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ORIGINAL PAPER

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CALIBRATION OF SURVEYING INSTRUMENTS AND TOOLS – MEANS TO THE QUALITY INCREASE OF DEFORMATION MEASUREMENTS

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ABSTRACT

Purpose	This paper describes selected control and calibration procedures of some surveying instruments and tools (digital levels and code bar levelling staffs, total stations and electronic tacheometers, and reflective systems).
Methods	The calibration of horizontal circles of optical and electronic theodolites can be carried out under laboratory conditions, e.g. on an automated device for the calibration of optical polygons EZB-3 in the Slovak Institute of Metrology in Bratislava (SIM).
Results	The results of testing the influence of lighting when working with a digital levelling instrument are presented. Furthermore, the procedure and results of the calibration of horizontal circles of surveying instruments on a calibration device (Slovak Institute of Metrology in Bratislava) are described in this paper.
Practical implications	The result of such calibration is a set of horizontal scale corrective values for particular nominal values of the scale, determined using a series of measurements, and eventually the provision of the parameters of approximating function.
Originality/ value	The use of a laser interferometer (laser measurement system XL 10 f. RENISHAW) for the calibration of the code leveling rod, respectively of the system calibration (digital leveling device – code late) prepared by the Department of Geodesy, SUT Bratislava with the help of European projects, will then be implemented in a unique facility in the Slovak Republic.

Keywords
calibration, testing, digital level, bar code levelling staff, electronic tacheometer, horizontal circle

1. INTRODUCTION

Currently, in addition to the conventional measurement systems: theodolites, electronic distance meters, total stations and GPS units are the most frequently employed instruments in surveying. The optical levels are gradually replaced by digital automatic levels and conventional invar staffs by bar code levelling staffs. These new levels equipped with a CCD sensor enable the full automation of staff reading and offer new benefits, such as greater accuracy of reading, automatic registration, the elimination of gross errors and mistakes, and the data measured is in electronic form with the possibility of further processing in different software environments.

2. TESTING AND CALIBRATION OF LEVELS AND ANCILLARY EQUIPMENT

Among the most frequently occurring errors in levelling, using digital levels, is the staff graduation error (Hánek, 2001; Melicher, 2001). This error has a systematic character and significantly affects the accuracy of the results of precise levelling measurements, e.g. measurements in the National Levelling Network, measurement of the vertical displacement of building structures etc. The calibration of the levelling staffs means that the influence of this error is minimal. The calibration measurement is performed using, for example, a linear laser interferometer. This method is suitable for levelling staffs with conventional graduation as well as for bar code levelling staffs. Calibration itself can be realized by various arrangements of the calibration equipment, i.e. by placing the levelling staff in a horizontal or vertical position. Below are examples of some calibration equipment – comparators.

2.1. Comparator using a laser interferometer at the Department of Theoretical Geodesy of FCE of SUT in Bratislava

A comparator using a laser interferometer (CLI) with its accuracy and traceability to the national standard of length of the Slovak Republic at the Slovak Institute of Metrology (SIM) represents the most advanced item of metrological measurement of length at the Department of Theoretical Geodesy. Values of all onward comparators up to the parameters of the length baseline in Hlohovec are derived from CLI. CLI was calibrated at SIM by measuring the differences in the frequency of the laser Δf to the national standard of length of the Slovak Republic (laser SIM B2) with extended relative uncertainty $U = 6.8 \cdot 10^{-11}$ ($P = 0.95$) (Ježko & Bajtala, 2005). CLI allows for the contactless calibration of all linear measures whose scale (lines) can be set up under the adjustable microscope of the comparator. By using CLI invar levelling staffs of varying length, control invar measures and other working measures and standards can be calibrated. It is also possible to carry out verification (calibration) of the foldable levelling staffs (4 m), base staffs, measuring bands etc. (Ježko & Bajtala, 2005). Currently, these laboratories are not in use as they are currently under reconstruction.

2.2. Horizontal comparator for bar code levelling staffs

The core of the laboratory is the 30 m long calibration bench with two moving trucks (Fig. 1), their distance from the reference point is measured by the laser interferometer HP5507B. Levelling staff, located on the moving trucks, is supported at Bessel's points. On the bench an electro-optical microscope is mounted, trucks with fixed levelling staff move under the microscope. This determines the position of all elements of the staff code.

