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MEASUREMENTS OF DISPLACEMENTS OF ROCK MASSIFS IN THE ENVIRONMENT AND THE INTERIOR OF THE BEAR CAVE IN KLETNO

K. Monkolski, P. Rozmus, K. Piyenkosh, P. Goldyn
Institute of Geodesy and Geoinformatics of Wroclaw University of Environmental and Life Sciences.

L. Lubenets, I. Romanyshyn
Lviv Polytechnic National University

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Introduction

The paper is a review of geometrical height precision leveling of research network established in the environmental and the interior of the Bear Cave in Kletno, Eastern Sudeten, carried out by members of Students' Scientific Circle of Geodesists in July 2010 and compared to earlier measurements results. Displacements surveying are conducted on initiative and under supervising Institute of Geodesy and Geoinformatics workers (Wrocław University of Environmental and Life Sciences): Stefan Cacoń, Krzysztof Mąkolski, Mirosław Kaczałek – managers of SSC of Geodesists. The surveying has carried out annually from 1984 (Cacoń S. et al. 1989, Cacoń S. et al 1996, Mąkolski K. et al 2008).

The paper presents research of reference system stability, precise leveling measurements and vertical displacements of controlled benchmarks graphs. Surveying are conducted to ensure the object and visitors safety.

Bear cave characteristic

Bear Cave is located in Kletno, small village in southern Poland in a wider tectonic fault zone of Sudeten under Mt Śnieżnik, Klodzko Valley. It is the biggest cave in Sudeten and the one of the largest in Polad. Its formation is associated with occurrence marble in Sudeten, which favours karst formation. In Bear Cave there are many beautiful stalactites, stalagmites and other characteristic forms. All of them we can watch walking along visitor's path inside the Bear Cave, which were opened for public in 1984. Almost all the time inside the cave there is constant temperature (6˚C) and humidity reaching 100 %.

Precise levelling network in the environment and the interior of the bear cave

Opening the Bear Cave in Kletno for public called for permanent stability observations in the area, especial when in nearby quarry were mined marbles. Precise levelling network were established in 1984 to ensure safety of tourist path passing through the cave, provide information about crustal changes near the Bear Cave and superficial displacements of cave massif.

Localization of the network points had to take into consideration geological, tectonic, and geomorphologic characteristics of the massif, also details and topographic mountainous region.

There were established two connected networks outside and inside the cave. Inside the cave there are 24 benchmarks along the tourist path, and 23 benchmarks in the cave surroundings, along the Kleśnica river and Kletno – Kamienica road. Network points which are located outside the cave were stabilized by concrete blocks down to depths below ground freezing level. Levelling network points which are permanently connected with the rock or located directly above the rock is a great source of information about rock massif. During the surveys four damaged benchmarks had to be restored. It were benchmarks 3, 4, 7 and 27.

Measuring principles and instrumentation

Precise leveling measurements network in the environmental and the interior of the Bear Cave give us information about vertical benchmarks displacements.

