# MONITORING OF TEMPERATURE IMAGES OF OBJECTS

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*In this study, the temperature images of different objects were observed using the IR thermographic camera and a system of thermosensors connected to the eight-channel system for temperature monitoring based on the PC and LabVIEW package developed for the purpose of this research. The ambient (laboratory) temperature was recorded using the special digital instrument. The surface temperatures, measured by system of thermosensor and obtained by thermal imaging camera, were compared resulting in the establishment of the appropriate correlations.*

*Keywords: temperature monitoring, LabVIEW, IR thermography.*

Monitoring of the temperature images of the heated or cooled objects is of great importance. For example, the chemical reaction of cement hydration that results in the formation of hardened cement stone, is an exothermic reaction, therefore, the certain amount of heat is released [1]. The amount of the released heat (the heat of cement hydration) mostly depends on the following parameters: type and composition of the cement, ambient conditions (temperature and humidity), amount of cement in the concrete, other components of the concrete, and the dimensions of the concrete elements that are produced [2, 3]. The heat of cement hydration also affects the structure of the hardened concrete, its strength and durability. The excessive heat of hydration may cause the cracks and fractures in massive concrete elements only a few hours after the concrete works are finished.

During the experimental examination described in this paper, the four types of concrete with different compositions were prepared. The concrete compositions differ in the mass of the following components: water, cement, mineral admixture (fly ash and chemical admixtures) superplasticizers and binding accelerators.

**Experimental technique**

The heat of hydration effects were monitored simultaneously on the four representative samples of prepared concretes (fresh concrete casted in the cube with edge length of 15 cm on the vibration table), using the IR thermographic camera (FLIR AX8) for temperature monitoring at the surface of the objects. At the same time, the monitoring was as well performed by two thermocouples (IC LM35), installed in the centre and at the surface of each sample.

The thermographic video was recorded using the VLC program. The eight-channel system for measuring, displaying and storing the temperature in time with the installed thermosensors was provided for four concrete samples. The ambient temperature (in the laboratory), recorded by a suitable device (FLIR DM93), ranged from 24.3°C at the beginning to 22.2°C at the end of the experiment. Temperature monitoring of fresh concrete lasted for 24 hours.

Experimental setup for monitoring the effects of the heat of fresh concrete hydration includes an IR thermographic camera FLIR AX8 connected to the computer that records thermographic video. LabVIEW application for temperature measurement in 8 points is running at the same time on the other computer.

**Multi-channel system for temperature measuring**

For the purposes of this study, a system was developed for measuring the temperature of the samples in 8 points. The system was based on the PC and LabVIEW package.

*A. Hardware*

Based on the expected temperature range and the required accuracy, an integrated circuit LM35 was used as a thermosensor [4]. With an additional resistor (100k) towards the negative source (5V), measuring of the negative temperatures was enabled. Fig. 1. presents the hardware of the developed eight-channel system for temperature measuring.