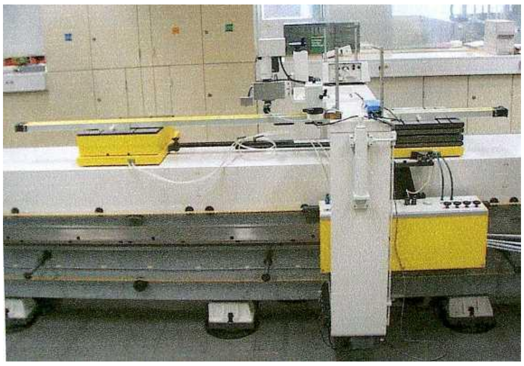

Fig. 1. Horizontal comparator

2.3. Vertical comparator for bar code levelling staff and system calibration

The vertical comparator (Fig. 2) enables the calibration of levelling staff in the vertical plane. The value of movements is measured by a laser interferometer, similar to the horizontal comparator. The vertical comparator can be used for the calibration of levelling staffs in the vertical plane and for, so called, system calibration as well. The advantage of this procedure is during calibration the levelling staff is in the same position as it is in field measurement.

In general, it is assumed that the scale of the measuring system is a scale of staff determined by calibration. Eventually, the properties of a level and levelling staff can vary, and thus in order to control the whole system it is necessary to carry out system calibration. During system calibration the correct values of the readings on the staff are determined, from which it is possible to determine the scale of the whole digital levelling system, the stability of the whole system in time and also to estimate the accuracy of the whole measuring system. A similar system is in use in Japan (The Geographical Survey Institute) and in Slovenia (The University of Ljublana). The vertical comparator for the calibration of levelling staffs in the vertical plane, also enabling system calibration, is in operation in the metrological laboratory of the Technical University in Graz (Austria). The Finnish Geodetic Institute has been performing automatic calibration of levelling staffs by means of a vertical comparator from 1996 and system calibration from 2002. A similar calibration system is also in operation at the Technical University in Ostrava.

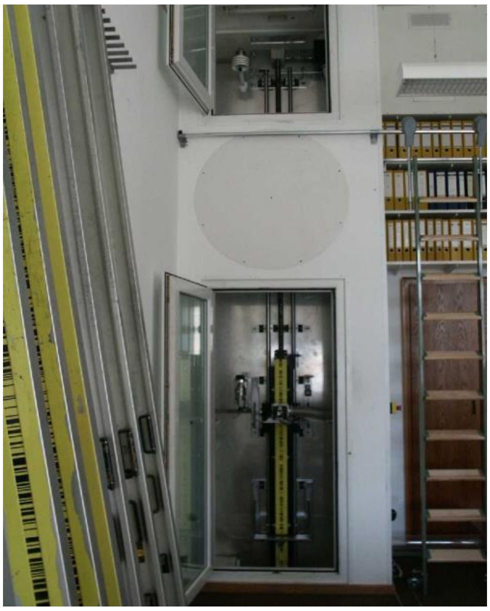

Fig. 2. Vertical comparator

2.4. Calibration system at the Department of Surveying of FCE of SUT in Bratislava

The preparation of the calibration system is carried out using a laser measuring system. The linear interferometer is based on a frequency stabilized He-Ne laser of energetic class II (it can be used without special safety equipment). The laser head also contains an optoelectronic sensor of interference field and electronic network in order to process the values measured, i.e. the interpolation of the interference signal with a resolution of up to 1 nm and the compensation of the length expansion of the measured object. The interference system together with the units for environment compensation and with the electronic part of the system enables the measurement of length with a resolution of up to 1 nm (dynamic measurement is also possible), angle measurement in a range of ±10° and the measurement of differences of evenness. The system can be used in order to calibrate invar and bar code levelling staffs, to test electronic distance meters, to observe movements of constructers etc.

The Department of Surveying of Faculty of Civil Engineering at SUT in Bratislava has currently at its disposal the laser measuring system XL 10 co. RENISHAW (Fig. 3, 4), working with an accuracy (P = 95%) of linear measurement 0.5 μm per 1 m of measured length in the entire range of the defined measurement conditions – air temperature from 0 to 40°C and a pressure of 650–1150 hPa in the measured path – with a maximal range of linear measurements of 80 m. This system means that the reading of values of length with a frequency of 50 kHz at maximal speed of length change