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FLOOD EMBANKMENTS MONITORING SYSTEM

The article presents a concept of a system of continuous monitoring of flood embankments with the use of currently available ICT technologies. Architecture and the system description as well as benefits resulting from its implementation were presented. Measuring sensors proposed for use in the measuring part of the system were characterized. Presented in the article concept of the system is a result of scientific cooperation between IHP Frankfurt (Oder) and University of Zielona Góra.

SYSTEM MONITOROWANIA WAŁÓW PRZECIWPOWODZIOWYCH

W artykule przedstawiono koncepcję rozwiązania systemu ciągłego monitorowania wałów przeciwpowodziowych z zastosowaniem współcześnie dostępnych technologii teleinformatycznych. Przedstawiono architekturę i opis systemu oraz korzyści wynikające z jego wdrożenia. Scharakteryzowano czujniki pomiarowe proponowane do użycia w części pomiarowej systemu. Prezentowane w artykule rozwiązanie systemu jest wynikiem współpracy naukowej pomiędzy IHP Frankfurt i Uniwersytetem Zielonogórskim.

1. INTRODUCTION

Flood embankments are an important element of the flood protection infrastructure. The disastrous floods that occurred in Poland and Europe in recent years (1997 and 2010) have caused significant damage to the economy and infrastructure of individual countries. This situation necessitated the development of national and international flood protection programs. The European Union also addressed this problem in two documents: the Water Framework Directive of 2000 and the Floods Directive of 2007. In assessing the risk of flooding, resulting from the condition of flood embankments, and for the needs of crisis management during floods, continuous monitoring system of flood embankments can play an important role. The article presents the concept of building the system for continuous monitoring of the flood embankments of the Odra River at the neighbourhood of the cities Słubice/Frankfurt, using IoT technology.

2. FLOOD EMBANKMENTS MONITORING

The current practice of assessing the technical condition of a flood embankments is based on annual inspections and periodic inspections of the technical condition (every five years). The designed system is not intended to replace the conducted inspections and control of the technical condition of the flood embankment. The scope of continuous measurements carried out at research points will cover only selected geotechnical parameters of embankments and will be a guide for inspections, which may affect their rationalization. Periodic inspections are insufficient to reliably assess the condition of flood embankments, which directly affects the extent of losses caused by floods due to damage or breakage of the embankment. Appropriate assessment of the condition of flood embankments should be carried out basing on data from measuring sensors obtained in a regular manner, which would be collected and processed by the designed system. This approach allows you to constantly compare the results, and especially to analyse their trends over a longer time horizon. The automation of the process of collecting sensor data in real time, proposed as a part of the system, involves the use of sensor measuring nodes, grouped into a wireless sensor network. Due to the assumed many years of unattended operation, the sensor measuring nodes will work in the measurement/standby mode and will provide information at discrete moments about the measured physical quantities, such as temperature, humidity, pore pressure or water level. Based on the measured values, other intermediate features of the measured shaft will be determined. Information from the measuring sensors will be collected in a databases located at the University of Zielona Góra Computer Centre and at the IHP Frankfurt (Oder) and will be used by the developed application software. Data from measuring sensors (current and historical data for the selected period) and the results of their processing will be made available to authorized end users through a web applications, other defined protocol as well as API to implement additional services.

