

A LOW-COST TECHNOLOGY IN A STRUCTURAL MONITORING ON AN EXAMPLE OF CEILING BEAMS

Wilczyńska Izabela¹, Ćmielewski Bartłomiej², Patrzalek Ciecchosław³

Abstract

One of the parameters describing the state of a structural element of building – ceiling beam is the joist deflection. To its designation are used classical measurement methods such as levelling or tachometry. However, when it is required constant supervision - 24h, these techniques are not economical. To fill this measurement tools gap, authors proposed to use, simple measuring devices to ensure the continuity of observation with high accuracy. These devices would allow for real-time monitoring and the obtained data collecting to the database. In case of exceeding threshold limits, the alarm will be triggered to perform classical surveying and warned the building manager from possible danger.

Keywords

ceiling beam, MEMS, structural monitoring

1 INTRODUCTION

The construction works are usually composed of such components as foundations, walls, columns and roof beams, the functions of which may serve components such as beams or trusses. For monitoring of structural elements many geodetic surveying (tachometry, precision leveling, laser scanning, photogrammetry, etc.) and other (clinometers, inclinometer, extensometers, strain gauges, feeler gauges, pendulum, plummet, etc.) techniques can be used [6]. These methods allow to perform measurements with high precision and detecting the first signs of danger arising from exceeding the thresholds (defined by the designer). However the usage of such measurements is expensive, and the majority of this techniques base on periodic and spot metering.

2 CONCEPTION OF MEASURING DEVICES

Authors present the concepts of low-cost devices, performing real-time measurements. Prototypes have ability to freely configure and connecting the additional sensors in sensitive areas of the element. In the measuring instruments were used accelerometers, vibration sensors, piezoelectric elements and microphones [3,4]. These sensors base on MEMS technology (Micro Electro-Mechanical Systems), and their sizes are very small eg. 4x4mm. In laboratory studies cheap equipment (costing less than 2EUR) showed high accuracy allowing for the use of them in measuring systems [1]. In addition, accelerometers can detect vibrations, and this information is supplemented with data from piezoelectric transducers allow them to identify the amplitude and frequency [2,7]. Knowledge of these phenomena occurring at the facility will allow for the detection of deviations from the planned position of the element.

A simple solution designed to measure the deflections may be a system using a laser diode and a camera CCD/CMOS. The laser diode emits a beam, which is reflected from a mirror placed underneath the building walls on the matrix ccd. From the matrix position of the beam is being read in the system x, y. On the basis of the function $w = f(\delta x, \delta y)$, the displacement of the mirror can be determined, and thus the construction element. To perform such measurements is essential: diode laser, camera CCD/CMOS, plane mirror and the image recording module in digital form. Diode characteristics are: small size and weight, low supply voltage, light intensity dependence of the value of the supply voltage, low beam divergence and power, long period of work. The basic properties of ccd matrices are: cooperation with the computers and the ability to detect a laser light. The advantage of the method presented would certainly be the low price of preparation and handling of the measuring system, and continuity of measurements [5].

2.1 Prototypes

Geodetic survey on construction projects are dependent on many factors. These include first of all the dimensions and geometry of observation. Dimensions of the object and its structural relations of elements and phenomena occurring on the optical road (refraction, turbulence, dust, smoke, variable illumination). On the object the phenomena affecting the metrological characteristics of measuring instruments such as temperature, shock and vibration can occur.

¹ Wilczyńska Izabela, M.Sc. Eng, Wrocław University of Environmental and Life Sciences, Faculty of Environmental Engineering and Geodesy, Institute of Geodesy and Geoinformatics, Grunwaldzka 53, izabela.wilczynska@igig.up.wroc.pl

² Ćmielewski Bartłomiej, M.Sc. Eng, Wrocław University of Environmental and Life Sciences, Faculty of Environmental Engineering and Geodesy, Institute of Geodesy and Geoinformatics, Grunwaldzka 53, bartlomiej.cmielewski@igig.up.wroc.pl

³ Patrzalek Ciecchosław, M.Sc. Eng, Wrocław University of Environmental and Life Sciences, Faculty of Environmental Engineering and Geodesy, Department of Land Management, Grunwaldzka 53, Wrocław, Poland, ciecchoslaw.patrzalek@up.wroc.pl

In laboratory there are the appropriate conditions for testing of building elements in terms of the availability of components and the ability to control the burden process. Developed instruments will be tested in the laboratory. The measurements will be conducted under optimum conditions for geodetic surveys, therefore, will not be limited negative side effects.

