THE STABILITY OF ROCK BLOCKS IN THE MORAVIAN KARST

Vlastimil Hanzl[1], AntoninPaseka[2]
[1] Institute of geodesy, Brno University of Technology
[2] Institute of geology and geotechnics, Brno University of Technology
E-mail: hanzl.v@fce.vutbr.cz

Abstract: The latest investigation for reconstruction a road (maybe for a new bridge construction) above ponore of the brook Bila voda is presented. Determination of rock blocks displacements was done using a special approach.

1. Introduction

The Moravian karst is one of the Czech National Parks with typical karst phenomena that is under governmental protection. In recent years special attention has been paid to the rock wall above the Bila voda ponore. Large rock falls have been observed in this place since the half of the nineteens century. The periodicity of these falls was approximately 65 years, the last fall occurred in the year 1965. Because the rock wall is situated close to road, engineering-geotechnical and geodetic prospecting were made. One of the goals of the project N. 205/04/0047 of the GACR (the Grant Agency of the Czech Republic) focused on the Bila voda ponore has been determination of the failed rock blocks displacements. In the protected area of the Moravian karts is not allowed to use pillars as stable observation stations. In the end of narrow valley, where the water flow is sinking, there are very difficult conditions to find suitable stable places for observation stations. Mixture of coble gravel, clay loam and wooden ends occurs between. Due to high humidity of air the rock block are very slipper. The observed points on blocks were placed close to edges of blocks and were stabilized using copper snap-head rivet with small drill hole. Therefore has not been possible to use them as standpoints. The standpoints were chosen as free on relatively stable places ensuring safe observations and good intersection condition, similarly as photo station in close range photogrammetry.

2. Determination of displacements

For determination of space coordinates of points has been used method of space resection using measured horizontal and zenith angles. Elevations of the accessible points have been determined by precise levelling. Space distances between some standpoints and points have been measured. Observation equations for measured polar data (α, ς, s) according [1] are following:

$$\begin{bmatrix} v_\alpha \\ v_\zeta \\ s+v_S \end{bmatrix} = \begin{bmatrix} -1/s.\sin\zeta & & \\ & 1/s & \\ & & 1 \end{bmatrix} \begin{bmatrix} \sin\alpha & -\cos\alpha & 0 \\ \cos\alpha\cos\zeta & \sin\alpha\cos\zeta & \sin\zeta \\ \cos\alpha\sin\zeta & \sin\alpha\sin\zeta & \cos\zeta \end{bmatrix} \mathbf{R}^{\mathbf{T}} \begin{bmatrix} X-X_0 \\ Y-Y_0 \\ Z-Z_0 \end{bmatrix}$$

Matrix **R** describes orientation of local Cartesian coordinates of instrument (x, y, z derived from α, ς, s) and global geodetic coordinates (X, Y, Z):

$$\mathbf{R} = \begin{bmatrix} \cos\varphi\cos\kappa & -\cos\varphi\sin\kappa & \sin\varphi \\ \cos\omega\sin\kappa + \sin\omega\sin\varphi\cos\kappa & \cos\omega\cos\kappa - \sin\omega\sin\varphi\sin\kappa & -\sin\omega\cos\varphi \\ \sin\omega\sin\kappa - \cos\omega\sin\varphi\cos\kappa & \sin\omega\cos\kappa - \cos\omega\sin\varphi\sin\kappa & \cos\omega\cos\varphi \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \sin\alpha & -\cos\alpha & 0 \\ \cos\alpha\cos\zeta & \sin\alpha\cos\zeta & \sin\zeta \\ \cos\alpha\sin\zeta & \sin\alpha\sin\zeta & \cos\zeta \end{bmatrix}$$

Two of the rotation angles ω, φ are zero due to levelling of instrument. We can treated as observed data:

$$\varphi = v_\varphi + \varphi_{obs}$$

$$\omega = v_\omega + \omega_{obs}$$

The same treatment was used for Z coordinates of points determined by levelling:

$$Z = v_Z + Z_{obs}$$

Accuracy of observed data introduced in adjustment was following: $\sigma_{\alpha,\varsigma} = 4\,mgon$, $\sigma_{\varphi,\omega} = 5\,mgon$, $\sigma_s = 0.002\ m$, $\sigma_Z = 0.0005\ m$. Position and orientation of network in the basic stage were given using two points from speleological measurements made several years ago. One of them (point 39) stabilised by rivet in solid rock near the brook fixed the position and second one served for orientation of network. The basic stage was measured independently twice (two groups of surveyors) in the summer 2004, when the brook is sinking several hundred meters in front of ponore due to lack of water and brook bed is dry. Adjustment of network has been done using photogrammetric software ORPHEUS (TU Vienna) allowing combine various type of observations. The second stage was measured one times after spring flood (April 2005), third one in the summer 2005. On the top of the largest block failed in the year 1965 is speleological point 33. We compared former observations (tab. 1) for prediction of displacements. We expected displacements approximately 10 mm per year. There was surprising that after flood displacements of blocks were smaller than were expected. During flood are most of the blocks under water level (fig.1).