3. SENSORS FOR FLOOD EMBANKMENTS MONITORING

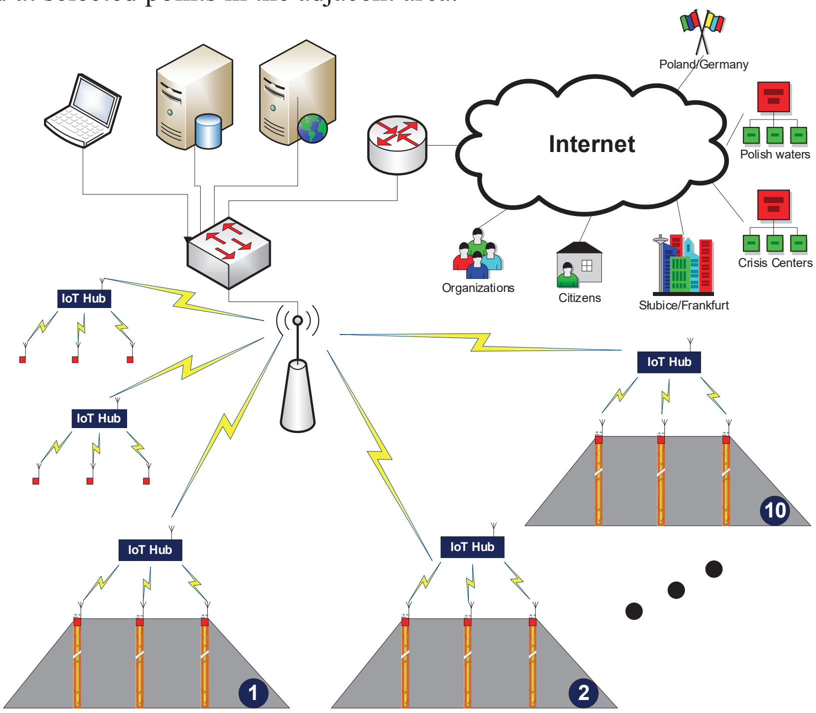
In order to determine the condition of flood embankments, and in particular to locate places where the development of filtration and erosion processes take place, temperature, humidity, pore pressure, soil pressure, piezometers and inclinometers are used in flood embankment monitoring systems. The sensors are installed both in the body of the flood embankments and in its surroundings. Temperature sensors measure gradients of temperature changes that are dependent on changes in thermal conductivity within the monitored shaft. The dominant type of temperature sensors used and recommended for flood embankment monitoring systems are resistance sensors [1,3,4]. There is also a growing interest in fiber-based temperature sensors. Depending on the type of flood embankment body, these sensors are recommended to be used on the air side of the embankment or behind the vertical partition in the embankment crown. The temperature measurement accuracy of the sensors is 0.1 °C and measurement methods used as well as the resolution achieved (measurement with an accuracy of one meter) allow for very precise indication of places where hazardous filtration and erosion processes occur. These solutions are expensive and are currently used only in sensitive places [3]. In assessing filtration processes, it is important to know the dynamics of changes in the groundwater level in relation to the water level in the river. To this end, piezometers with string sensors are installed [1,3]. One of the most important sensors used in flood embankment monitoring systems are pore pressure sensors. They allow locating and assessing the development of the embankment destruction process. The pore pressure sensors also allow the measurement of groundwater levels. To measure displacements in the shaft body, angular displacement sensors used in inclinometers are used. Due to the way this parameter is measured, this type of sensor is not foreseen in the proposed flood embankment monitoring system. Based on the assessment of the functioning of the flood embankment monitoring systems constructed so far, fiber optic thermal monitoring and measurement of changes in pore pressure are the most effective methods of locating and developing filtration and erosion processes. [1,4] In Poland, a team of AGH scientists from Kraków built an experimental embankment in Czernichów and a system of continuous monitoring for research purposes. The above-mentioned measuring sensors were used in it and during the tests it was shown that the data obtained from the measuring sensors were useful for assessing the condition of the flood embankment [2].

4. IoT ACHITECTURE

The evolution of the Internet has led to a situation in which simple devices, logically addressable with public IPv.6 addresses, are connected to the hierarchical structure of the public Internet, created by Internet operators and routing devices. The devices operate in our environment or industry creating the Internet of Things (IoT). In the IoT architecture, to this already existing hierarchical structure of the Internet, data from these simple devices are sent via IoT hubs (IoT Hub) or IoT gateways (IoT Gateway) to the cloud, where they are collected, processed and analysed. IoT hubs and IoT gateways are new devices that perform the function of aggregating data from simple nodes most often through wireless communication links and data transfer to the cloud. New lightweight application layer communication protocols such as MQTT, CoAP, AMQP, XMPP and the tunnelling protocol of the 6LoWPAN network layer have been developed for this communication, to compress IPv.6 address fields. However, the key device in the IoT architecture is the IoT gateway, which, in addition to data aggregation functions, IoT device management, implementation of functions related to data security and operational security, performs Edge Analytics functions. The functions of analytics at the edge of the network will be crucial especially for large IoT domains [2]. In the case presented in the article, due to the small number of measuring nodes, IoT Hub was provided as a device constituting the Internet access.