Tests are designed to measure the displacements and deformations of structural elements such as beams (made of: concrete, wood, steel), trusses, columns. Measurements will be carry out in the traditional manner, using laser techniques (Fig. 1) and MEMS sensors (Fig. 2).

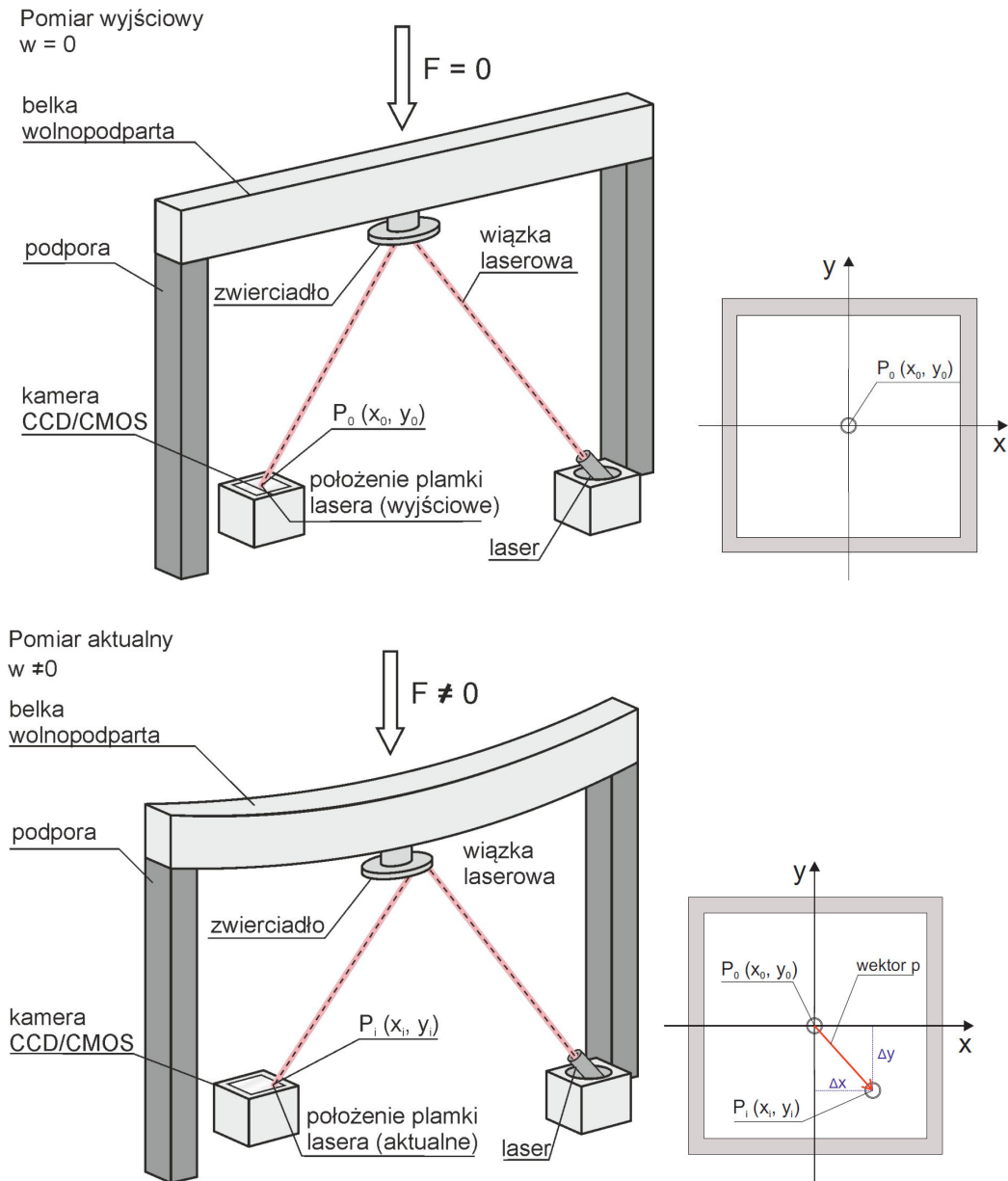


Fig. 1. Functional diagram of measuring system using of laser technique.