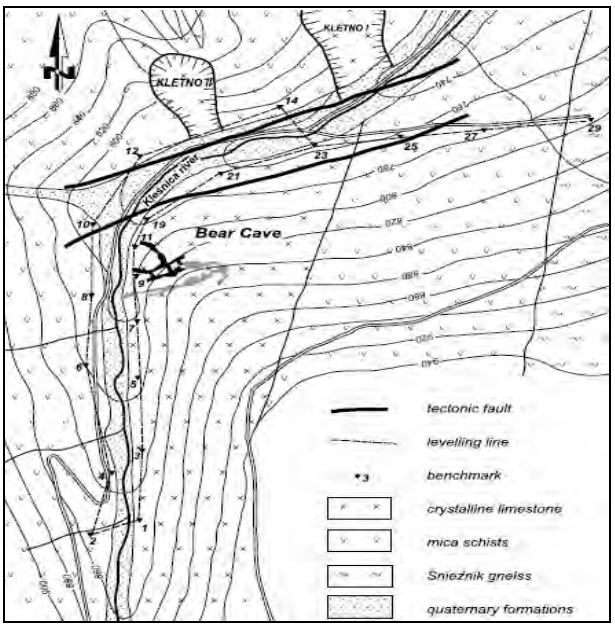


Fig. 1.Precise levelling network in Bear Cave surroundings

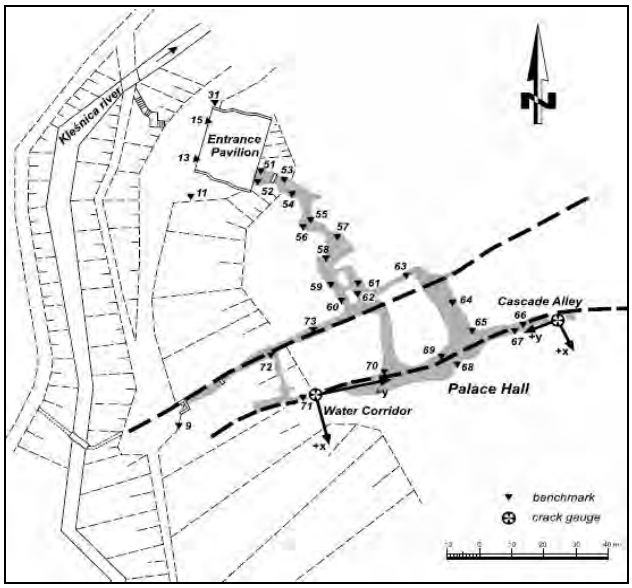


Fig. 2.Positioning of benchmarks in Bear Cave

Measurements have been performed during summer by members of Students' Scientific Circle of Geodesists since 1984 (the beginning of surveys). Benchmarks inside and in surroundings the cave has been measured every year.

Measurements have been made using compensative levels of high precision: Ni 005, Ni 007, precise leveling rods with brackets and metal wedges needed for detailed identification of implicit measurement points. Since 2008 benchmarks outside network have been measured by precise digital level Leica DNA 03.

Analysis and geometrical interpretation of results

The main analysis issue is selection of appropriate reference points. It is not easy, because rock massif is not a typical object. The best solution is selection points among existing networks. Three points are recognized as fixed and two of them are localized directly in rock, near the entrance and exit from the cave. Stability of these points is checked every year.

Corrected results of measurements from each cycle are elaborated using Cgeo v.8 software by Softline.

Calculations made after each part of measurements provide: adjusted benchmark elevations (Hi) and their mean errors (mHi); displacements of controlled benchmarks (ΔHi) and their mean errors (mΔHi).

Displacements analysis

Displacements analysis in this paper applies to measurements in 1984, 1998, 2002, 2006, 2010. Geometrical interpretation is based on comparing displacements value and its mean errors, according to formula: $\mathbf{p \geq 2}$ **mΔH** where: p- displacements value, mΔH- mean error of displacement value.

Benchmarks displacements in surroundings Bear Cave shows graphs. From the beginning of measurements points 2, 8, 27, 31 was significant moved (fig. 3). In the next period of time benchmarks change might be a result of changing water level in the ground, especially in 1998 when in that region were rainfalls and flood. This fact proves all benchmarks subsidence (fig. 4). After next four year displacements values were higher than earlier (fig. 5). Those changes might be result from instruments conditions, which after that time were not so accurate like it had been earlier. Benchmarks located above Bear Cave uplift in turn these located beneath – depress. Recent measurements (fig. 6) show height's changes of benchmarks which are established near tectonic fault (benchmark 14 and 23). Those points behave different than others located beyond tectonic fault impact. It might be an effect of movements in this area.

To analysis were chosen benchmarks: 1, 2, 5, 6, 14, 23 outside the cave and 52, 75 inside. Graphs of resulting displacements are arranged in pairs. Points in pairs are on the same side of Kleśnica river (the same bedrock) or located on both sides the river (different bedrock). Line connecting periods of time is dotted, because the annual measurement interval is too long, so it is not a permanent surveying.

The benchmarks pair inside the Bear Cave, benchmark 52 is located near the entrance, benchmark 72 is next to the exit from the cave (fig. 7). Clear parallel course of replacements values,it means that the same bedrock movements impact.

