Using of the Tape Extensometer for Possibilities of Landslide Monitoring or another purposes

Barbara Matuszková¹, Jili Qu², David Neuman¹

¹VŠB-Technical University of Ostrava - Faculty of Mining and Geology - Department of Geological Engineering, 17 listopadu 15, 708 00, Ostrava, Czech Republic
²University of Shanghai for Science and Technology, School of Environment and Architecture, 516 Jungong Road, Yangpu District, Shanghai 200093, China

barbara.matuszkova@vsb.cz

Abstract. The main goal of this article is to analyze the possibility of using tape extensometry. It is one of the methods of evaluating the development of slope deformation. Tape extensometry is used to monitor the movement of the slope on the surface. Tape extensometry is used for fast and accurate measurement of relative distances between pairs of reference points on the surface of structures, including radial movements and convergence of tunnels, linings, shafts and caves. Then deformations of excavations in underground caves and displacements of retaining walls, bridge piers and arches. The digital tape extensometer is a portable device used to measure the displacement between pairs of eye bolts. The principle of measuring on a slope consists in directly measuring the distance between the stabilized measuring points. The measuring points are located in both stable and unstable parts. The measuring points are concreted into boreholes drilled to a non-freezing depth, which in the Czech Republic is about 0.8 m below the ground. The direction of movement can be determined by measuring the change in distance between several points located in the stable part and points in the unstable part. If we also measure in time intervals, we can also find out the approximate speed of movement. The tape extensometry method is performed using a tape extensometer. It is a specially adapted zone in which emphasis is placed on the material from which the meter is made, because it is important that the material has a low thermal expansion, for example nickel steel is suitable.

1. Introduction

Tape extensometry is one of the methods of geotechnical monitoring, with which we control and observe slope movements in a certain period of time. Using geotechnical monitoring, we can detect not only changes in physical properties, mechanical properties and speed of landslide movement in the landslide zone, but also changes in slope geometry. If landslide remediation has already taken place on the slope, geotechnical monitoring is used to check the functionality of the remediation measures used. Geotechnical monitoring is a long-term process and the monitoring process usually takes more than ten years.

Tape extensometry is used to measure the relative position of the stabilized points, provided that at least one point is outside the slope deformation. By anchoring several points in the stable part and measuring the change in distance from the points in the unstable part, it is possible to determine the direction of movement. If we measure in time cycles, it is possible to determine the approximate speed
of movement. We measure with the help of a tape extensometer. This is a specially modified tape. It is important to choose a meter material with low thermal expansion. For example, invar steel (nickel) is used as the most common material. The accuracy of tape extensometry measurement depends on the quality of the meter material, the normal deviation is 0.5 - 1.0 mm. With an extensometer with a measuring indicator clock, the deviation is reduced to 0.05 mm. The device consists of a firmly anchored measuring point, tape reel, invar steel tape, band stretching the tape, string tensioning the tape, dial indicator and point outside the landslide. For each measurement, the air temperature is recorded for the necessary temperature corrections. [1]

2. Band extensometry

2.1. Principle of measurement with a tape extensometer on a slope
The method is based on measuring the mutual position of stabilized points, provided that at least one of these points is located outside the slope deformation we have chosen. The measuring points are anchored to the pre-drilled boreholes using concrete. The borehole must be drilled to a non-freezing depth. In the Czech Republic, a non-freezing depth of about 0.8 m below the ground is considered non-freezing. Steel protectors are led above the terrain surface, which are equipped with a screw-on closure. These closures serve to protect the measuring points. The measuring points have a spherical shape and are made of stainless steel. These points are led on the spacer pipes to a height of about 0.2 m above the ground so that it is always possible to measure between adjacent points. For each measurement, the air temperature is recorded for temperature correction purposes and the measurement itself is not carried out in direct sunlight, so as not to distort the results due to the thermal expansion of the tape.

The principle of measurement with a tape extensometer is shown in Figure 1.