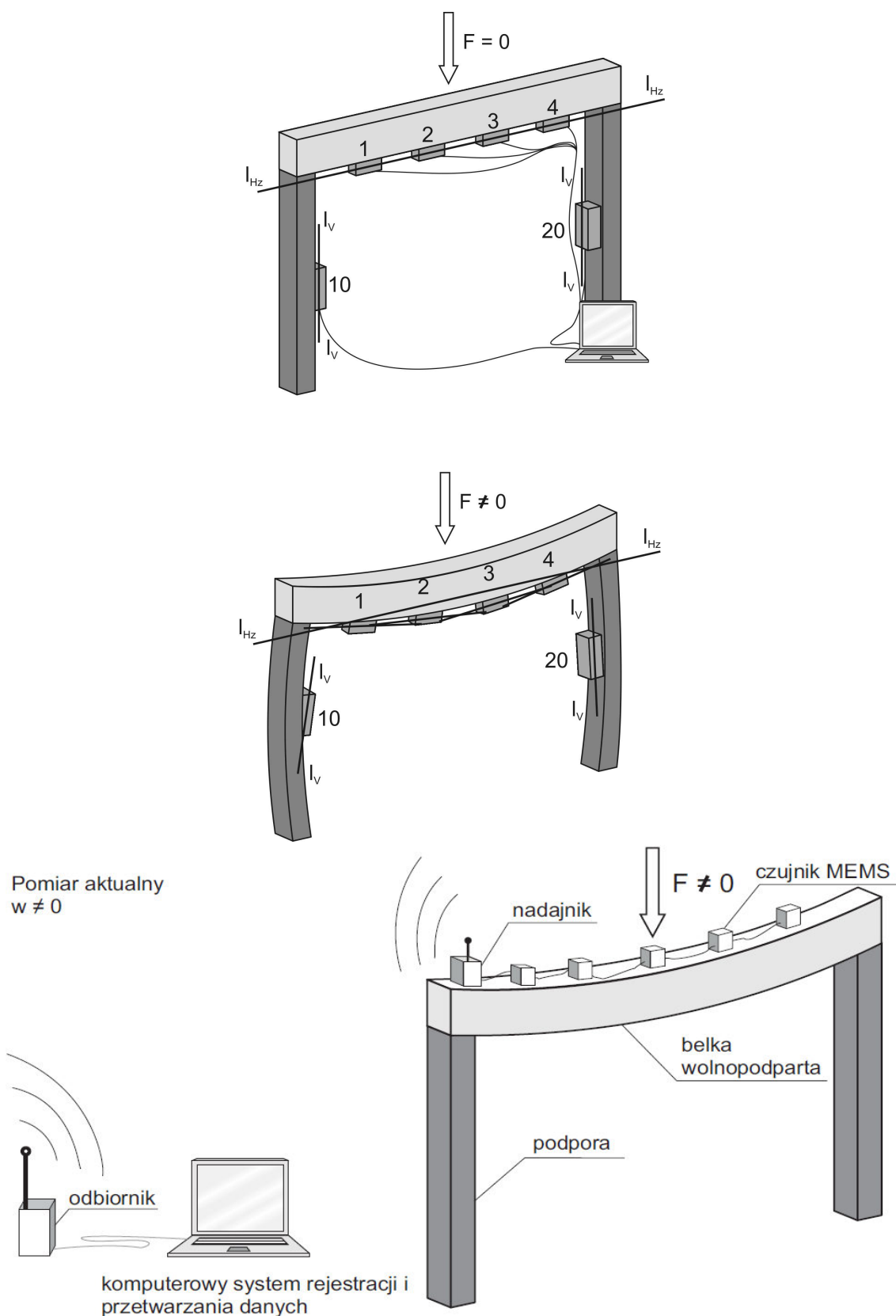


Fig. 2. Measuring system diagram of MEMS sensors, monitoring chosen section.

In case of beam or load bearing columns deformation occurring, the MEMS sensors transmit in real-time data to a central management computer which warns system in the object.