Table 1: Comparation of observations for prediction

Observation / year	1994	2002	2004
Horizontal distance 33-39	26,76	26,68	26,66
Height difference 33-39	-3,60	-3,48	-3,46

Figure 3: Flood - only top of the largest block above water level

The larger displacements have appeared in the period between spring and summer stage. Accuracy of adjusted coordinates is shown in tab. 2. The stability of fixed point (N.39) was checked by means of 5 points placed in the rock wall above ponore.

Table 2: Average standard deviations

Year	σ_X [mm]	σ_Y [mm]	σ_Z [mm]
2004 summer	0.6	0.7	0.3
2005 spring	0.8	1.0	0.7
2005 summer	1.0	1.2	0.4

The accuracy of adjusted coordinates of points can be independently checked. There are compared some tape measured distances with computed ones from adjusted coordinates. The adjusted coordinates of points of chosen blocks are checked by orthogonal transformation as well. A block can be shifted and rotated, but relative position points of block must be kept. On the largest block are 5 points. After transformation of coordinates "summer 2005" to "summer 2004" were calculated differences between coordinates. The largest difference was 0.7 mm in X axe. The average differences were 0.3mm in planimetry (X, Y) and 0.1 mm in Z axe. Average subsidence of points between basic and third stage were 11 mm, the largest 16 mm. Planimetric displacement were about 5 mm (the largest 16 mm) and there are directed to the ponore (fig.2).

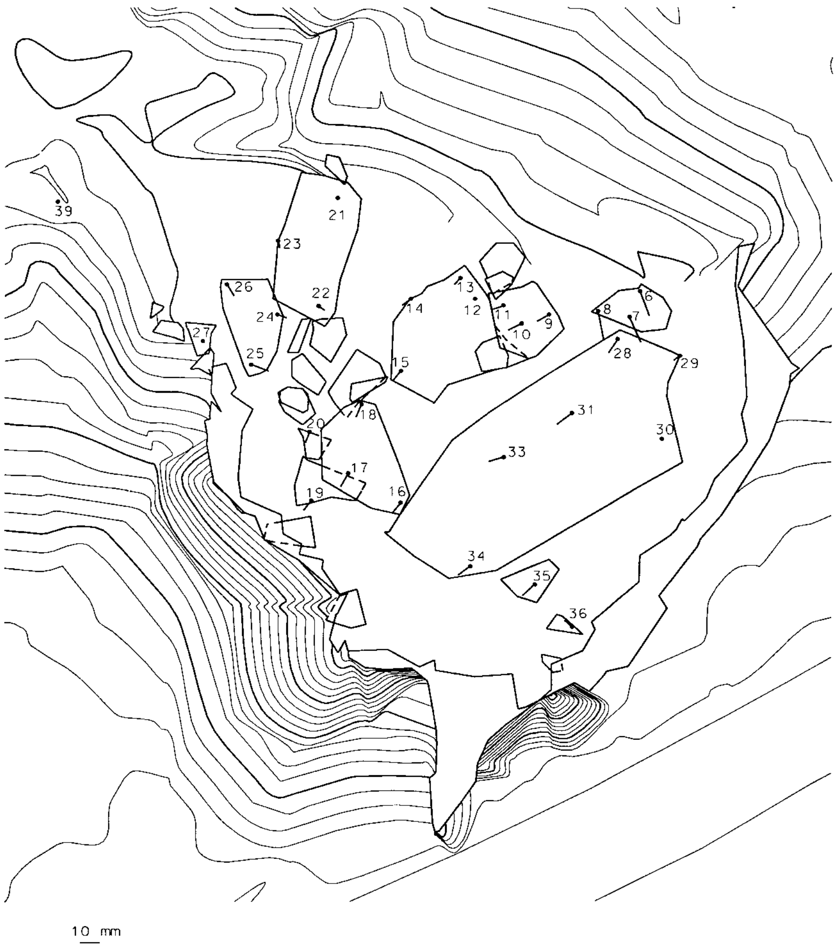

Figure 2: Planimetry dispalements

3. Conclusion

The displacements of the rock block in special conditions have been determined. Achieved accuracy is sufficient for these purposes. For better understanding of space relation of the neighbourhood of ponore has been evaluated 3D model based on photogrammetric a geodetic measurements. In the end of the year 2005 was part of area measured using laser scanner. After spring flood in the year 2006 will be displacements determined again using laser scanning and geodetic measurements.

Reference:

[1] Kraus, K.: Photogrammetry, Vol. 2, pp. 466, Bonn 1997.