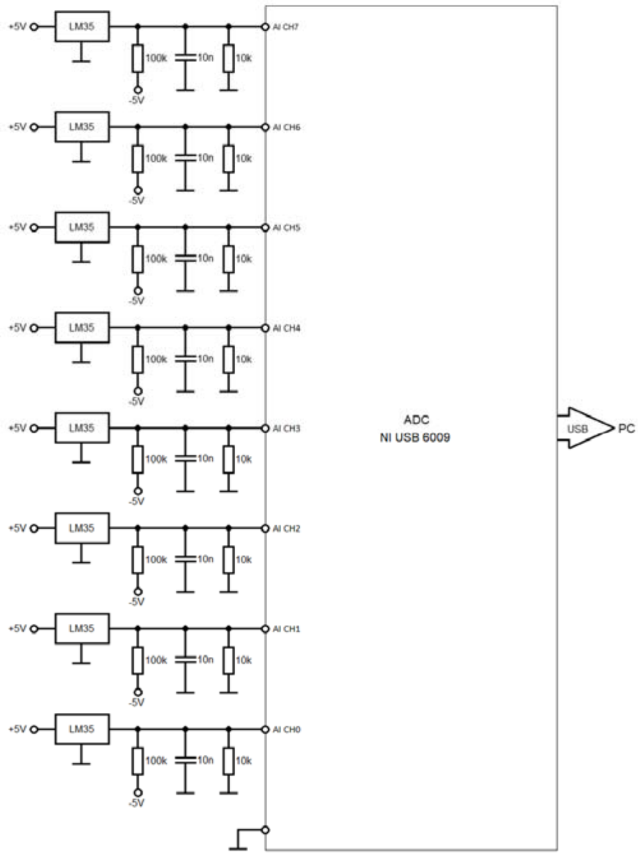


Fig. 1. General scheme of hardware of the system for temperature measuring

After the filtration (capacitors of 10 nF) and the adjustment (resistors of 10 kΩ) the signals from thermosensor were lead to the input channels (from AI CH0 to AICH7) of the analog-to-digital converter (ADC USB 6009) [5]. The obtained digital signals through the USB port were transmitted to the computer (PC) in order to be processed by the software.

Thermosensors are manufactured in the range from –40 to 110°C, so the further adjustments are not required. Since the system is widespread, for the transmission of the analogue signals to relatively large distances (a few meters) the shielded conductors for each channel separately were used.

*B. Software*

The application for measuring, displaying and storing the temperature in 8 points was implemented in the software package LabVIEW [6, 7].

Graphic code (block diagram) of the application is presented in the Fig. 2, and the front panel of the virtual instrument is presented in the Fig. 3. Analog signals from the thermosensors are measured by DAQ Assistant, standard module of the LabVIEW package for the data acquisition. Then, the obtained data are divided into eight channels, averaging (MEAN) and multiplying with 100, temperature in 0C (output from LM35 is 10 mV/0C). The obtained temperatures are shown on displays Ti[0C] and diagrams (XY Ti), and furthermore are stored in text file that’s name is defined before the measuring process. The program can be stopped at any time by clicking on the STOP button.

