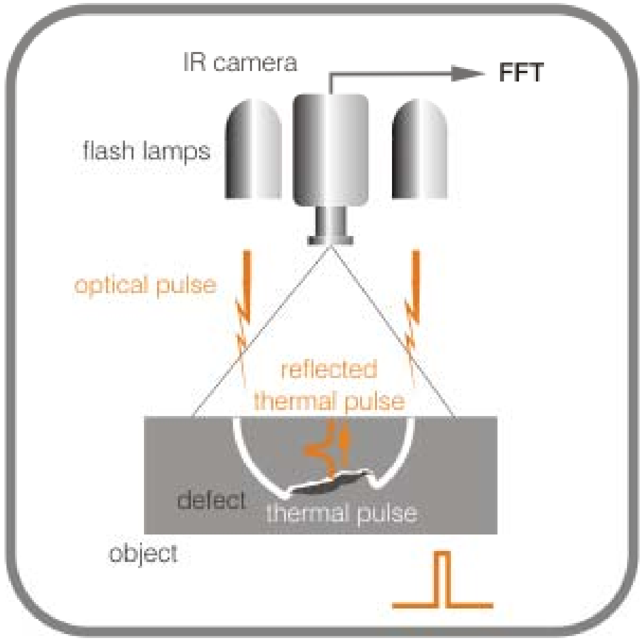
- Engineers seek to determine whether voids and delaminations in such reinforced concrete elements can be detected through the use of **active infrared thermography**.
- Also, by using active thermography techniques, *quantitative measurements of defect depth and dimensions* can be conducted



Pulsed thermography - PT

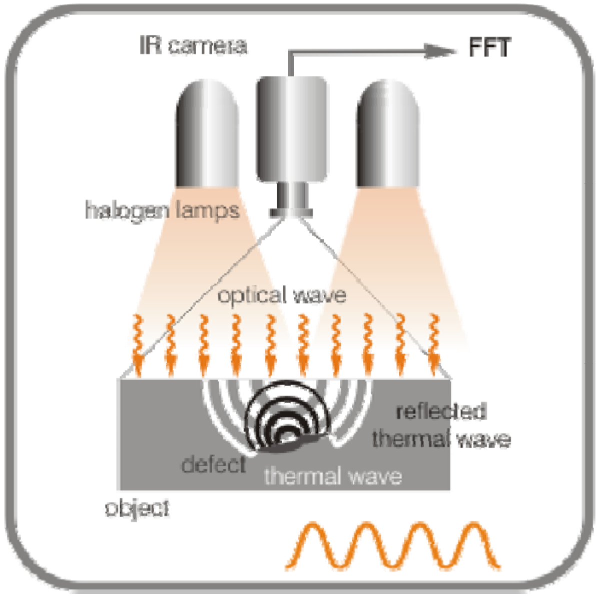
- Basically, PT consists of heating the specimen briefly and then recording the temperature decay curve.

- Thermal stimulation method
  - a short thermal stimulation pulse lasting from a few milliseconds for high-conductivity material, such as metal, to a few seconds for low conductivity specimens, such as plastics, is used.



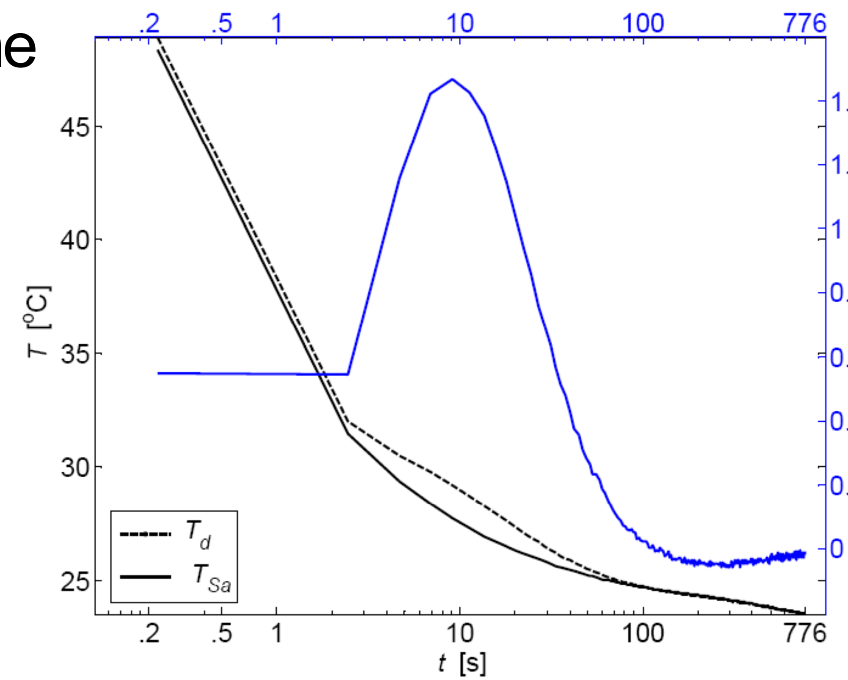
Lock-in thermography

- Based on thermal waves generated inside a specimen and detected remotely.
- Wave generation is performed by periodic deposition of heat on a specimen´s surface while the resulting oscillating temperature field in the stationary regime is recorded remotely through thermal infrared emission



Defect detection

- The temperature profile for a non-defective area decays approximately as the square root of time
- *Thermal effusivity e*, is greater for sound material than for air - sound material acts better than air as thermal sink.
- once the thermal front has reached the defective area (air), surface temperature will be higher above the defective zone than above the sound area, from this moment to a given stabilization time.



