XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22 –27, 2003 Dubrovnik, Croatia

ELECTRONIC METHODS OF DIKE STATUS MONITORING

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Abstract – Original electrical methods of piled up dikes status monitoring are described. Using these methods, progress of water infiltration and deformations inside of the dike body can be indicated. Some results are shown and discussed.

Keywords: dike, thermistor, electrical impedance.

1. INTRODUCTION

Frequent floods initiated intensive effort oriented to the hydrological situation forecasting in regions endangered by water and to the protective dikes building. Knowledge of dike properties and mechanisms of their damage by rush water makes possible to size up the importance of the endangering, and to ensure the life and possession protection in the risk region in advance. For purposes of forecasting the hydrological situation, mathematical modeling is applied. Physical models are used for studies of dike properties and destructive effects, and, thus test credibility of mathematical modeling results. These models are built up in laboratory conditions. The experiments described in this contribution, were worked out at the Laboratory of the water management of the Institute of Water constructions, which belongs to the Faculty of Civil Engineering of TU Brno. For purposes of these experiments, a brand new test channel has been built. It makes possible to pile up experimental dikes of defined shapes and dimensions. The channel is equipped with water control system, which can simulate different degrees of rush water, digital camera system, which provides visual monitoring of dike surface deformation, and makes possible to apply and manipulate electronic and piezometric measurement systems. Experiments worked out on physical models can be divided into three groups:

- Measurements of the water infiltration process inside of the dike body,
- Measurements of the dike deforming process because of the rush water slop over the top of the dike,
- Monitoring of structural changes of the dike construction.

For measurements on physical models of piled up dikes, two original electronic methods have been used besides traditional visual and piezometric methods. They made possible to observe dike properties and their changes because of rush water acting inside of the dike body.

The first method is based on the monitoring of the thermal scalar field inside of the dike body; the second one takes advantage of the electrical impedance measurement in different parts of the dike. The next paragraphs describe both methods, and show achieved results.

2. MONITORING OF INTERNAL TEMPERATURE

Thermistor sensors have been used to the temperature monitoring in the internal space of the tested dikes. The sensors have been placed to defined equidistant positions to create space matrix inside of the dike body. The goal of the measurement is to capture the point of the thermal jump caused by the contact of infiltrating water with the sensor. Well-known sensor position and system time make possible to observe the process of infiltration in the space of the sensor matrix, and to reconstruct the progress of this effect in time. As far as the effect of the dike damage has been concerned, the second thermal jump, caused by denudation of the sensor and subsequent water flow round the sensor, indicated the dike brake in the place of the sensor.

Applied thermistor sensors were small (diameter of 1 mm), comparable with the grain size of the dike material, so that did not affect the dike properties. The thermistor pearls were coated by a waterproof paint and placed in the insulating tube. The entire thermistor matrix contained 128 sensors.

The unique data logger, built up for these measurements, supplies the sensors by the constant current, provides switching of channels, and measures voltage drop on sensors. Measured voltage drops are digitized in a 12-bit ADC and processed in the embedded digital signal processor, which controls the data logger function and sends data to the PC via the asynchronous serial link. Measured voltages, which represent thermal state of the sensor, are compared with the beginning magnitude, and the differences between both values, the present and the beginning ones, are archived.

The typical process of this voltage difference measured on one sensor during time of the experiment of the water infiltration is shown in “Fig.1”.

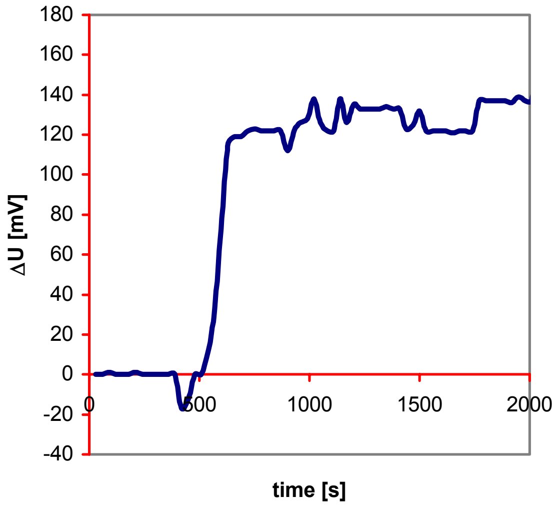

Fig.1. Example of the voltage drop on a thermistor. The rapid growth of its magnitude indicates the contact of infiltrating water with the sensor

The archived results have been processed off-line. Moments of the contact of sensors with water have been evaluated and compared, and probable water position in defined time periods have been calculated. Such a result is visible in the “Fig. 2”.