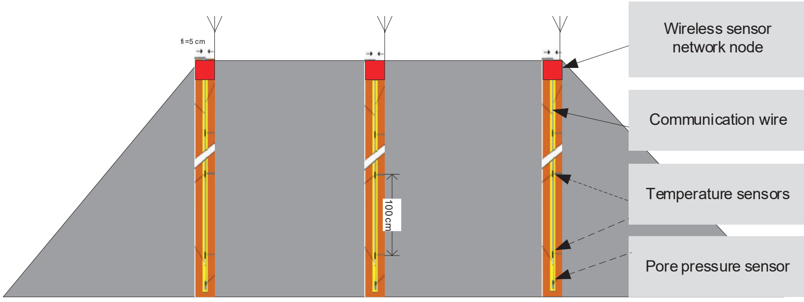
5. STRUCTURE OF THE MONITORING SYSTEM

The structure of the designed continuous monitoring system for flood embankments is presented in Fig. 1. The source of data in the designed system will be measuring sensors located in the flood embankment and at selected points in the adjacent area.



Rys. 1. Struktura systemu monitorowania wału przeciwpowodziowego
Fig. 1. Structure of the embankment monitoring system

The exemplary structure of the measuring node formed in cross section is shown in Fig. 2. The measuring node consists of a group of measuring sensors (humidity, temperature and pore pressure sensors) mounted in specific places and at specific depths in the shaft body. Adopting the convention of the measuring node with one IoT Hub, which includes measuring profiles arranged in the body of a flood embankment or in its vicinity is a solution that allows reducing the demand for electricity to power devices. Communication with a distant central node will be performed only through the IoT Hub. Local controllers that support measuring profiles will communicate with the IoT Hub, which aggregate measuring data. This solution is energy efficient. This system architecture solution also allows for simple implementation of protection of measuring profiles installed in the field against damage or devastation. Low Power WPAN class standards such as Bluetooth Low Energy, ZigBee or Thread can be used for local wireless communication between local controllers mounted in the upper part of the measurement profiles and IoT Hub. However, Low Power WWAN class standards such as LoRa, Sigfox, Weightless or NB-IoT can be used for communication between the IoT Hub and data centre.



Rys. 2. Węzeł pomiarowy w przekroju wału przeciwpowodziowego
Fig. 2. Measuring node in the cross-section of the flood embankment

Sensors for measuring temperature and humidity will be installed in each of the measuring profiles, with a defined distance between them, e.g. 1 m vertically, and a pore pressure sensor will be installed at the bottom part of measuring profile. Measurement information from sensors placed in the measurement profile will be read by the local controller, which is one of the nodes in the wireless sensor network. From the wireless network node, the measurement data will be sent wirelessly to the aggregation node IoT Hub, and then - also by wireless means - to the measurement server where they will be saved to the measurement database. It is assumed that both local controllers and the aggregating node will be maintenance-free devices. Measurement data will be processed by application software, and the results of the software will be made available to authorized users (in text and graphic form). From the user's point of view, the basic interface for processing results will be a web browser.

6. CONCLUSIONS

The article presents the concept of the system for continuous monitoring of the condition of flood embankments and adjacent areas in the Słubice region. The architecture of the monitoring system was presented and the basic requirements for the designed system were presented. Based on the analysis of data obtained from the measuring nodes and using the developed model for their processing, it will be possible to pre-assess the state of flood protection and indicate flood risk locations in the city of Słubice. Assessments obtained from the system of continuous monitoring of the flood embankments may be an indication for carrying out a more detailed identification of flood hazards on a given section of the embankment using geophysical methods.

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