Fig .3. Benchmarks replacements 1984-1998

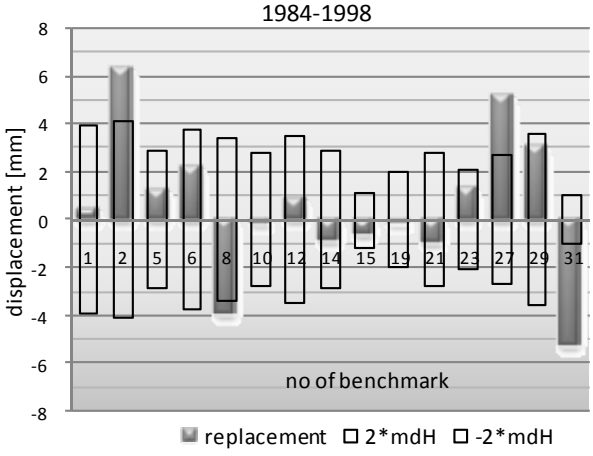


Fig. 4. Benchmarks replacements 1984-2002

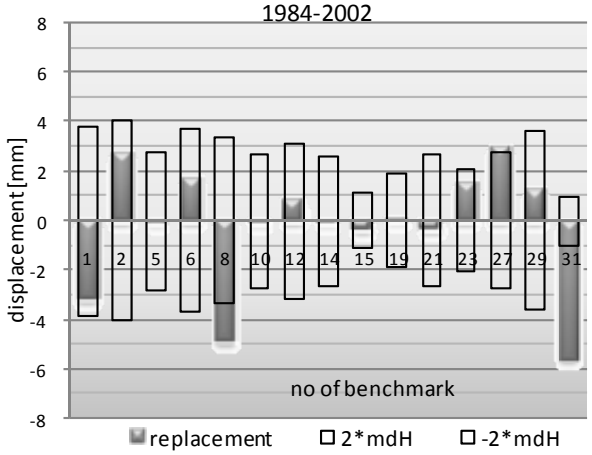


Fig. 5. Benchmarks replacements 1984-2006

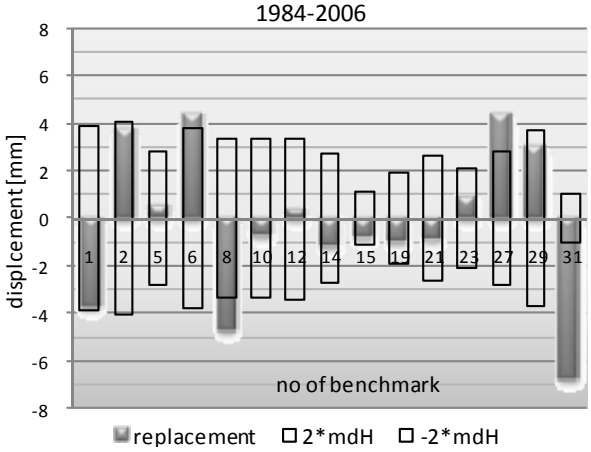
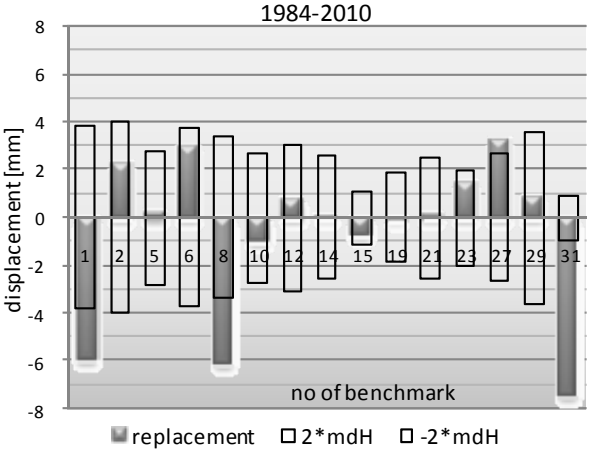
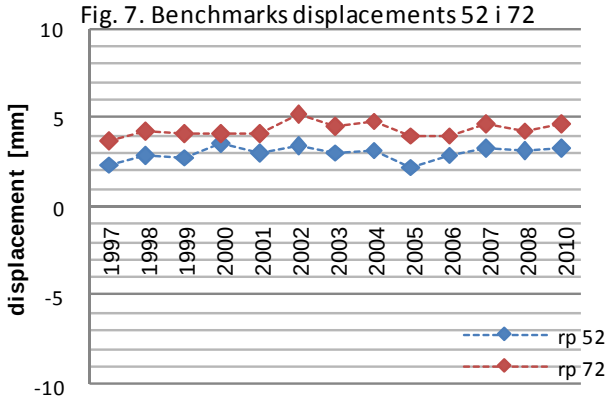
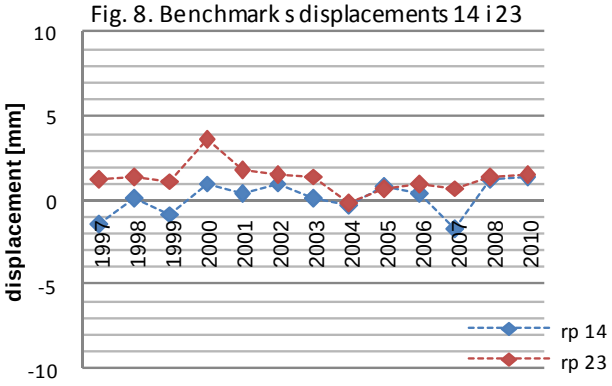
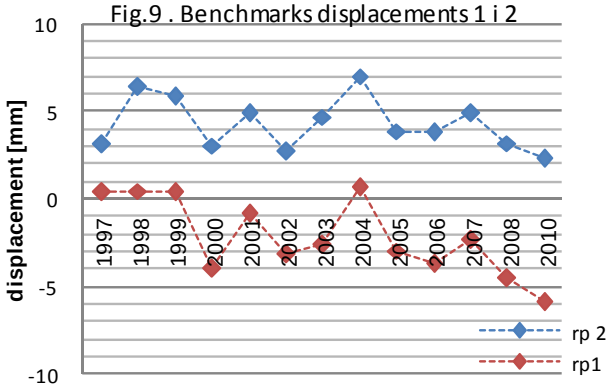