![Figure 1. Principle of measurement with a tape extensometer on a slope](image)

The new digital tape extensometry instrument consists of a precision punched steel tape incorporating a repeatable tensioning system and dial gauge readout. The tape winds onto a reel, which incorporates a tape tensioning device and a digital LCD readout. [2]

2.2. Principle of measurement with a tape extensometer in a tunnel
Digital tape extensometers can also be used for measurements in a tunnel. The principle of measurement is shown in Figure 2. There is a hook connector on the body of the extensometer, which is connected to the first anchor point. The same hook is attached to the free end of the tape. This hook attaches to the opposite anchor point. Then it is necessary to turn on the device and it will record the values from the digital LCD display. The performed measurements are not absolute compared to the previous measurement, but relative. For this reason, this type of measurement provides us with an accurate record

2
of the time shift. Digital tape extensometers can be installed on a structure or in an excavation, such as a tunnel or shaft. [2]

![Tunnel Lining with Tape Extensometer](image)

**Figure 2.** Principle of measurement with a tape extensometer in a tunnel

2.3. Risks of performing tape extensometry

Temperature induced deformations of the connecting element also have to be carefully considered during data processing, it is best to measure when the sun is not shining. [3]

A possible source of errors, common to all types of extensometers, including a tape extensometer, concerns the stability of the fixed points which may deteriorate through time disrupting the time series of the measurements. [3]

3. Measurement procedure by using tape extensometry

The common measuring apparatus (Figure 3) used for tape extensometry consists of a precision punched steel tape incorporating a repeatable tensioning system and dial gauge readout. The tape winds onto a reel, which incorporates a tape tensioning device and a digital LCD readout. [2]

![Measuring Apparatus for Tape Extensometry](image)

**Figure 3.** The measuring apparatus used for tape extensometry
Values, which we obtained during measurement with a tape extensometer are used to calculate changes in the distance between two reference points. It is not difficult to obtain good measurements, but you must follow a standard procedure, which is described below.

First you need to hook the tape to the prepared reference points. It is necessary to check whether the tape can be wound up. Hook the carabiner into the eye of the first reference point. Connect the other end of the tape extensometer to the opposite reference point and let the belt unwind while walking. We must select an index hole at the time we make the initial measurement of a pair of reference points, after that we must use that same index hole for all subsequent measurements of that pair of points. [4] [5]

The next step is to tension the tape. We need pull on the tape and slide it into the nose slot. If we look at the tape, we will usually see index holes punched every 50 mm. After that we engage the pin into the index hole to hold the tape securely. Now we can tension the tape. Grasp the body of the extensometer and turn the tensioning collar until the tension control marks are aligned. Proper tape tension is very important for accurate measurement results. Figure 4 shows us how to tension the tape correctly. The Figure 4.a shows a tape that is not tensioned. The Figure 4.b shows a tape that is over-tensioned. The Figure 4.c shows a tape that is tensioned correct. [4] [5]

![Figure 4. Correct tension of the tape, a) under tensioned, b) over tensioned, c) tension is correct](image)

The next step is to obtain the measurement. When the tape is properly tensioned, we can read from the display of extensometer (Figure 5). The metric tape is marked in centimeters and each index hole will have a mark for meters with a measurement in centimeters below it. Millimeters we can read from the digital display. [4] [5]
Figure 5. Display of extensometer used for tape extensometry

When we finished measurement we remove tape tension and retrieve the tape. It is necessary to rotate the tension collar to release the tension, after that we remove the tape from the nose slot. Unhook the extensometer body and wind the tape towards the second reference point. [4]

Based on the tape extensometry measurement, we find the result, which is measured differential movement. For example to measure movement of structure, it is necessary to examine movement of the structure relative to the surroundings. [6] Our result will be for example a graph of the dependence of deformation (mm) on time (hour).

Displacement data, obtained by tape extensometers, provide a direct means of evaluating slope, tunnel, retaining walls or mine openings and others stability. Displacements that have exceeded the predicted elastic displacements usually have resulted in decisions to modify support methods. [5]

4. Conclusions
The tape extensometry is used to monitor deformation in structures and supports and to measure movements of unstable slopes. The tape extensometry has been designed to be able to predict slope movements and reduce damage to property and human health. Using tape extensometry, we can also measure small changes in the distance between opposite walls, in tunnels, foundations, retaining walls or mine openings and ect. There are many different models of tape extensometers. The principle of measurement with a tape extensometer depends upon fixing the rod and surrounding sleeve at one end and measuring movement at the other. The movement may be read by dial gauge or we could measure remotely by electronic methods. Tape extensometers may be used for measuring relative movements on slopes, in foundations, on retaining walls, in tunnels or in soils and rocks stressed by anchors or affected by excavation or other special works. Tape extensometers are accurate and reliable, movements of up to 50 mm being recorded to an accuracy of perhaps 0.01 mm. We must follow correct procedures and measured accurately, so as not to measure inaccurate results. Also must be careful not to destroy the anchored points that we will need for further measurements.
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