“Fig. 2” shows the progress of water infiltration in the dike body in the longitudinal direction. The daggers show sensor positions. The curves are isotherms measured during the time of the infiltrating process. Deformation of curves indicates material inhomogeneity.

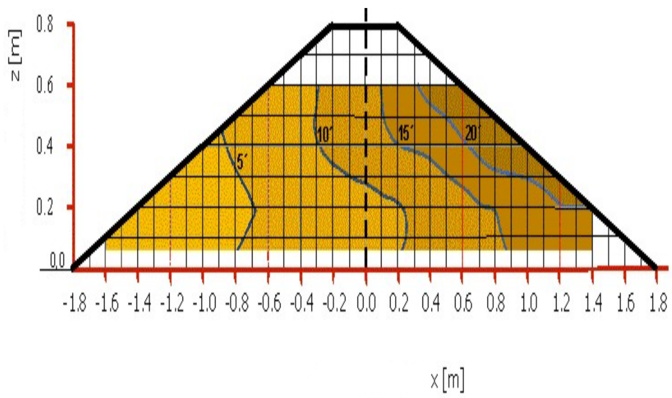

Fig. 2. Curves of infiltration inside of the dike.

3. MEASUREMENT OF THE DIKE MATERIAL IMPEDANCE

The method of the electrical impedance spectroscopy [1] has been used to the measurement of the structure and state of the dike, piled up in the laboratory flume. The stainless steel electrode system consisting of several electrode pairs has been plugged-in to the dike body. An electrode pair installation is shown in “Fig. 3”. In this picture, the principal of two-electrode, and two-terminal method of impedance measurement is shown. Electrodes E1 and E2 create the electrode pair, which is supplied by the a.c. signal of selected amplitude and frequency generated in the digital synthesizer (A.C). The impedance meter (Z-meter) is connected in parallel to the a.c. power supply. This creation is simple and makes possible good manipulation with electrodes and the instrumentation. Nevertheless, this simplicity adds the transient resistance error to the results, and, therefore, the use of this method is limited on cases of observing the water infiltration process.

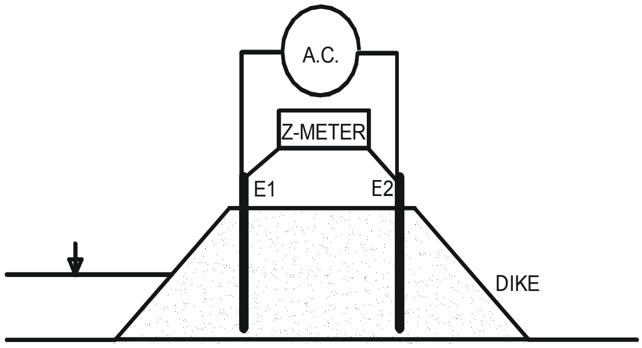

Fig. 3. Installation of an electrode pair and connection of the instrumentation

If changes of the dike structure or shape are to be monitored, the use of the second (potential) pair of electrodes, connected with potential terminals of the Z-meter, is necessary.

The impedance spectrometer connects the a.c. voltage to the measuring circuit and measures three voltages - voltage drops on measured impedance and the standard resistor connected in series with measured impedance, and on the a.c. power supply. If the quadrature detection is used, there is possible to construct the impedance vector diagram and evaluate both, real and imaginary parts of the measured impedance. Two basic types of the experiment have been worked out. For dike material studies, the measurement of the imaginary part within the frequency range 1 – 100 kHz has been done (“Fig. 4”). Narrow glass cylindrical vessel has been used for this group of measurements. Electrodes have been placed to fix positions inside of the vessel, and the vessel has been filled by tested material of defined humidity. The distance between electrodes has been small enough (… cm), so that measured reactance has been determined by dielectric properties of the tested material. These properties are determined by material permitivity and size of its grain. The difference of the experiment results can be seen in the “Fig. 4”, where samples signed as Sand 1 and Sand 2 come from the same sand mine, but differ in the grain size (Sand 1 is rougher), and sample signed as Glass contains glass globes (very pure silicon dioxide). All samples have had the same level of humidity.