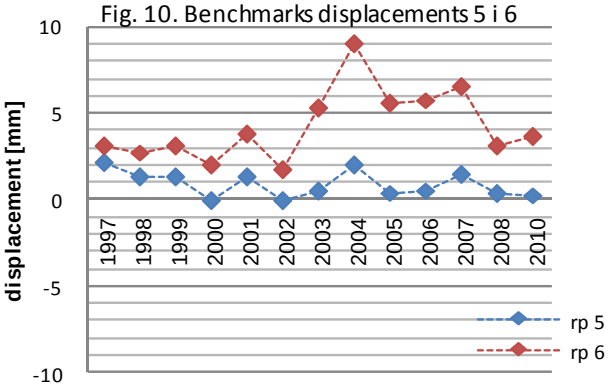
Fig. 6. Benchmarks replacements 1984-2010











The two points, 14 and 23, are positioned on the opposite sides of tectonic fault not far from the originally active quarry Kletno I (fig. 8). The graph course of those two points is almost parallel. However, the graph lines are separated by about 2 mm. The difference might be caused tectonic fault affect.

The benchmark pair located on the both side of the Kleśnica river (fig. 9). Benchmark 2 is located on mica schist, benchmark 1 on crystalline limestone. The course of those two is principally similar, but replacements values are different. Increasing benchmark number 2 with slight decrease benchmark number 1 might indicate mica schist subsidence.

The two points, 5 and 6, are positioned on both sides of Kleśnica river on varying geological structure (fig. 10). Large displacements values of point 6, values of displacements fan out. Course indicate different height changes between two riverside and mica schist subsidence.

Summary

Benchmarks displacements in the environment and the interior of the Bear Cave in Kletno oscillate. While points localized above the cave uplift, points localized beyond depresses. That changes might be result of the marble quarry exploitation and spreading some vibration through rock massif between tectonic faults.

Stabilized method, measurements and calculations surveying in the environment and the interior of the Bear Cave provide reliable information about rock massif changes.

As we can see closure quarry Kletno I (1993) caused disappearing vertical height changes of controlled benchmarks and stopped Bear Cave degradation.

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Дослідження деформацій гірського масиву поблизу Печери Ведмедів у Клєтно

К. Монкольські, П. Розмус, К. Пієнькош, П. Голдин, Л. Лубенець, І. Романишин

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Исследование деформаций горного массива вблизи Пещеры Медведей в Клетно

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The article shows the benchmarks displacements in the environment and the interior of the Bear Cave in Kletno oscillate. There are measurements calculations of deformation of benchmarks during surveying works from 1997–2010.