3 RESEARCH

The test of prototypes was conducted on press in Technology Laboratory of Materials and Structures at the Institute of Civil Engineering at the Wrocław University of Life Sciences. The beam equipped with several control methods is shown on Fig. 3.

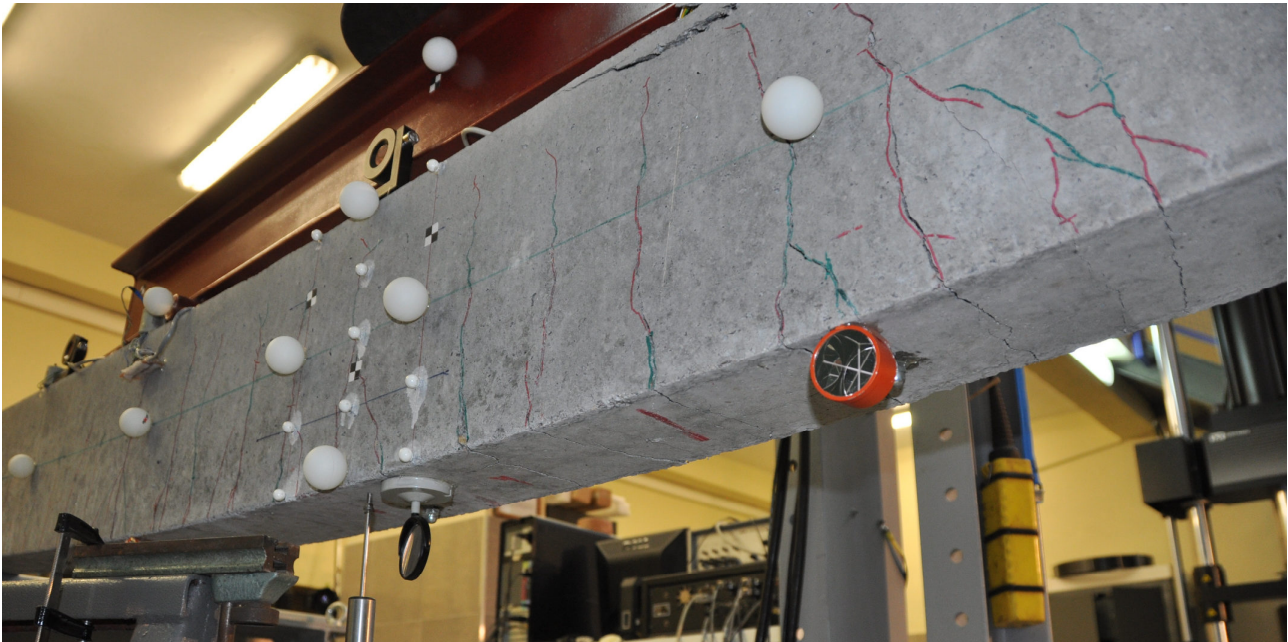


Fig. 3. Reinforced concrete beam on testing stand.

There were several method tested: tachometry, precise levelling, linear displacement sensor, hand laser ranging device “Disto”, MEMS technique and laser beam. Results of survey is presented on figure 4.