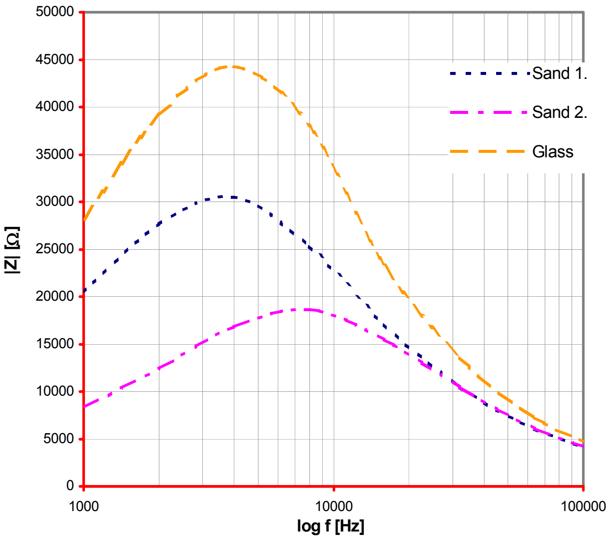

Fig 4. Absolute value of reactance of different materials

For purposes of the infiltration process monitoring, the measurement of the real part at a single frequency (10 kHz) has been used. The goal of this measurement is the observing of changes of the material conductance with the degree of water infiltration in the dike material. The conductance in a square cross-section of the dike material is proportional to the infiltration water level. This effect makes possible to monitor changes of this level inside of the dike. "Fig. 5" shows such an experiment result. For this experiment, the dike of the cubic shape has been piled up. During this measurement, rush water level rapidly grew up, went down (rush water curve), and this cycle has been one more time repeated. The other curves are the responses on the water level changes in different parts of the dike body presented by electrode pairs positions.

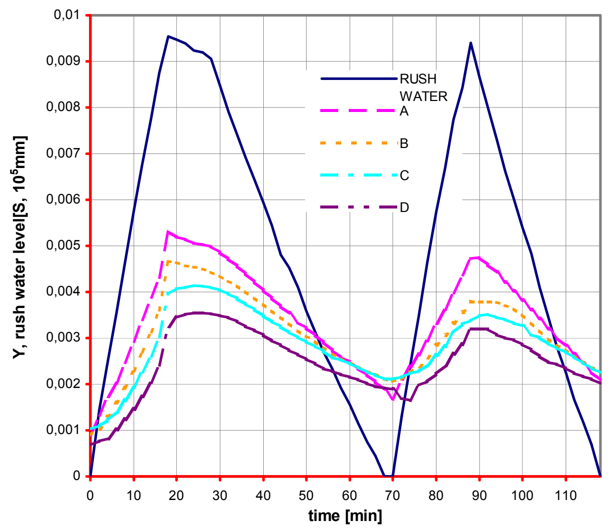

Fig.5. Response of the penetration process on water level fluctuations.

4. CONCLUSIONS

Both methods show the possibility to observe dynamic effects of water infiltration and deformations inside of the dike in laboratory conditions. Comparing with frequently used visual methods; the capability of discovering material inhomogeneities, together with the possibility of indicating the internal dike status, mean the important contribution of these methods. The results that have been gained on prototype-like models show the possibility of the application of both methods on real dikes. The results also show further possibility of improvements of the sensitivity and information content of used methods. As to the thermistor application, their use in a form of anemometer is planned. The use of the anemometric method promises improvement of the method sensitivity in cases, when dike material and infiltrating water have the same temperature. Further development of special potential electrode system should make possible to observe structural changes of the dike construction, as well as its deformation. The research goes on, and is carried out within the granted project No 103/01/0057 (Czech Grant Agency).

REFERENCES

[1] The Impedance Measurement Handbook, Application Note Hewlett – Packard, 1994.