Górnictwo i Geoinżynieria • Rok 34 • Zeszyt 2 • 2010

Miloslav Kopecký, Ľuboš Hruštinec*, Martin Ondrášik*, Jana Frankovská**

DEFORMATION OF UNSTABLE SLOPE AT THE RESERVOIR DAM NOVÁ BYSTRICA**

1. Introduction

The reservoir Nová Bystrica is located in the northern part of Slovakia, about 6 km southward of the border with Poland (fig. 1). It is used to supply the population with drinking water and was put into operation in 1989. Rock environment of the area consists of rocks belonging to Outer Flysch Zone. The flysch formation is characteristic by the alternation of pelite (clay stone, marly soil and siltstone) with sandstone. The most dominant strike of the flysch layers is E–W, while their dip is almost vertical (80–90°). The formation has due to multiple folding of the area complex over thrust structure.

Fig. 1. Localization of the water reservoir Nová Bystrica

* Department of Geotechnics, Faculty of Civil Engineering, Slovak University of Technology, Bratislava, Slovakia
** This research was funded by the grants No 1/0599/08 and 1/0578/08 VEGA Agency

Even before the construction of the water reservoir Nová Bystrica, during the implementation of a detailed engineering geological survey [3], the presence of slope deformations was observed at the slopes on left side from the projected dam (fig. 2), which are located above the maximum shoreline.

Two slope deformations of varying activity can be allocated on the slope. In the area between the reservoir shoreline and the forest road there are active landslides with overall area about 120×60 m (fig. 2). The landslides were probably caused by improper interference during building of the forest road. Active landslides are bound only to the slope debris containing coarse fragments from 40 to 80% and the shear surfaces were detected by the inclinometric measurements at depths from 3,5 to 5,0 m.

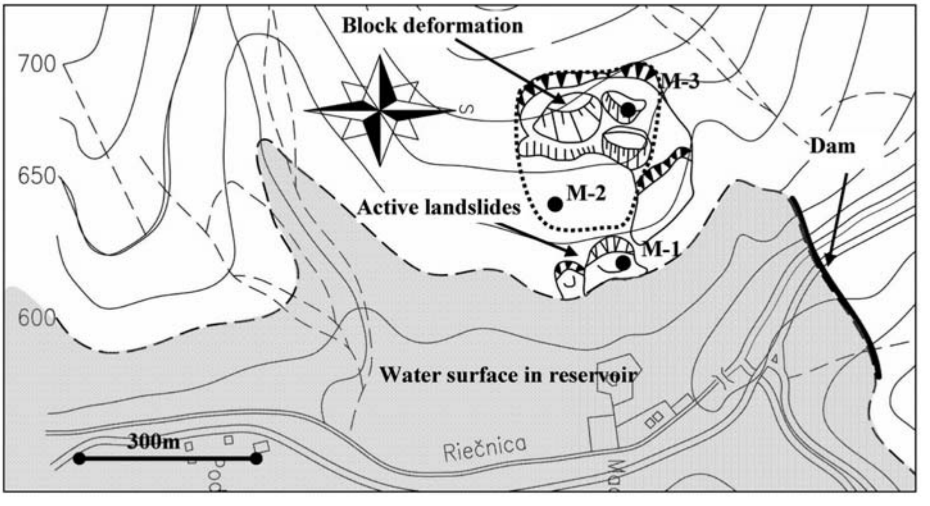

Fig. 2. Scheme of the landslides in the slope located on the dam left-hand side

In the higher part of the slope (in the range of about 630–690 m above sea level) there is a block deformation (fig. 2). Based on initial investigation works [1] its dimensions were predicted to approximately 100×140 m. According to our latest knowledge, this could be up to 220×140 m (dotted line in fig. 2). Block deformation is result of gravitational movement of relatively rigid sandstones over the surface of plastic siltstones, and during the movement from the main slope zone the sandstones were disintegrated to individual blocks. The maximum depth of the shear surfaces was detected by inclinometeric measurements at a depth of 34,0 m below the around surface.

2. Landslide monitoring and its results

In 1993, exploratory boreholes [1] were equipped for the combined observations of groundwater levels (GWL) and movements on the shear surfaces (7 control points).

Four of them, which were placed in the active landslides, become inoperative since 2001. In 2002 there was made 6 new inclinometric boreholes (without possibility of measuring GWL) in the active landslide on the forest road. Furthermore, in 1995 there were built 4 fans (each with 3 horizontal boreholes) of drainage wells, and their discharge is monitored. At present, GWL can be measured in 3 wells and moves on the shear surfaces in 7 inclinometric boreholes (of which 5 are in active landslide and 2 in the block deformation).

The analysis of measurements of movements in the inclinometric boreholes are the most important. Due to the nature and depth of the measured movements it was necessary to assessed independently the active landslides with the forest road and the block deformation.

2.1. Active landslides

In the landslide area with the forest road it has been confirmed that the activity of the movement still persist. The maximum deformation observed from 1993 to 2006 is 300 mm (sum of deformations from two inclinometers). The movement is probably not a continuous and uniform, it occurs only under extreme climatic conditions (rainfall and snow melting).