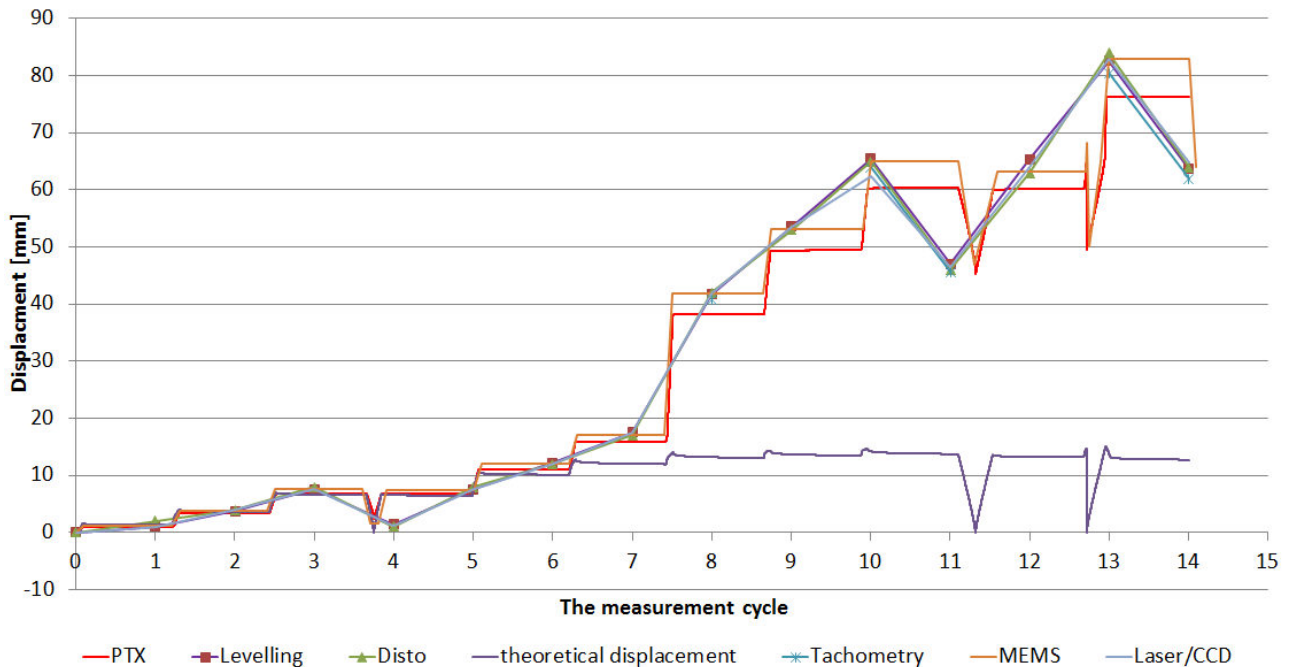


Fig. 4. Survey comparison

4 CONCLUSION

All tested methods gave consistent results. It is possible to create a low-cost assistive devices for structural surveying of beam components. These devices achieve sufficient accuracy to be used in warning systems, and help in control measurements by continuous survey. Prototypes using MEMS technology do not need visibility of the element.

ACKNOWLEDGEMENT



HUMAN CAPITAL
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN
SOCIAL FUND



This work is co-financed by the European Union as part of the European Social Fund

LITERATURE

- [1] Ćmielewski B., Kontny B., Ćmielewski K., Use of MEMS technology in mass wasting research, Reports on Geodesy, Vol. 1 No. 90, Warszawa 2011, pp. 85-92.
- [2] Gajek A., Juda Z., Czujniki. Mechatronika samochodowa, Wydawnictwa Komunikacji i Łączności, Warszawa 2008.
- [3] Grosse, C. U., F. Finck, J. H. Kurz and H. W. Reinhardt. 2004. "Monitoring techniques based on wireless AE sensors for large structures in civil engineering", in Proc. EWGAE 2004 symposium in Berlin, BB90, pp 843-856. Berlin: DGZfP.
- [4] Grosse, C. U., H.-W. Reinhardt, F. Finck: Signal-based acoustic emission techniques in civil engineering. J. of Mat. In Civ. Eng. 15 (2003), No. 3, pp 274-279.
- [5] Lukáč S., Žák M. 1999. Monitoring of deformation processes of the nuclear power plant J. Bohunice. Proceedings of 9th FIG International Symposium on Deformation Measurements, Olsztyn (Poland), 27-30 September, pp. 348-353
- [6] Setan H., Abidin Md Som Z., Idris K. M., 2003, Deformation detection of lightweight concrete block using geodetic and non-geodetic methods. Proceedings of 11th FIG International Symposium on Deformation Measurements, Santorini (Greece), 25-38 May, pp. 635-642
- [7] Spencer B.F. Jr., Ruiz-Sandoval M., Kurata N., Smart sensing technology for structural health monitoring, 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 1791

REVIEWER

Ćmielewski Kazimierz, Assistant Professor (dr hab. inż.), Wrocław University of Environmental and Life Sciences, Faculty of Environmental Engineering and Geodesy, Institute of Geodesy and Geoinformatics, Grunwaldzka 53, Wrocław, Poland, kazimierz.cmielewski@up.wroc.pl