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Monitoring of Structural Safety of Buildings Using Wireless Network of MEMS Sensors

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1 Introduction

Structural cracks are a phenomenon occurring in all types of buildings, regardless of the technology and material used. Ensuring structural durability and safety requires engineers to analyze the causes of cracks, as well as to plan and carry out appropriate repairs. Repairs and remedial measures are effective if engineers correctly identify the true causes of cracks.

One of the techniques for automatically collecting data on the operating conditions of the facility is a wireless monitoring network.

Selection of parameters for monitoring of building structural safety was influenced by currently conducted research in the Institute of Building Engineering, at the University in Olsztyn. In connection with the cyclical inventory of construction damages carried out at the Faculty of Geodesy, Geospatial and Civil Engineering by the Social Labor Inspectorate, it was decided to build a wireless system for monitoring the width of cracks and the impact of dynamic loads on building structures. The prototype system was installed in the building located at 4 Heweliusza Street in Olsztyn.

The design assumptions of the network were as follows:

- data transmission: LoRa wireless,
- registration of dynamic actions: acceleration sensor,
- registration of changes in crack width: Hall-effect sensor,
- reading frequency: one reading per minute,
- internal memory capacity (lost connection): data saved from 24 hours of observation,
- power supply: 3.6 V 18650 lithium-ion battery.

In the project, the service platform is a program that handles all events related to external requests and commands as well as internal, programmed tasks. Software (created in C++) was installed on a hardware platform equipped with a microcontroller. Due to the low requirements for computational power and the strictly defined range of processed numbers (mainly integers, without floating point numbers), the implementation of the hardware platform was based on Atmel 8-bit Advanced RISC Architecture AVR microcontroller - ATmega328PA.

In total, five modules were designed and manufactured (four nodes and one request center).

The dynamic loads have a negligible impact on the building structure. Noticeable changes in acceleration values are recorded during the building's hours of use, at night the sensors do not record vibrations of significant amplitudes, which is in line with expectations.

The width of the cracks changes its value cyclically, which indicates the normal operation of the building structure and does not indicate the development of further discontinuities that could lead to a failure condition. Observations made in the laser scanning laboratory confirmed that dynamic interactions coming from users are completely imperceptible. This confirms the correctness of the purpose of this room for a workshop of precise geometric measurements.

Preliminary results of measurements confirmed the effectiveness of the constructed monitoring system of the building structure. The most important conclusions that can be drawn from ongoing observations are as follows:

- LoRa wireless communication systems ensure trouble-free data transmission from sensor networks in high electromagnetic wave conditions (cell phones, WiFi, bluetooth etc.),
- cheap MEMS sensors can be successfully used to monitor dynamic effects on building structures,
- the monitored building, despite numerous wall cracks, shows no signs of progressing structure degradation.

It is obvious that observations lasting several weeks may not be sufficient to make recommendations regarding the safety of buildings, but created sensor network can certainly act as an early warning system for an impending failure or disaster.

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