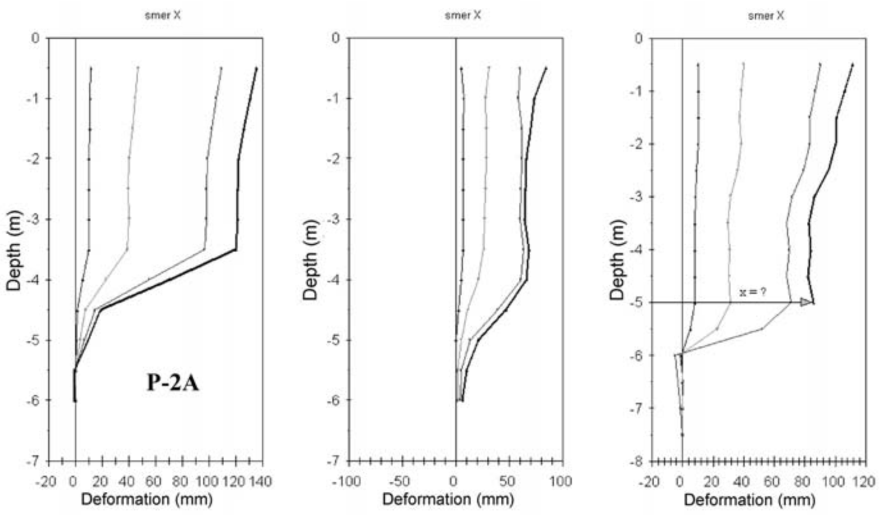

Fig. 3. Movements in the inclinometer located in the active landslide on the forest road

The depth of the shear surface of the active landslide on the forest road was found 3.0–5.5 m bellow the surface (fig. 3).

Based on the analysis of the inclinometric measurements in 2 inclinometric boreholes located outside the presumed area of the landslide active in 1993, it was found that since 1999 there was gradual expansion of the landslide and significant distortion of the forest road (fig. 4).

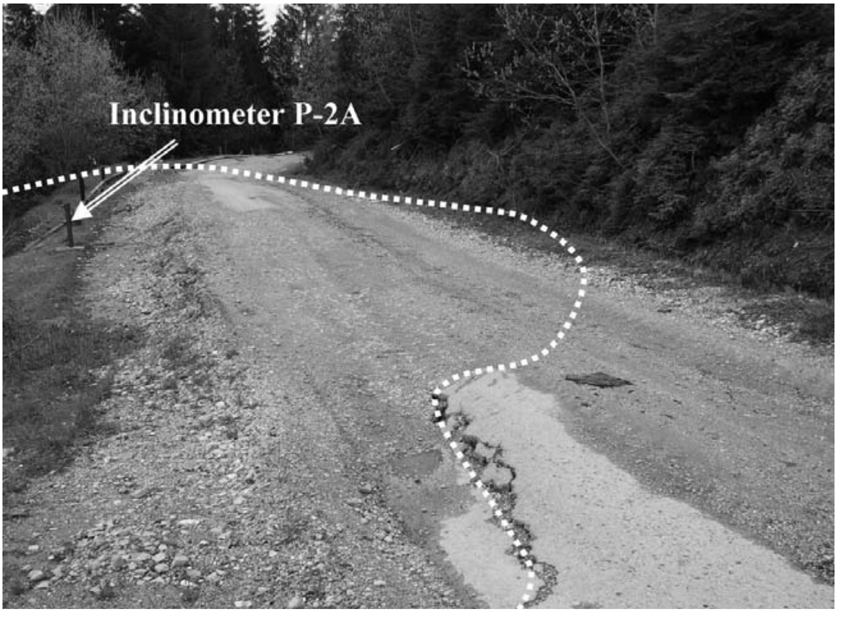

Fig. 4. Main slope area of the active landslide in the body of the forest road

2.2. Block deformation

The block deformation, which is situated in the slope above the forest road, there is a gravitational movement of relatively rigid sandstones over the surface of a plastic claystone. Inclinometric measurements under the main scarp zone of the block deformation (borehole M-3) confirmed the existence of a relatively thick shear zone (about 7 meters), along which there is