Defect detection

- Several data processing algorithms have been developed for defect characterization:
  - determination of the size,
  - depth and thermal resistance of a defect

- Most of these techniques use thermal contrast calculations.

Defect detection

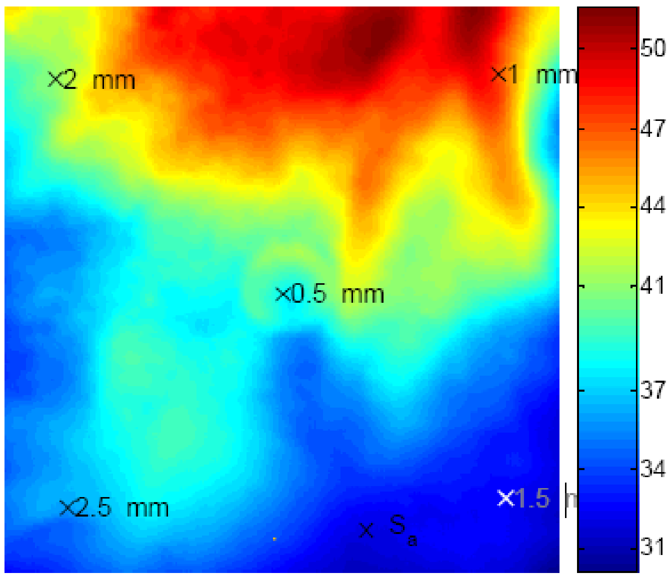
- The basic definition of thermal contrast is the *Absolute Thermal Contrast*, which measures the difference between defective and non-defective regions :

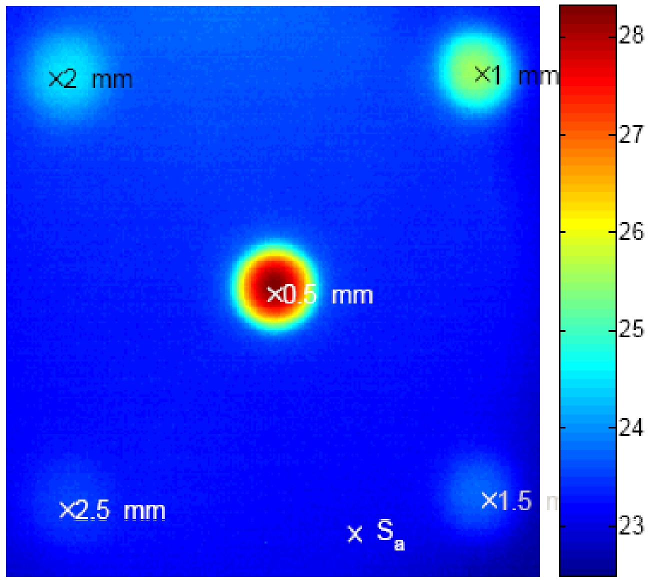
$$\Delta T = T_d - T_{Sa}$$

- Thermal contrast based analysis provide
  - a good indication of defect characteristics (qualitative and quantitative) when working with relatively shallow defect in homogeneous materials

Non-uniform surface heating

- Given that defect detection principle is based on temperature differences, non-uniform heating may produce confusion, especially for defect quantification.





Conclusions

- Infrared thermography, due to its non-contact character that allows for quick 2D surface mapping, represents a powerful tool for non-destructive evaluation (NDE) of materials and structures.

- Infrared thermography is still **not completely exploited.**

Conclusions

- Passive infrared thermography strongly depends on weather conditions

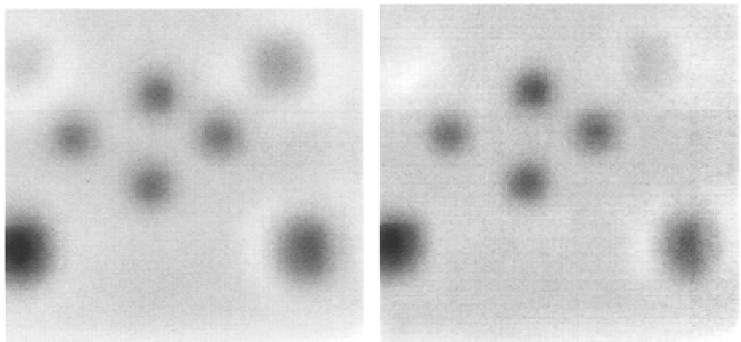
- The most important result from presented research is that
  - *simulated defects can be detected by using passive infrared thermography under certain conditions and only few of the existing defects are visible*

Conclusions

- By using active infrared thermography and appropriate post processing techniques, detection of near-surface inhomogeneities and common subsurface defects in typical structural elements is possible.

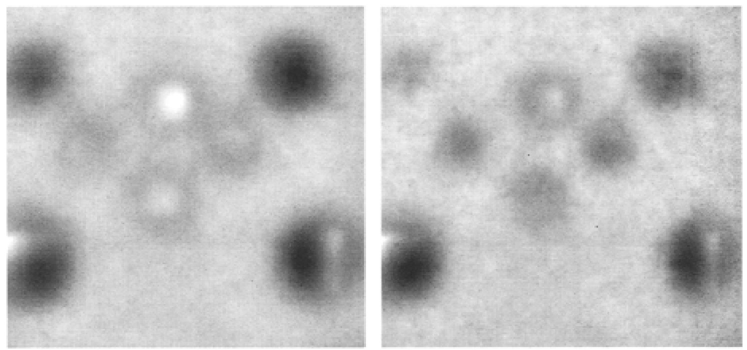
Amplitude

0. 14 mHz 0.28 mHz



Phase

0. 14 mHz 0.28 mHz



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Thank You for Your kind attention!

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