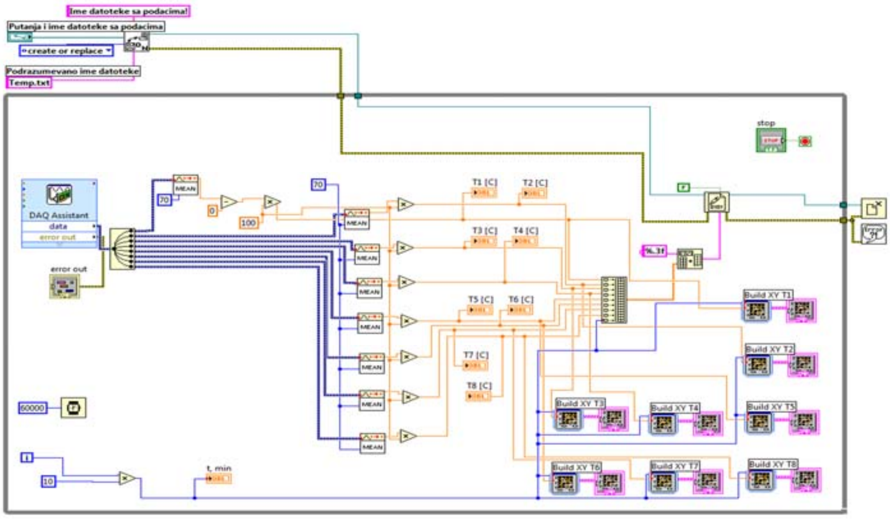


Fig. 2. Application block diagram

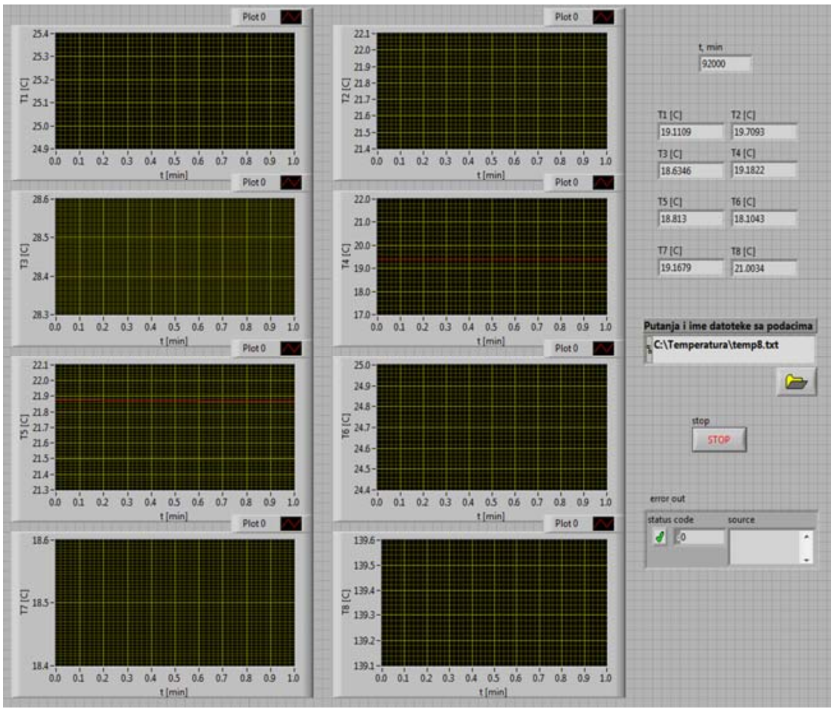


Fig. 3. Front panel of the virtual instrument

The separated diagrams are shown on the front panel of the virtual instrument in order to have transparency. The numerical displays Ti [0C], time display *t* [min], filename field, taster STOP and error code, if applicable, are as well displayed on the front panel.

**Results and discussion**

The measured temperatures for one set of samples are presented in Fig. 4. The obtained results have proven that the amount of released heat from the cement hydration process directly depend on the amount of the cement. The first and the second concrete samples reach the temperature of 26°C, the third — 25.5°C, whilst the fourth concrete sample have not shown any significant rise in temperature during the hydration process (the highest value of the measured temperature of the fresh concrete was 23.5°C). In this experiment, the binding accelerators caused the faster increase of the sample temperature (measured both on the surface and inside of the concrete), until the maximum point for the certain concrete type. The thermosensors have proven to be a highly reliable and simple way of forming the full picture of the cement hydration effect in concrete. Despite the fact that the surface of the concrete may release different amount of heat comparing to the inside of the concrete, the thermographic camera have provided the comparable results for all of the four types of concrete.

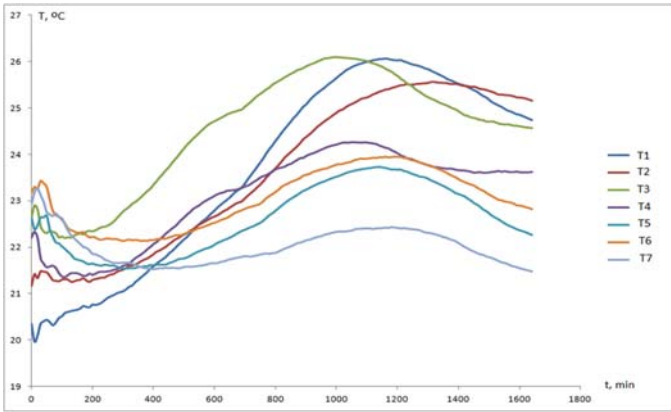


Fig. 4. Measured temperature values

**Conclusion**

The presented experiments have proven the ability to use the designed system for monitoring the hydration heat releasing process both with test samples and in the field, that might indicate important effect such as concrete structure disturbance, as well as monitoring the process of cement binding in concrete at both low and high temperatures of the environment. Following the previous, the increase of the scope of the research is expected, in order to have full insight in further development directions and limits of opportunities of the proposed method. The experiment setup has completely justified the expectations.

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**Мониторинг температурного изображения объектов**

*Температурные изображения различных объектов контролируются использованием тепловизионной камеры и термодатчиков, подключенной к восьмиканальной системе контроля температуры на основе ПК и пакета LabVIEW, разработанного для целей данного исследования. Температура окружающей среды (лаборатории) записывается и сохраняется использованием специального цифрового прибора. Выполняется сравнение температур поверхности, измеренных с помощью термодатчиков и тепловизионных камер. Исходя из этого, были установлены соответствующие корреляции.*

*Ключові слова: мониторинг температуры, LabVIEW, ИК-термография.*