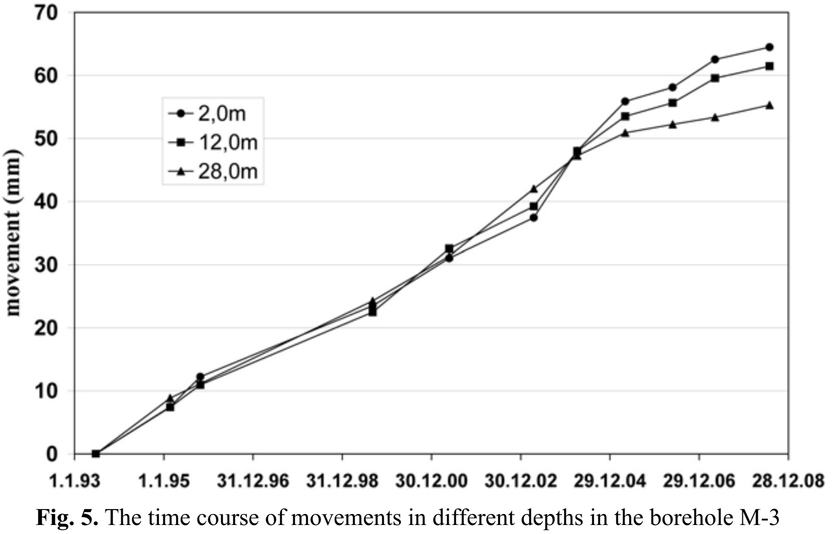

Fig. 5. The time course of movements in different depths in the borehole M-3

a movement of the block of sandstone up to 24 meters thick. Total movement of 44 mm for 13 years was detected. However it is important that the movement at a depth of about 28.0 meters is up to now relatively uniform (fig. 5).

Borehole M-2 (fig. 2) was situated on morphological platform about 60 meters above the forest road, and it was assumed [1], that the platform was not the result of the slope movement. However, subsequently realized inclinometric measurements showed quite a clear movement on the contact between sandstone and claystone (13.0 meters below the surface). The total resultant movement in this depth is almost 63 mm for 13 years. These findings lead us to an opinion that the area and depth extent of the block deformation is greater than it was originally anticipated.

3. Forecast of development of the slope deformations and their influence on the operation of the water reservoir

Development of the existing slope deformations and their potential impact on the operation of the water reservoir can be forecasted based on the measurements of the monitoring network (especially in inclinometric boreholes), and also calculations of slope stability [2]. Results of the calculations of the slope stability showed that the most important factor affecting the stability of the slope deformation is the groundwater level in the slope. This fact will have to be taken into account when designing remediation and stabilization measures.

3.1. Active landslides

It is obvious that, if no remediation works will be made on the active landslide area with the forest road [2], in some time there will be an absolute destruction of the slope and sliding of the diluvia sediments to its lower part and partially into the water reservoir. About 55 000 m^3 of debris can get into the movement. However we assume, that in this process there is no threat to the inflow waterworks facility remote about 150 m from the accumulation of the active landslides. On the other hand, removal of rock masses from this area can cause acceleration of movements of the block deformation situated above the forest road.

3.2. Block deformation

Basing on the inclinometric measurements a link between deformations in an area of borehole M-2 with the deformations around the borehole M-3 can not be ruled out. The knowledge of the fact whether there is accelerated motion or movement is steady is crucial to the prognosis of further development of the movements (fig. 5). However, if the inclinometric measurements are carried out only once a year, it is not possible to reliably determine the nature of the movement.

If there are demonstrably accelerated movements in the area of the block deformation, it will be necessary to proceed to remedial or other measures, because at certain acceleration it will not be possible to stop the given movement. The subsequent movement of the rocks would likely jeopardize the operation of the water reservoir.

4. Recommendation for the following monitoring

Assessment of the stability of the slope on left side from the dam Nová Bystrica and forecast of its future development with respect to the operation of the water reservoir were based only on pre-existing knowledge, where the inclinometric measurements have the crucial role. Assumptions obtained by calculations and analysis reflect the accuracy of all existing data.

For clarification of existing knowledge (especially in the area of the block deformation) the recommended further works are summarized (tab. 1).

TABLE 1

Recommended remediation works on the unstable slope

RECOMANDED WORKS	PURPOS AND OUTPUT OF THE WORKS
Geodetic survey of the terrain morphology	Creating a representative model of slope deformations (active landslides and block fields)
Mounting surface geodetic points and measuring their movement	Understanding the relative speed and direction of the movement of blocks on surface (forecast their future development)
Inclinometric measurements (2 times a year) Construction of 2 pieces of new inclinometer boreholes in the block deformationRestore functionality of inclinometers P-5 and M-1	Finding the depth and size of the deformation in the rock environment — prediction of further development of the movements with identification of critical values of their velocities
Groundwater level (3 new piezometers with continuous measurement of GWL), discharge of horizontal drainage boreholes	Optimization of boundary conditions for stability calculations and determination of the critical levels of GWL
Geophysical measurements	Determination of areal and depth extent of the block deformation + specification of location of new inclinometers

REFERENCES

[1] *Jadroň D., Fussgänger E.*: VN Nová Bystrica — sanácia zosuvu. Final report. INGEO a.s., Žilina, Geofond Bratislava 1993

[2] *Kopecký M., Hruštinec Ľ.*: Posúdenie stability ľavostranného svahu VN Nová Bystrica. Department of Geotechnics Svf STU Bratislava 2006

[3] *Nevický V. et al.*: VN Nová Bystrica — podrobný inžinierskogeologický prieskum. Final report. IGHP, n.p., Žilina, Geofond Bratislava 1977